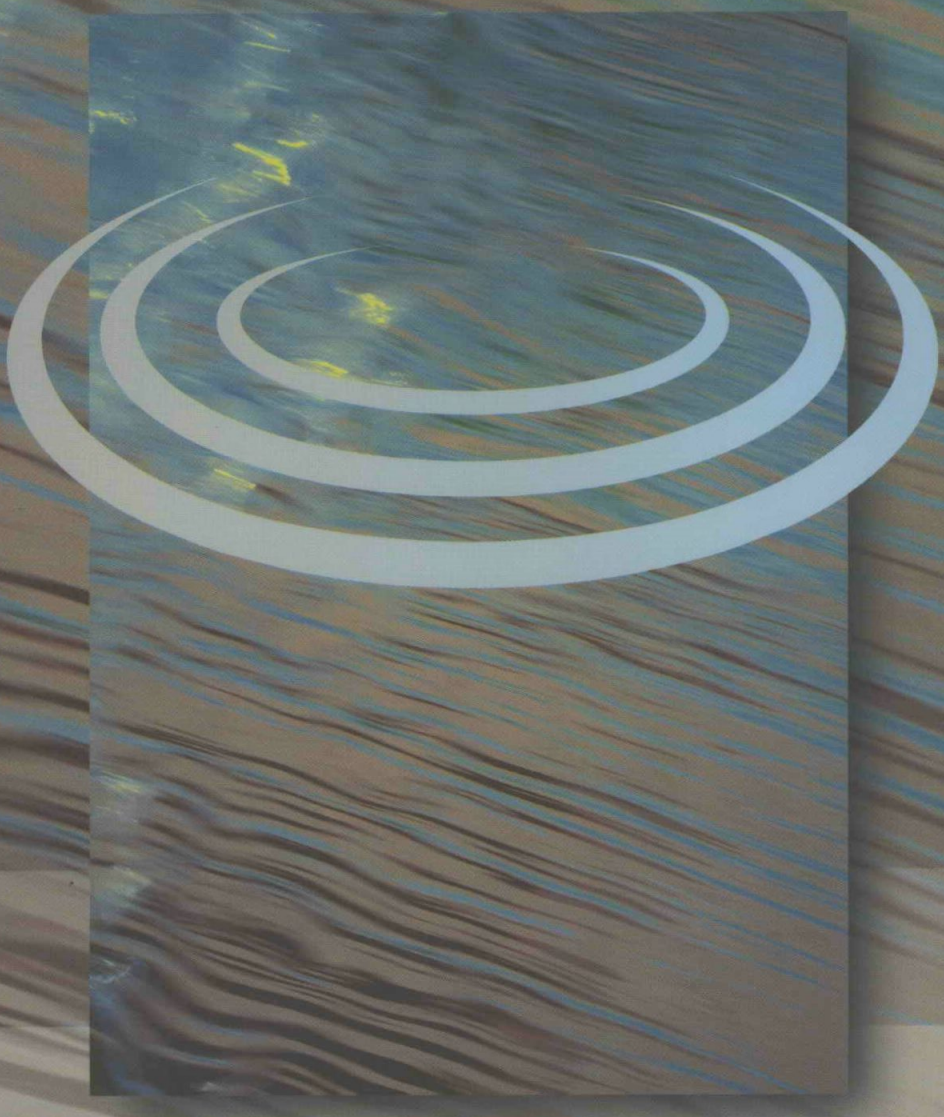
WATER RESEARCH COMMISSION

TECHNICAL REPORT

2000



2000 Technical Report

WATER RESEARCH COMMISSION

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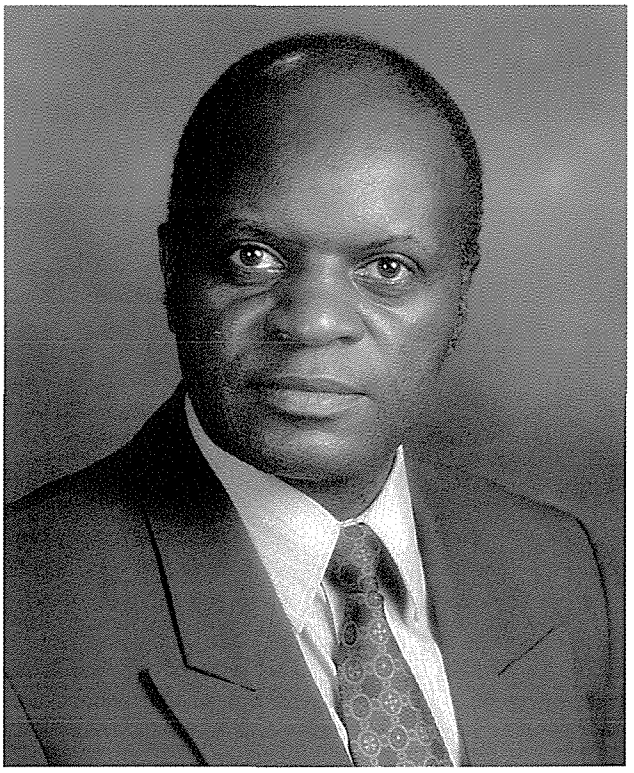
Mission statement

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.*

Foreword



As we come to the end of one year of exciting research challenges and exciting activities, we also embrace the new year with great anticipation, looking forward to the challenges that it brings.

This also marks the end of the first 18 months of a new Board, during which they have confronted many new issues with great energy and enthusiasm. The fresh thinking they have injected into the work of the WRC has already begun to reflect itself in some of the new policies, the effects of which the readers will soon see. These range from the distribution of resources amongst thrusts and the identification of new thrusts in alignment with national imperatives, to policies relating to the general administration of the WRC. The composition of the new Board, in terms of the professional backgrounds of its members and demographics, clearly shows the WRC's commitment to be in line with developments at the national level.

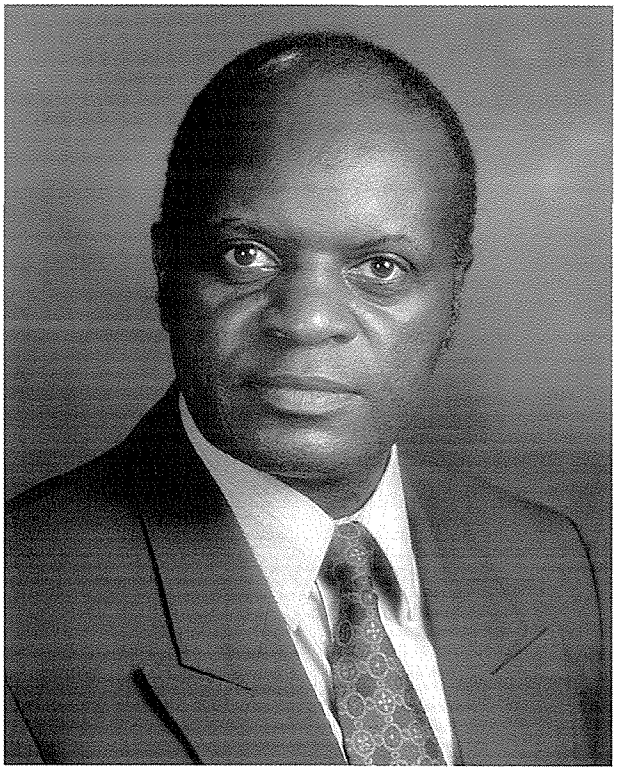
Amongst the major challenges facing the WRC and the water sector as a whole is the need to retain an effective pool of researchers in the field and, perhaps even more important, to rapidly build up a strong cohort of researchers from sections of the population which have previously not been well represented in this field. The issue of capacity-building, of both individuals and institutions, has been the subject of great attention and debate by the Board. While the results are still a long way from the ideal, significant strides have already been made in the right direction. We invite you, the readers, to also assist us in a campaign to make the public aware of the importance of the water sector to our lives and to the economy and, therefore, as an important area for investing in human capital development, all the way from pre-school level.

A notable development of the last few years has been the shift in focus in resource allocation, from a bias in favour of the "hard sciences" and engineering, to the "softer" issues that have more immediate and direct benefits to communities. Research projects on softer issues permeate fields such as **Rural Water Supply and Sanitation; Water Policy; Water Services (Institutional and Management Issues); Integrated Water Resource Management**; and **Health-Related Water Issues** which together received 24% of the WRC research budget. This figure shows our serious commitment to our citizens' right of access to sufficient (and clean) water as enshrined in our constitution and articulated in the Water Services Act, 108 of 1997. Compared to historical patterns, significantly larger amounts of funding (27%) have been allocated to the closely linked cluster of research fields which aim to protect the water environment and its associated water quality in order to promote sustainability. This cluster includes **Conservation of Water Ecosystems; Water Quality Management; Municipal Wastewater Treatment**; and **Mine-Water Management**. In our relatively arid environment, **groundwater** remains an important but somewhat poorly understood and managed resource. Our concern in this area is clearly reflected in the generous allocation of 8% now being made to that field. In addition, 18% of the research budget has been allocated to research activities targeted at addressing the perpetual quest for new ways of improving water-use efficiency, across all areas of use. Relevant fields are **Agricultural Water Management; Industrial Water Management**; and **Integrated Urban Water Management**.

Without the continuing support of the various water users and Water Boards and government's support, the WRC would not be able to do its work. This support alone, without the hard work and dedication of researchers would come to nought. I, therefore, on behalf of the Board and members of the WRC wish to express our sincere gratitude and appreciation for the roles played by each of these stakeholders. We count on your continuing support as we truly start the new millennium and, in return, promise you a year of new levels of achievement and competitiveness.

Prof Kingston Nyamapfene
Chairperson

2000 Board members of the



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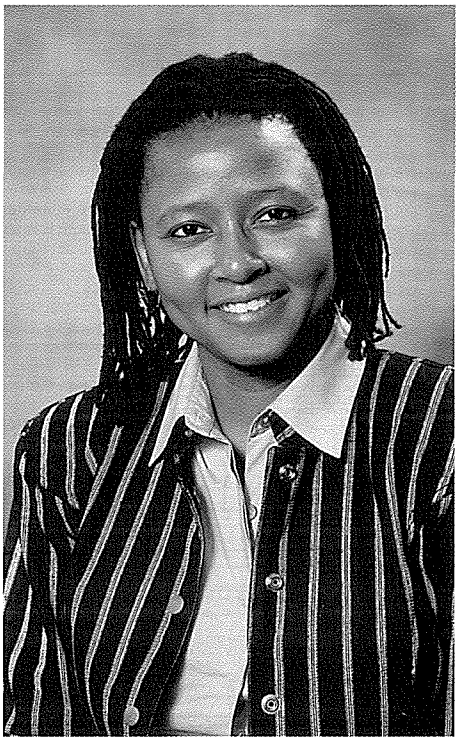

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(Vice-Chairperson)
Deputy Director-General, Environmental Management: Department of Environmental Affairs and Tourism

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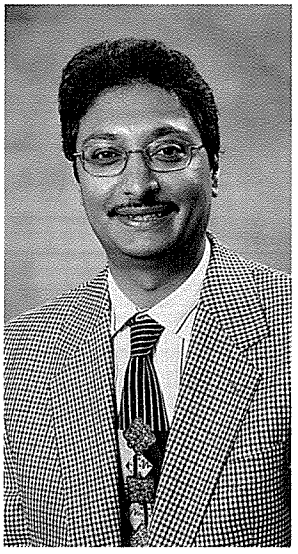
Private Consultant



Dr HC Kasan

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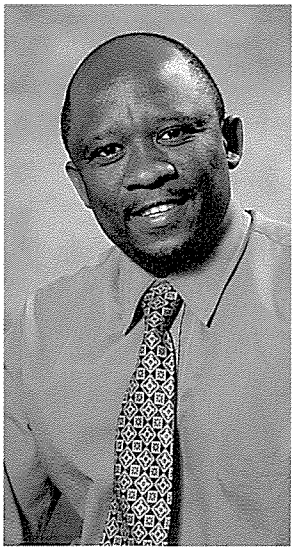
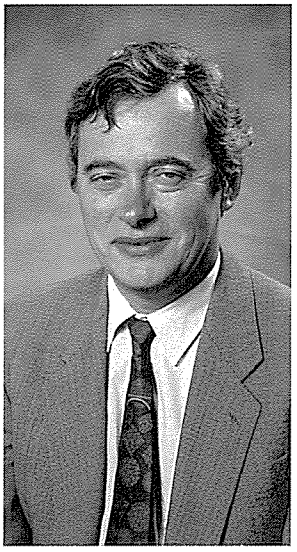


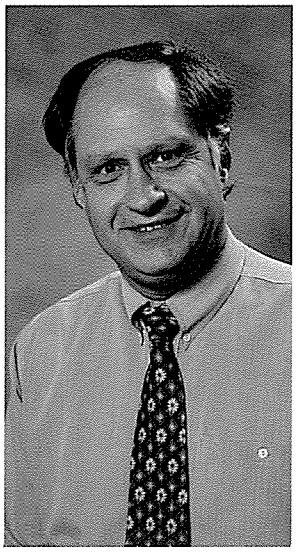
Dr MB Molope

Acting Executive Officer,
Agricultural Research Council



Mr AM Muller

Director-General:
Department of Water Affairs
and Forestry, Pretoria

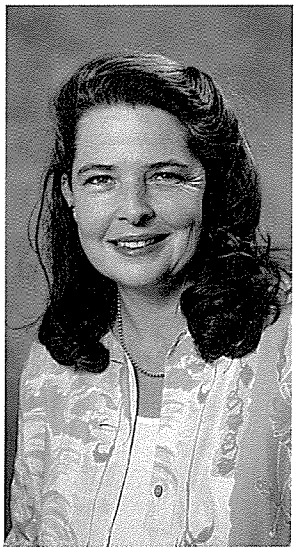


Mr RJC Nay

Executive Officer: Wastewater,
Johannesburg Water, Broadway

Mr PE Odendaal

Executive Director: WRC
(Retired at the end of
August 2000)



Prof CG Palmer

Institute for Water Research,
Rhodes University,
Grahamstown

Senior personnel

Professional

Deputy Executive Director

Mr DS van der Merwe

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

Deputy Executive Director

Dr GC Green

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

Research managers

Dr GR Backeberg
Mr JN Bhagwan
Dr SA Mitchell
Dr NP Mjoli
Dr S Mkhize
Dr G Offringa
Mr GN Steenveld

Research managers

Mr HM du Plessis
Mr H Maaren
Dr IM Msibi
Mrs APM Oelofse
Mr K Pietersen

Administrative

Director: Administration

Mr JA Venter

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1 The year under review

The year 2000 saw the Water Research Commission (WRC) continuing to provide substantial research support to South Africa's water sector. Such support is necessary to assist the sector in meeting a range of challenges.

These include providing safe water and sanitation to the many communities who do not have access to such services, using scarce water resources sparingly, effectively and in a manner which promotes social and economic development, and at the same time, ensures the health and sustainability of aquatic ecosystems. The details of the research support given are contained in the various chapters of this report.

Some notable staff movements took place during the year. The posts of Executive Director and Deputy Executive Director fell vacant upon retirement of the incumbents, Mr PE Odendaal and Mr DS van der Merwe, respectively. Both have been stalwarts who have made significant contributions to the growth and development of the WRC and deserve great credit for the strides made by the organisation. While their skills will be missed, the vacancies that they leave provide welcome opportunities for transformation of the top management cadre of the WRC, to reflect better the make-up of South African society. At Research Manager level, the appointment of Dr Sizwe Mkhize will greatly enhance expertise in the field of **Agricultural Water Management**.

The year also saw a sharpened focus on the powerful role that water research is able to play in capacity-building initiatives. By actively promoting inclusion of individuals and institutions from disadvantaged backgrounds in the knowledge-seeking and skill-building activities of various water research teams, we not only secure and extend national water research capacity, but we also help to ensure that a more representative pool of skilled people is available for the benefit of the broader water sector.

Shifts in priority research areas have resulted in some re-organisation of the WRC's research fields. The areas ***Rural Water Supply and Sanitation, Water Services: Institutional and Management Issues, Integrated Urban Water Management*** and ***Health-related Water Issues***, which were previously accommodated in various other well-established research fields, have now been recognised as research fields in their own right. This not only gives greater prominence to these fields as focus areas, but also facilitates the initiation and management of research in these areas.

Recognition of individual research fields does not mean that the WRC encourages fragmented research. On the contrary, the WRC, recognising that most water sector-related problems and questions faced in the real world are highly complex, is committed to finding integrated, applicable, cost-effective solutions. The direct route to such solutions is, undoubtedly, the multidisciplinary programme route which cuts across fields and disciplines and, invariably, also encompasses the economic and social disciplines. Increasingly, the WRC's portfolio of research projects is being given greater cohesion by ensuring that project aims serve the goals of structured research programmes.

The remainder of this introductory chapter focuses on some specific milestones and highlights achievements during the year under review.

Senior staff changes

Mr Pieter E Odendaal, Executive Director, retired on 31 August 2000 after a long and distinguished career in the water field. His retirement marks the end of an era at the WRC since he was the last of the small group, including the late Dr GJ Stander, the first Executive Director, who helped to establish the organisation in 1971.

Appointed as Senior Adviser, Piet Odendaal advanced to Chief Adviser before becoming Executive Director in 1985. He led the WRC through a period of unprecedented growth. Between 1985 and 2000 the number of projects, which were initiated annually, increased more than 5-fold.

Piet Odendaal has been active internationally in the water research field since he joined the WRC. This activity culminated in his election as Vice-President of the International Association on Water Quality (IAWQ) in 1994 and as President in 1998. In 1999 he was instrumental in bringing about the merger of the two major international water organisations, namely the IAWQ and the International Water Services Association (IWSA) to form the International Water Association (IWA) which has about 9 000 members from 30 countries. Currently, Piet Odendaal and Mr Vincent Bath (Chief Executive of Rand Water) are co-Presidents of IWA.

Mr David S van der Merwe, Deputy Executive Director, retired on 30 April 2000 after spending 24 years with the WRC. Because of a Board decision to delay the appointment of his successor, David continued to serve as Deputy Executive Director in a temporary capacity until 31 December 2000. He was a member of the WRC's Top Management since 1981. With his agricultural engineering background, David played a major role in guiding irrigation and hydraulics research in South Africa. He was honoured by the agricultural engineering profession by being awarded two gold medals by the South African Institute of Agricultural Engineering for services rendered to the profession: one in 1986 and one in 2000.

David worked exceptionally hard at forging close contact between the South African and the international irrigation communities. He took the lead in establishing the South African National Committee on Irrigation and Drainage (SANCID), a vital step towards South Africa's gaining membership of the International Commission on Irrigation and Drainage (ICID). David was not only Chairman of SANCID for 6 years, but he also served on a number of ICID working groups and was one of the ICID Vice-Presidents from 1997 to 2000.

Dr Sizwe Mkhize assumed duty as Research Manager in the research field of **Agricultural Water Management** on 2 October 2000. He holds a B.Sc. Agric degree (University of Fort Hare, 1988), a Masters degree in Horticulture and Plant Physiology (Pennsylvania State University, 1991) and a Ph.D. degree in Soil Science (University of Pretoria, 1995).

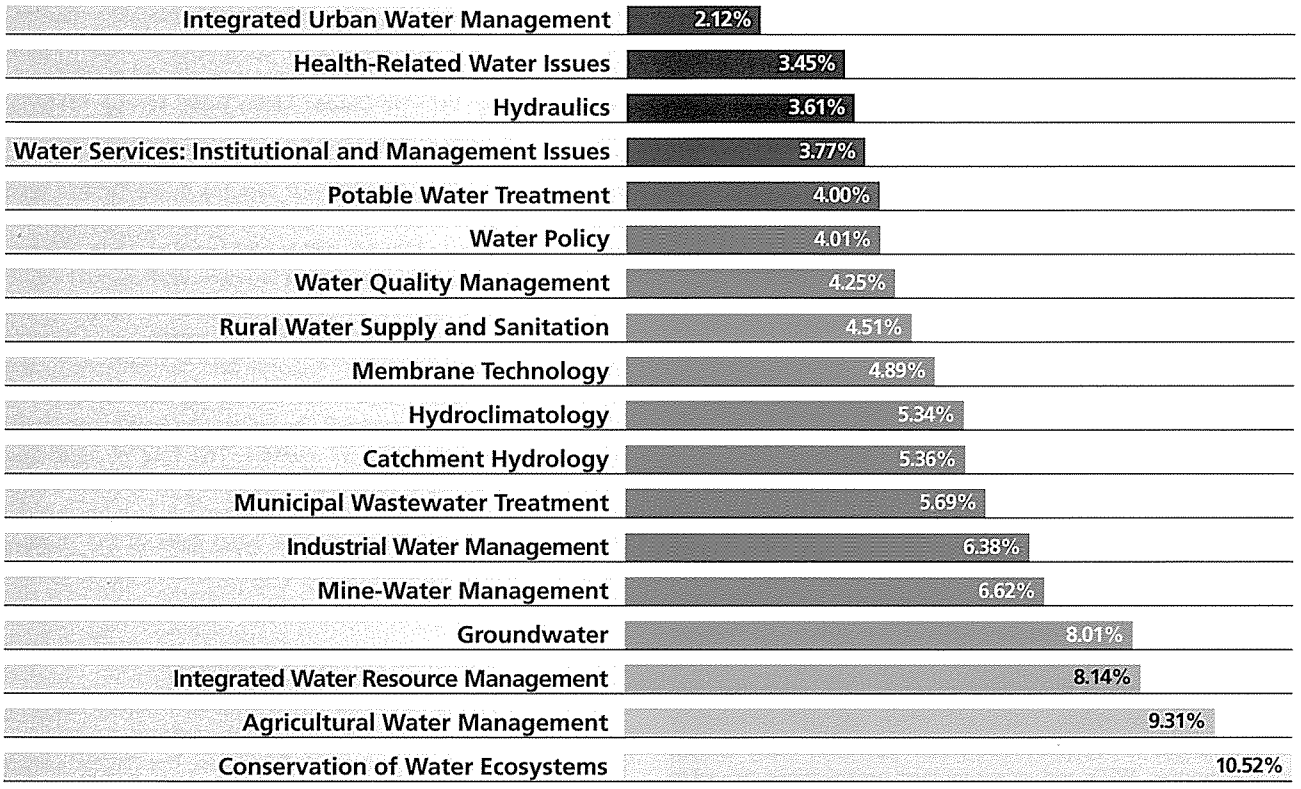
Previous positions that he held included that of Head: Specialist Services at the KwaZulu Finance and Investment Corporation and

that of Project Co-ordinator at the KwaZulu Training Trust. In 1997 he founded a Durban-based agro-industrial development company which became involved in business and institutional development among farmers and communities, the establishment of irrigation schemes, agro-processing plants and agricultural co-operatives, and the raising of funds for and facilitation of agricultural development projects in KwaZulu-Natal and the Eastern Cape.

Distribution of funds among research fields

The diverse number of research fields supported by the WRC bears testimony to its multidisciplinary approach to water research. The research fields and allocation of funds to the various fields for 2000 are indicated in Fig. 1.

Figure 1: Allocation of funds (%) per research field during 2000



Participants in WRC-funded research

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.

From the figures it is evident that universities are involved in 51.57% of the total number of contracts. In 2000 the WRC financially supported 318 projects at a budgeted amount of R62 069 100.

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.

Table 1

Research sector	Number of times involved	%
Universities	164	51.57
Consultants	69	21.7
CSIR	36	11.32
ARC	13	4.09
Water Boards	12	3.77
Government Departments	11	3.46
Technikons	9	2.83
Local Authorities	4	1.26
TOTAL	318	100

Capacity-building: The Research Partnership Fund

Scarcity of water, vulnerability of aquatic ecosystems, a growing population and the key role of water in social and economic development combine to create an ever-growing need for skillful, sustainable management of South Africa's water resources. It is the WRC's responsibility, not only to research the water resource management problems of today, but also to ensure the availability of research and management skills for addressing the problems of tomorrow and beyond. These skills will necessarily have to reside among the vast majority of previously-disadvantaged peoples, which makes capacity-building a priority for the WRC.

Over and above a range of initiatives and strategies which are already in place, the WRC in 2000 launched a capacity-building Research Partnership Fund. The concept of such a fund was strongly supported during the course of a WRC workshop to promote capacity-building held with research directors of historically-disadvantaged universities and technikons. The fund offers historically-disadvantaged institutions and SMMEs, that have been traditionally lacking in research skills and culture, added opportunities and incentives to develop such skills in partnership with established centres of research excellence.

To qualify for support from the fund, the previously-disadvantaged institution must select the water research topic, recruit an appropriate research partner with an excellent research track record and accept the responsibility of project administration and reporting. Initial interest in the fund has been overwhelming. Forty research proposals were received after the first announcement and the call for proposals. Of these, 7 have been selected and will commence in 2001.

Research support for small water institutions

Institutional Arrangements for the Delivery of Water Services was the topic of a WRC workshop held during the WISA 2000 Congress at Sun City during June 2000. Three researchers working on WRC-funded projects, designed to provide support for the implementation of the Water Services Act of 1997, presented their findings at the workshop. This event, which was well-attended by representatives of key stakeholders such as DWAF, water boards, local authorities, NGOs and various research organisations, proved to be an effective platform for marketing the results of research which were relevant to water service institutions.

Among the many problems faced by small water service institutions are difficulties associated with human resource planning and management. Assistance is now available in the form of a computerised Human Resource Planning and Management System. This software, developed through a WRC-funded project, includes both a Management Information System and a Decision Support System.

Water supply and sanitation for schools

A study undertaken by the University of the Western Cape has highlighted the serious problem of inadequate access to drinking water and sanitation for rural and peri-urban schools in South Africa. The study showed that even in schools where these services are available, poor operation and maintenance is a major problem. The recommendation emerging from the study is that parents and teachers co-operate to address this problem, which threatens the health of school children.

Free water for the poor

Rural Support Services undertook a study on behalf of the WRC to investigate rural people's experience of the impact of current water policies. The study identified extreme poverty as a serious threat to the sustainability of new water supply schemes. Rural communities believe that free water should be provided to the very poor. Unemployment and dependency on grants and pensions were prevalent in all case-study areas. Based on the research findings, the study has recommended that an integrated approach to rural development should be adopted; that is, building of new water schemes must be linked to other local development projects.

The shallow sewerage pilot project

An initiative to find appropriate and affordable sanitation solutions for underprivileged and poor urban communities is beginning to show promise. A partnership agreement was initiated at the beginning of the year, between Durban Metro Water Services (DMWS), the WRC and Water and Sanitation Services South Africa (WSSA) to develop a pilot sanitation project to test the concepts of shallow sewerage or Brazilian Condominial Systems in the Durban area and to provide innovative solutions that could be replicated and extended to the rest of Durban and to other parts of South Africa.

The shallow sewerage pilot project has been implemented in two low-income communities: Emmaus and Briardale. Owing to the innovative technical, social and institutional approaches and, most importantly, the communities' response and commitment to the project, it has proved to be a resounding success. The physical construction has been impressive. The project successfully connected all 250 households within 12 months. The cost of extending Durban's sewerage systems to meet the needs of all residents would have been prohibitive if conventional technology had been used. Preliminary findings indicate that financial gains of the shallow sewerage project allowed capital cost savings of 52%. Further research is continuing.

Groundwater strategic plan reviewed

The strategic plan for the groundwater research field was reviewed during 2000. This was necessary because the previous groundwater research master plan was more than 5 years old. The strategic plan is a crucial guide to researchers wishing to enter the groundwater research field, or to submit research proposals which may qualify for funding. It is also a benchmark against which research proposals can be assessed. The strategic plan prescribes a multidisciplinary agenda with scientific programmes that address both short- and long-term research needs associated with the sustainable use and management of groundwater resources in South Africa.

The following goals for groundwater research over the next 5 years were identified in collaboration with various stakeholders:

- To refocus groundwater characterisation within the context of integrated water resource management, which is in line with national needs and priorities.
- To manage groundwater quality with emphasis on the prevention of contamination/pollution.
- To support research that develops appropriate professional, institutional and management practices for achieving integrated water resource management.
- To encourage lateral thinking and innovative and imaginative research with the potential to contribute to meeting the identified vision for groundwater research.

Expected outcomes are research outputs which are relevant to real problems, injection of research outputs into policy-making and enhanced public understanding and community empowerment with regard to groundwater issues.

International co-ordination and collaboration in the groundwater research field

The WRC has been involved in various international collaborative activities in the groundwater research field. This includes co-ordination of the International Atomic Energy Agency (IAEA) country programme framework for South Africa; serving on the steering committee for a Norwegian-assisted programme to DWAF on community groundwater supplies; and lecturing on groundwater legislative aspects to a Swedish-sponsored course.

The IAEA project is a regional project involving several sub-Saharan countries. The South African component will focus on groundwater resource protection and assessment in two contrasting aquifer systems (dolomites and sandstones) using multidisciplinary isotopes and hydrochemical techniques.

The programme on the Sustainable Development of Groundwater Resources under DWAF's Community Water Supply and Sanitation Programme is funded by the Norwegian Agency for Development Co-operation (NORAD). The programme is being implemented by DWAF, the Council for Geoscience, the CSIR and Mvula Trust. The WRC serves on the project steering committee that guides the implementation of the project. The WRC's research manager responsible for groundwater research, received an invitation from Chalmers University of Technology in Gothenburg, Sweden to participate as a guest lecturer in their International Programme on Management of Groundwater Supply for Urban Areas. This 6-week training programme was funded by SIDA, the Swedish International Development Agency. A series of lectures was presented, focusing on South African water legislation and its implications for groundwater management.

Research Co-ordinating Committee for Membrane Technology formed

In line with the WRC's mission of promoting research in its various fields of activity in a structured and transparent manner, a Co-ordinating Committee for Water-related Membrane Technology (CCMT) was established during the year. Representation is from industry, local authorities, government departments, water boards, non-government organisations, development institutions, academic institutions and other interested and affected parties. The inaugural meeting was held on 3 October 2000.

The CCMT will act in an advisory capacity to the WRC, assisting in the strategic decisions which need to be taken in order to promote research on membrane development. The existing Strategic Plan for Water-Related Membrane Research will form the basis of decision-making until possible future review. The CCMT will also advise on information and technology transfer in order to promote the general acceptance and application of membrane technology in the country.

Ultrasonic "visualisation" of a membrane-fouling layer achieved

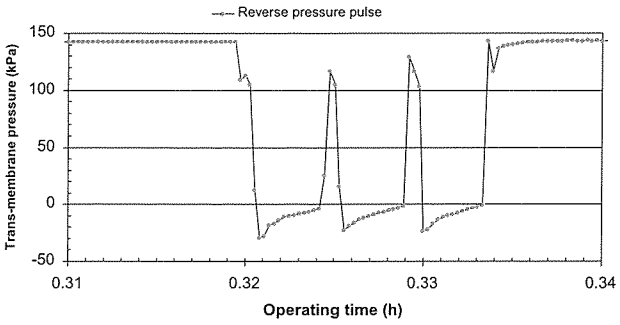
Researchers at the University of Stellenbosch have succeeded in developing a technique to measure the thickness of a fouling layer on a membrane in real time by means of ultrasonic reflectometry. They are also able to measure the relative increase in density of the fouling layer with time, which correlates with the simultaneous decrease in flux. This technique opens up avenues for the non-invasive measurement and control of membrane fouling in real time. Using this technique, the efficiency of fouling prevention strategies may, for example, be monitored immediately as they are applied. In addition to the measurement of fouling, the ultrasonic technique has also been employed successfully for the monitoring of membrane-cleaning operations. Since no real-time permeate data are readily available during cleaning operations in industrial applications, such a non-invasive monitoring device may prove to be valuable in monitoring and optimising cleaning strategies for membranes.

China-South African membrane technology workshop

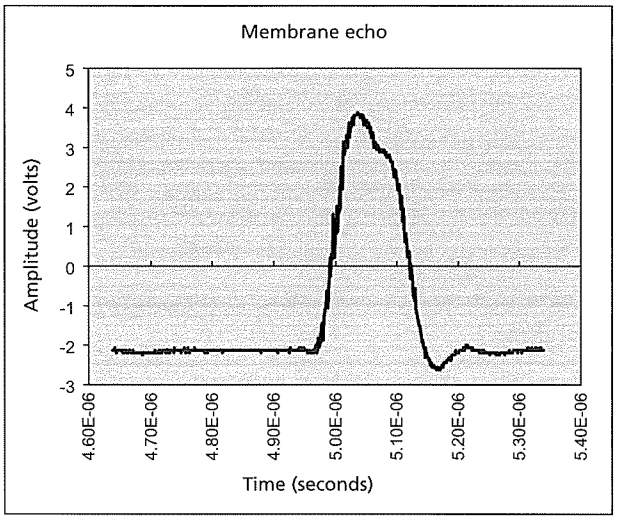
A China-South African bilateral workshop for water-related membrane technology was held in Beijing on 20 September 2000. The workshop was arranged in conjunction with the Membrane Industry Association of China, after initial contact was established between their Secretary General, Dr Guo Youzhi, and the WRC. The status of membrane development in the two countries was discussed by means of presentations by members of the academic and industrial sectors from both countries. The workshop was attended by 30 members from the Membrane Industry Association and 6 members from South Africa, of whom 4 presented overviews of current developments in South African membrane technology. Good contacts with Chinese membrane technologists and industrialists were established, and an impromptu tour of Chinese industries was arranged for the South African delegation after the workshop.

New membrane defouling technique developed

A simple but very effective technique for the defouling of ultrafiltration membranes by means of reverse-pulse generation has been devised by the Institute for Polymer Research, University of Stellenbosch. In contrast to normal back-flushing of the membrane with product water, which takes place over a period of several minutes, this technique provides a reverse-pressure spike over a very short period of time, thereby forcing the full feed flow of water through the membrane in the opposite direction to the filtration cycle. In this manner, a high momentum is achieved and the membrane pores are cleaned very effectively. Preliminary evaluations, performed in dead-end mode, have shown that the normal period between membrane cleaning may be extended many times by using this technique. The technique has been patented by the WRC.



An example of reverse-pressure spikes generated during reverse-pressure pulsation for on-line defouling of ultrafiltration membranes.



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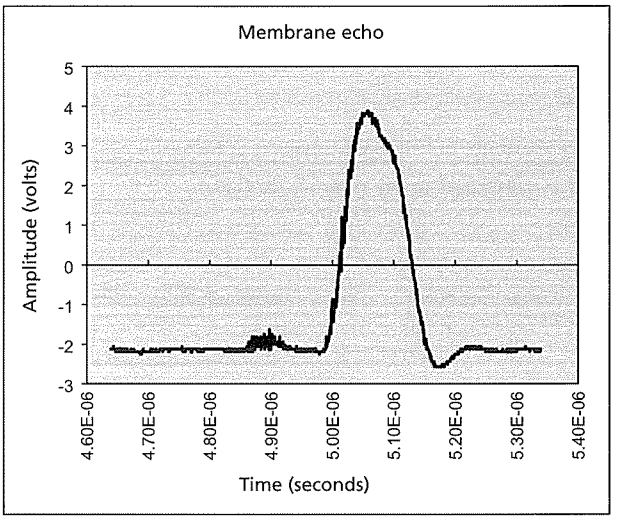

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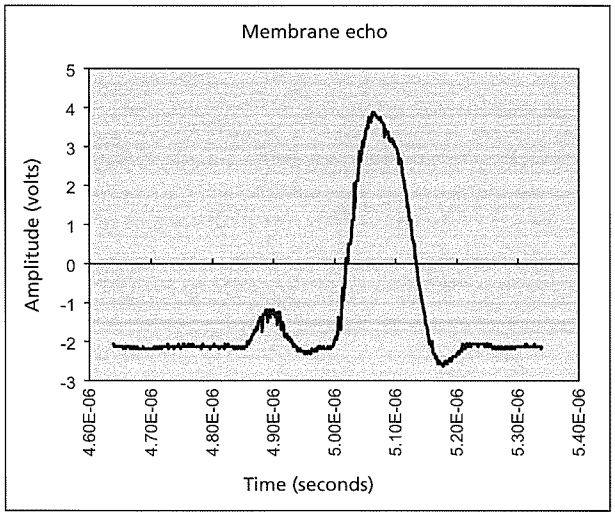

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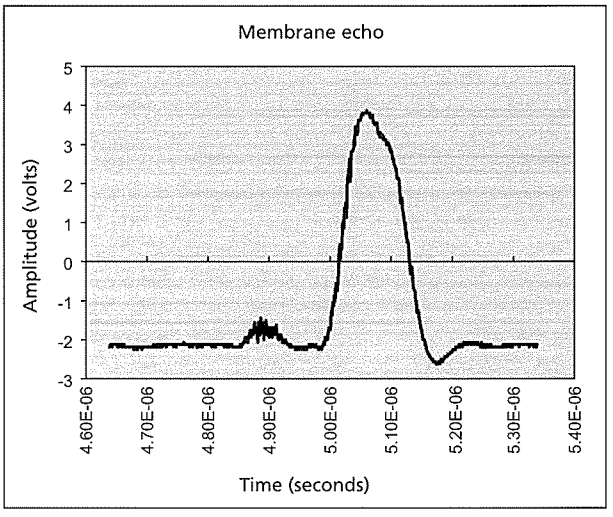


3 hours

Visualisation of membrane fouling by ultrasonic responses.

Health-Related Water Research Plan under development

The new research field, **Health-Related Water Issues**, was established during the year and several workshops were held to identify research needs and to develop a strategic plan for addressing these needs. The plan will be published for comment on the WRC website early in 2001. By providing ongoing comment, stakeholders will contribute to keeping the plan relevant and of value to researchers as a guide to ensuring that research proposals, submitted to the WRC, address topics which are crucial to providing communities with safe, affordable domestic water supplies.

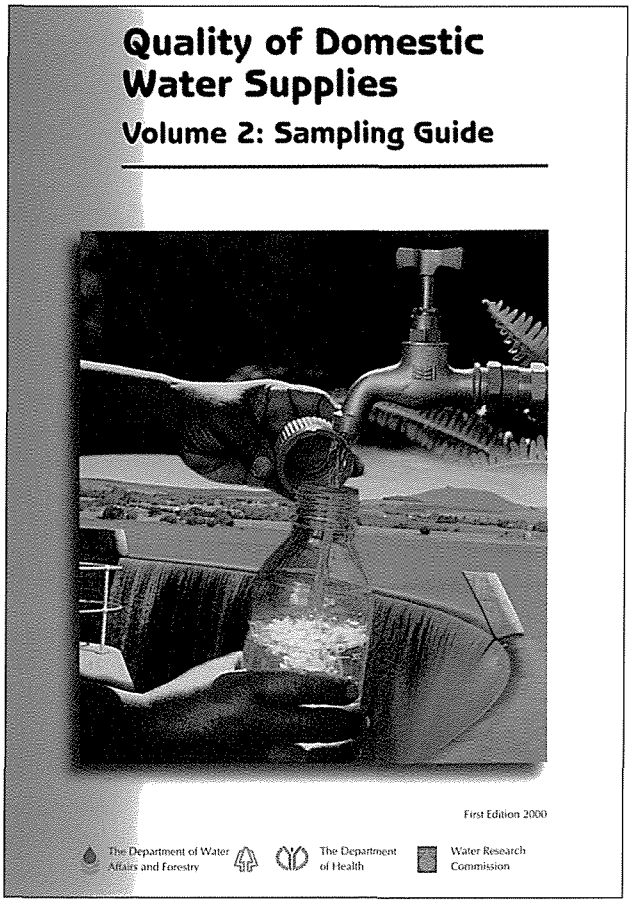
Priority areas given prominence in the research plan include research on the occurrence and control of algal toxins and of endocrine disruptors in potential drinking-water sources. Various steps, involving stakeholders, have already been taken in developing research programmes for these priority areas. The programmes themselves will hopefully get under way in 2001.

Series of guides on the Quality of Domestic Water Supplies

The demand for the *Assessment Guide*, produced in 1999 as the first in the guideline series *The Quality of Domestic Water Supplies*, a joint project of the WRC, DWAF and the Department of Health, was so great that it has had to be reprinted. The extent of this demand illustrates the widespread need which has existed for a sound, user-friendly guide on the interpretation of water quality data in terms of risk to the domestic user of the water. The second guide in the series, the *Sampling Guide*, has been published, while the remaining volumes in the 5-volume series (*Analytical Guide, Treatment Guide* and *Management Guide*) are expected to be released in 2001. Release of the Guides will be followed, shortly thereafter, by a series of workshops to ensure that potential users gain maximum benefit from these publications.

Waste minimisation clubs – a growing concept

A technology transfer evening was hosted by the WRC on 23 May 2000 in Durban to create an opportunity for sharing experiences among the club members of the two pilot Waste Minimisation (WasteMin) clubs which were established in the initial 3-year WRC project commenced in 1998 by the Pollution Research Group (PRG) at the University of Natal (UND) to investigate the feasibility and effectiveness of WasteMin clubs as a means of assisting industry to improve their environmental performance. The two pilot clubs are a Metal Finishing WasteMin Club in Durban, formed in June 1998, and the Hammarsdale WasteMin club, formed in November 1998. When their reduced environmental impacts are quantified in terms of monetary savings on water use, effluent treatment and disposal, energy, chemicals, and waste disposal, the two clubs report an annual saving of over R6 million per year. The experiences of the two pilot WasteMin clubs and their members indicate that the clubs have been successful in addressing some of the main barriers to companies implementing waste minimisation programmes, namely lack of time, resources and finance. The WasteMin club concept is being actively endorsed and promoted in a new DANCED project (commencing 2000, value R12 million) which aims towards cleaner production in the metal-finishing industry in the RSA, which *inter alia* will seek to establish a number of regional WasteMin clubs nationwide in the metal-finishing industry. A number of other WasteMin clubs have also been established recently in Cape Town, Pietermaritzburg, Port Elizabeth and Sasol Secunda (in-house), with several more in the pipeline in the immediate future. It is apparent, therefore, that the WRC's investment in initiating the establishment of WasteMin clubs has stimulated a very active interest and response from industry.



Activated sludge biomass – local and international collaborations

A new WRC research programme commenced this year. Its aim was to synergistically combine microbiological and engineering skills in determining the active heterotrophic and autotrophic fractions in biological nutrient removal activated sludge (BNRAS) systems. The active fraction is a concept used in the modelling and design of BNRAS processes, but has never been empirically determined and verified. The local RSA research programme has started with three collaborative projects which are being carried out by Technikon Natal (molecular biology), the University of Cape Town (dynamic modelling) and the University of Pretoria (microbial population distribution).

An exciting development is the entry of the Australian Cooperative Research Centre for Waste Management and Pollution Control (CRC-WMPC) into the programme, with support also from Lyonnaise-des Eaux. The collaboration of the CRC-WMPC was initiated at a workshop held in Stellenbosch in June 1999, when an overall research co-operation agreement was signed between the WRC and the CRC-WMPC. The Australian participation in the above-mentioned collaborative research programme to determine active biomass fractions in BNRAS systems has now been confirmed, and will be led by Dr Linda Blackall (molecular biology) and Prof Jurg Keller (simulation modelling), both of the University of Brisbane and both recognised internationally as leaders in their respective fields. The relevant partnership will build local RSA capacity in these specialised fields as well as greatly enhancing the prospects of rapid and far-reaching progress in this WRC research area.

Biological sulphate removal – much activity in 2000

In 2000 a number of significant developments and activities have taken place in the field of biological sulphate removal with regard to industrial, mining and domestic (sewage sludge) applications. Research in this area is being funded by the WRC in a number of closely-co-ordinated projects being carried out *inter alia* by Rhodes University (Department of Biochemistry and Microbiology) and the University of Cape Town (Departments of Chemical Engineering and Civil Engineering).

- During the BioY2K conference held in Grahamstown in January, a prominent theme was biotechnological treatment of acid mine drainage (AMD) effluents, with international participation from the UK, the USA, Canada and the Netherlands. In both active (rapid) and passive (slower) treatment systems, the RSA is clearly playing a lead role in the international arena in developing fundamental and application-oriented knowledge of biological sulphate removal processes for AMD treatment.
- Biological sulphate removal also featured significantly in the WISA 2000 conference held at Sun City in May 2000. International participation and interest in the RSA research in this area was again very evident.
- As a follow-up to WISA 2000, the Anaerobic Processes Division of WISA organised a 2-day technology transfer workshop in August 2000 in Pretoria on "Biological Sulphate Removal". A feature of the workshop was that the WRC thrust into active biological sulphate reduction systems, funded in a large number of research projects over almost a decade, is producing highly relevant, practical and implementable results which are being exploited in a number of collaborations with industry and others.

Accelerated sewage sludge digestion – interest shown by industry

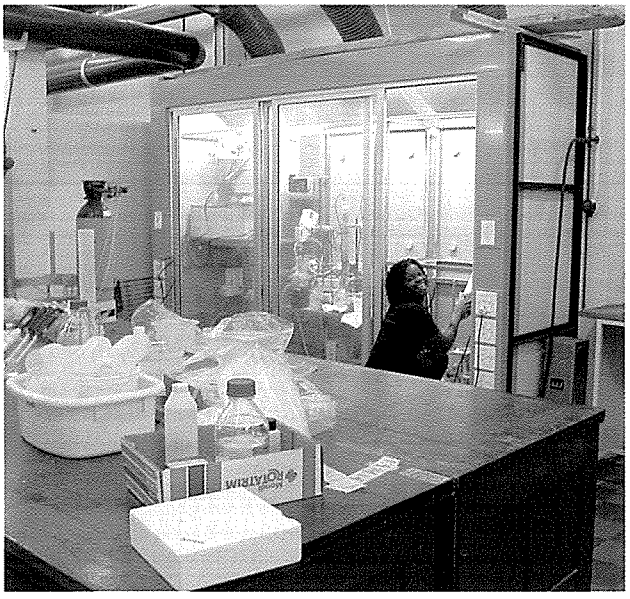
A spin-off from WRC-funded research on the biological sulphate reduction process using sewage sludge as the complex carbon source for sulphate-reducing bacteria (SRB) is the observed phenomenon of an accelerated hydrolytic breakdown of sewage sludge particulates in the presence of sulphate and SRB. This phenomenon is being further investigated in current WRC projects at enzymological, microbiological and engineering (modelling) levels.

The potential for a novel process to accelerate sewage sludge digestion has been recognised by a major sewage utility, the East Rand Water Care Company (ERWAT), which has entered into a contract with Rhodes University and the WRC to develop the process at full scale. ERWAT will provide capital for installing the process at their Ancor Sewage Works, Rhodes University is providing technology support through laboratory and pilot-plant studies being carried out in parallel, and the WRC is contributing towards the intellectual property rights developed in previous research projects as well as ongoing funding to Rhodes University. The results of the joint exercise, which will be operational on a full scale by 2001, are eagerly awaited by practitioners who are active in the management, treatment and disposal of sewage sludge, which contributes a very significant proportion of the overall cost of sewage treatment.

Cleaner production – national interest

Over the past several years, WRC-funded research into reducing pollution from industrial sources has promoted the progressive "cleaner production" approach, in which the emphasis is on developing sustainable improvements in environmental impacts by addressing the use of resources at process level at source in the factory. Techniques employed in achieving reductions in pollution range from relatively simple housekeeping measures, to the substitution of unit processes by more environmentally-friendly options, to the use of sophisticated analytical tools such as pinch technology for determining the optimum and minimum input levels at which interlinked processes can operate.

In 2000, developments by others in the area of cleaner production include the following:



The WRC sulphate reduction laboratory at UCT.

- The Danish Co-operation for Environmental Development (DANCED) has commenced two multimillion rand projects to assist in the implementation of cleaner production practices in the metal-finishing and textile industries. Both the DANCED projects will build on and utilise outputs from previous and current WRC projects on waste minimisation and cleaner production in these industries.
- DWAF has commenced a project for benchmarking water use and pollution generation in the industrial, mining and power generation sectors. Cleaner production will be an overall guiding principle in the project for defining "best practice" in these sectors.
- The Department of Environmental Affairs and Tourism (DEAT) has created three high-level posts to plan and manage integrated pollution and waste management, chemicals management, and waste minimisation. Each of these areas will focus on cleaner production and clean technology.

Grahamstown Biotechnology Field Station – new sulphate reduction unit

On 27 January 2000 Mr PE Odendaal, the now-retired Executive Director of the WRC, officially opened a major extension to the Rhodes Biotechnology Field Station located at Grahamstown Sewage Works. The original Biotechnology Field Station was opened in 1997 by Minister Kader Asmal, at that time the Minister of Water Affairs and Forestry. The Field Station is a unique collaboration between Rhodes University, the Municipality of Grahamstown and the WRC, and has been used continuously as a facility to test various aspects of high-rate algal pond technology for sewage treatment. The latest addition is a sulphate reduction pilot plant which will be used, *inter alia*, for trials on the rapid hydrolysis and digestion of sewage sludge in the presence of a sulphate source and sulphate-reducing bacteria. These pilot trials, along with ongoing laboratory studies at Rhodes University, will support the further development of the Rhodes BioSURE process for the treatment of acid mine drainage effluents, as well as for the full-scale testing of the rapid sludge hydrolysis process being carried out concurrently at full scale by ERWAT.

Workshop to determine the direction of research and implementation of ecotoxicology and bioassaying

The WRC has supported research in this field for some years. An assessment by Professors Liu and Dutka from Canada during the 9th International Symposium on Toxicity Assessment held in Pretoria in 1999 concluded, in the light of their experience, that there is sufficient expertise in the country to implement toxicological water quality monitoring in the country, and that South Africa should not directly import standards from other countries, but should develop or modify its own standards.

Prior to the promulgation of the National Water Act there was no requirement for the use of toxicity testing in any form. The National Water Act makes allowance for the use of organisms in the monitoring of water and effluent quality. This workshop was held to identify the research needs that are aligned with the requirements of the Act. The workshop aimed at establishing the current knowledge base in the field, identifing the steps necessary for implementation under the National Water Act, and in the light of potential implementation, identifing research needs.

A recommendation was put forward from the workshop to incorporate a toxicity-based clause in the General Authorisation to discharge a complex effluent.

Overview of the Kruger National Park Rivers Research Programme (Covered in greater detail in Chapter 16 – Conservation of Water Ecosystems)

After more than a decade of directed research, the Kruger National Park Rivers Research Programme was formally closed. This programme was innovative and delivered high-quality scientific study in a cost-effective manner. It contributed meaningfully to the establishment of user interest groups and Catchment Management Agencies, as well as to policy and strategy development. It also contributed practically to the adoption of strategic adaptive management principles and practices. These effects will endure.

Catchment management symposium and workshops

The Water Institute of Southern Africa (WISA) Division of River Basin Management and Division of Management and Institutional Affairs together with DWAF and the WRC organised a symposium and workshop on 15 and 16 February 2000. The theme of the event was **Catchment Management in South Africa: Turning Policy into Practice**. Some 350 people participated, which is indicative of the enormous interest shown by different sectors of society on this subject.

The workshop revealed that there are many existing catchment management initiatives in the country. There was a clear appeal for the establishment of a data network of all such initiatives.

Clearly, society has adopted an adaptive management approach, i.e. learning by doing. Some key perspectives were highlighted once again:

- By and large, it is not possible to manage resources such as water. All we can hope to manage is **what people do with water**.
- Sustainable development cannot be achieved by National Government alone. It will require acceptance and achievements at local level in the first place.
- An important first step in the process of developing a strategy would be to establish a shared vision of integrated water resource management in a catchment or water management area.
- Stakeholders need evidence that their inputs are not in vain.
- A shift from a technocratic approach to a social process was emphasised.

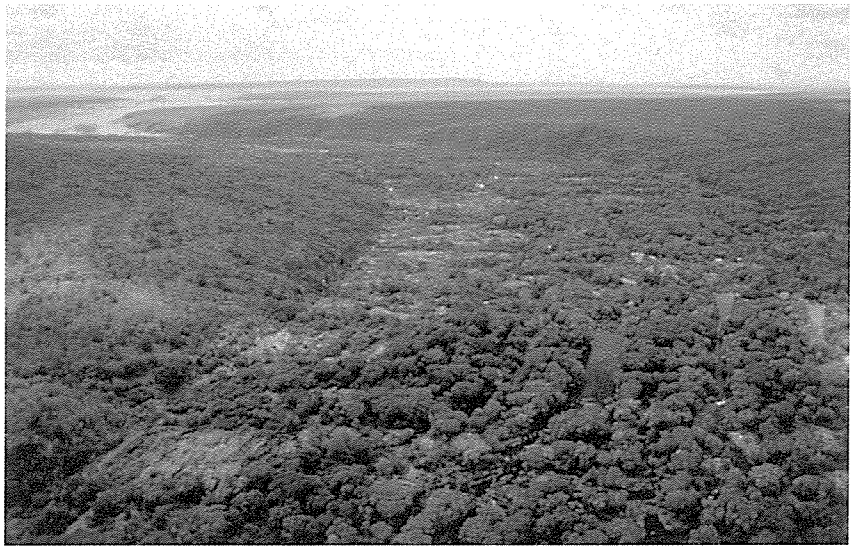
The **need** for a generic process charter for public participation in catchment management, based on the principles laid down by the Constitution, the National Environmental Management Act (NEMA), the National Water Act and others, is required to outline the roles, responsibilities and accountability of all stakeholders.

Kat River Valley Project

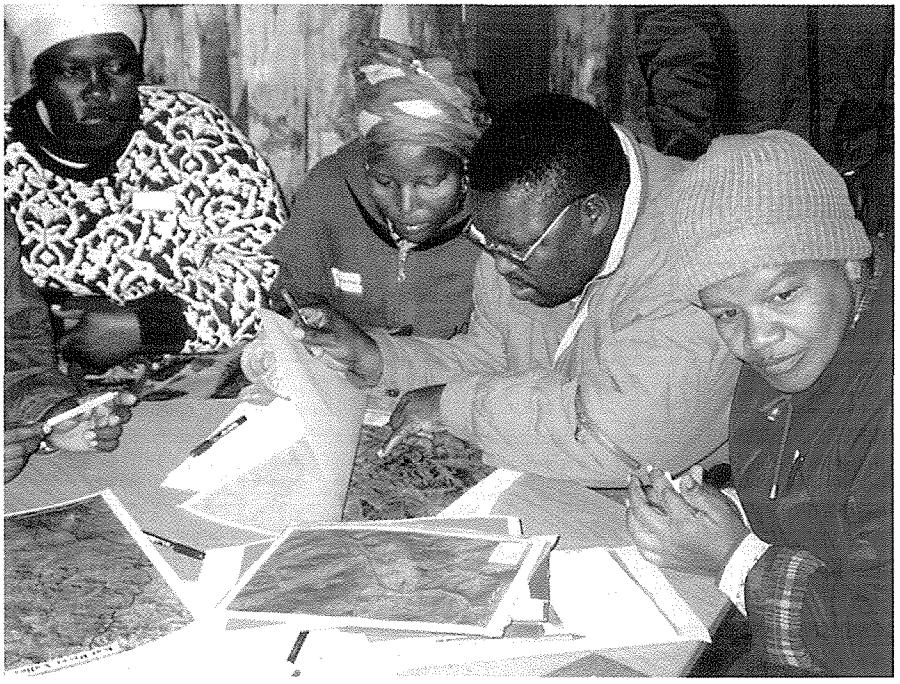
Kat River Valley project is the popular name adopted for a WRC-funded project at Rhodes University. This project was a finalist in the **Nedbank/Mail & Guardian Green Trust Awards 2000** competition. The official objective of this project is the development and co-ordination of catchment forums in the Eastern Cape through empowerment of rural communities. In the words of the project leader *"We sought actively to acknowledge the indigenous communities' environmental knowledge, in a series of participatory workshops. Usually, environmental studies employ a "top-down" approach that suppresses local values and management systems"*. One of the highlights of the project was a stakeholders' workshop held in the valley. Representatives from the Mpofu communities, citrus farmers, international, national and local advisors on catchment management and university academics got together to work out the future of water management in the valley.

A draft constitution for a water users' association is now on the table.

The project has demonstrated that even the most isolated and



The extreme floods of February 200 markedly changed the character of the Sabie River. The forested section of anastomosing channels in the Sabie River gorge before (photograph above) and after (photograph below) the floods.



Kat River Community participation in local water resource planning.

impoverished rural communities can play an important role in managing their environmental resources. During this work the effectiveness of using community drama and role-play was clearly demonstrated as being important avenues for all to follow in promoting water awareness among the many communities in similar situations.

DWAF, WRC and CSIR co-operate in research on streamflow reduction activities (SFRAs)

DWAF, WRC and Environmentek (CSIR) are major funders of research in the fields of water and land management in South Africa. The management of SFRAs, specifically, has been spelt out in the National Water Act and many new challenges have emerged.

Early in the year the three parties signed a memorandum of understanding (MoU) to co-operate in a research programme to support the implementation of the Water Act with regard to SFRAs.

The MoU is seen as an important step in co-ordinating the national research and development effort. The management committee, chaired on an alternating basis by the WRC and DWAF, includes representatives of important stakeholders such as the Forestry Industry and the Sugar Association. Representatives of the SFRA Licence Assessment Advisory Committee will ensure that the outcome of the research is relevant to the licensing process.

Discussion forums for the determination of practical problems and research priorities in the field of agricultural water management

During 1999 the **Co-ordinating Committee for Research on Agricultural Water Management** recommended strongly that discussion forums be organised in all provinces. The goal is to obtain first-hand information from irrigation farmers on what problems they experience and what they consider to be priorities for research and technology transfer. A start was made in 2000 by holding two discussion forums in the Free State and Northern Cape Provinces. In order to achieve representative participation, the Provincial Agricultural Union and the Department of Agriculture were consulted. Invitations were sent to approximately 35 individuals comprising farmers, Departmental officials, agricultural advisors and researchers affiliated to the University of the Free State and the Agricultural Research Council. Within the framework of the WRC Strategic Research Plan, problems that required urgent attention were identified through group discussions. These covered focus areas such as soils, crops, irrigation engineering and economics of water use on a farming level. A report of the discussions was compiled and sent to all participants for their approval. These reports will be a valuable guideline for the submission and evaluation of research proposals for funding on a priority basis in the next few years. Further discussion forums are planned for all other Provinces and arrangements are already under way for the Mpumalanga and Western Cape Provinces.

Impact of salinisation quantified

As the salt content of water increases, the water becomes less suitable for most users. Desalination incurs additional costs. The first serious attempt to quantify these costs in South Africa, was carried out as a desk study for the Vaal River by a WRC specialist consultant, and published in 1987: The so-called Heynike Report. Recently a follow-on study was undertaken in association with DWAF because of uncertainties about some of the methodology and assumptions used in the desk study and the need for a versatile economic model that can be used to quantify the effect of salinity in monetary terms and to compare the cost-benefit ratios of alternative water options. A generic methodology to determine the financial, economic and social impacts associated with an increase in salt concentration was developed first, and then applied by conducting a survey to determine the impacts of increased salt concentrations in the Middle Vaal River. Conceptual formulae were developed to describe the behaviour of different sectors of the economy, viz. households, agriculture, mining, industry and services. An increase of 100 mg/*l* from 500 to 600 mg/*l* could be expected to effect a R26 million increase in annual direct costs in the study area, approximately 85% of which would be borne by the household sector. Ratios of the direct, indirect and induced costs to the direct costs, ranged from 1 to about 3.3. Earlier research had already indicated that feeder systems and the natural environment would not incur significant additional costs within the studied range of 200 to 1 200 mg/*l* TDS.

Making the difference – improving agricultural water management

The implementation of research findings is the ultimate objective for the fulfilment of the mandate of the WRC. For this purpose, a wide range of approaches is followed including publication and distribution of reports, announcement of the availability of the report in the *SA Waterbulletin*, and organisation of workshops or training sessions. However, following a customer value study, it is clear that much more attention needs to be given to the marketing of WRC-

funded research reports.

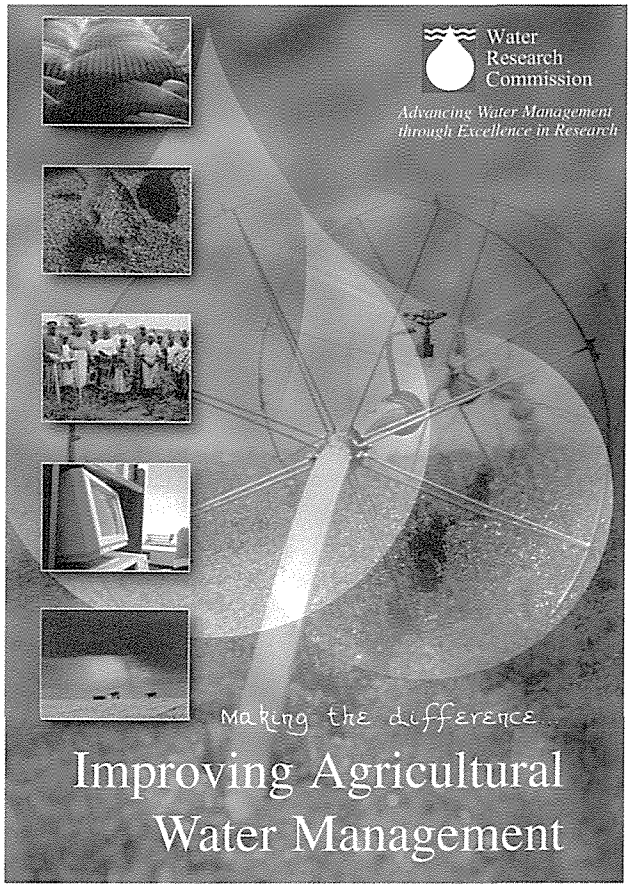
In a recent agri-market survey, it was also found that the most important type of information required by irrigation farmers was information on daily crop-water requirements. The training that is needed most is for simple irrigation scheduling. A very interesting preference was also expressed for popular magazines (in contrast to scientific journals) as a source of information. The observation that research findings must be more actively marketed, was confirmed by a relatively low awareness of WRC research reports.

In response, the initiative has been taken to present research findings of WRC reports to water users in agriculture in an easy-to-read and attractive format. This marketing report highlights research projects which are of practical relevance under the following headings:

- Irrigation
- Rainfed or Dryland Agriculture
- Livestock
- Weather
- Water Resources

The names and contact details of the project leaders are also provided to facilitate follow-up discussions and to obtain further advice.

This marketing report is published in English and in Afrikaans and is obtainable from the WRC, P O Box 824, Pretoria 0001.
Telephone: (012)330-0340. Fax: (012) 331-2565.
Internet: http://www.wrc.org.za



Contamination with agrichemicals assessed

Internationally there is considerable concern about the contamination of water supplies by pesticides. In spite of a marked increase in the expenditure on, and the variety of locally-used agrichemicals, there is a paucity of local research to date. The analytical capacity to determine very low levels of selected pesticides was developed at the Peninsula Technikon as part of this study. A significant spread of contaminant detections was made throughout all three areas that were selected for the study. Only a few of these would be cause for concern when judged by World Health Organisation standards. However, if the stricter European Union standards are used, many more detections would give rise for concern. A number of sampling points where water is used for drinking were consistently contaminated. The levels were, however, so low that they generally represented less than 1% of the acceptable daily intake. A striking and encouraging feature which emerged from farm surveys was the relatively high level of awareness demonstrated by both farm workers and employers concerning the health hazards associated with pesticides.

Eutrophication research revisited

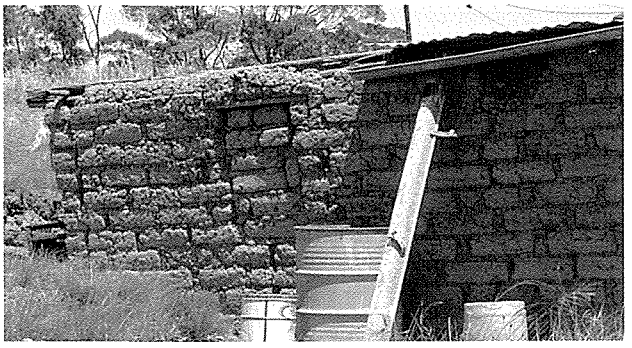
Eutrophication remains one of the major water quality problems of South Africa. There are few water systems that have not been affected to some extent by the problem. The potential cost implications for treatment and loss of fitness for use are high. Although this subject had received extensive attention in the past, it was largely neglected during the 1990s. With the aim to develop a framework for future eutrophication-related research, the WRC commissioned a review and discussion document which could assist in identifying those priority research areas which require further support from a South African perspective. The report presents a broad overview of concepts on eutrophication, its consequences and control. It, furthermore, represents a scan of the eutrophication problems in countries where eutrophication is regarded as a high priority water-quality issue. The situation in South Africa is dealt with by taking account of national policy and legislation. This suggests that increased attention to the problem is necessary.

Logical framework developed for mining-related water research

Mining, especially coal- and gold-mining operations, contributes significantly to water pollution in those catchments where mining takes place. Research and technology transfer in this field is overseen by the Co-Ordinating Committee for Mining-Related Water Research (CCMRWR), which comprises representatives from government departments, industry, NGOs and a broader pool of relevant expertise. Against the background of the present and expected future impact mining will have on water quality, the CCMRWR developed a logical framework for its future activities during a workshop in November 2000.

2 Rural water supply and sanitation

During the year under review, the WRC launched a new research field based on rural water supply and sanitation. This field replaces the research field on ***Developing Communities: Water Supply and Sanitation.***



A rural house made of bricks comprising special mud and sand obtained from the river bed and river bank (riparian zone). Also seen is an innovation to trap rain water for household uses. This saves time for other household activities and provides safe drinking water because of increasing poor quality and decreasing availability of river water.

This change was necessitated by the challenges facing delivery of services to the rural areas which were different from those of developing urban areas. The situation is exacerbated by extreme poverty which is characteristic of most rural areas in South Africa. Innovative approaches are required to ensure that research provides solutions that address the needs in rural areas. A new Co-ordinating Committee for Research on Rural Water Supply and Sanitation was established. This committee contributed to the development of two research programmes which will drive high priority research projects in order to support sustainable service delivery to rural areas.

The following five-year programmes will commence in 2001:

Effective institutional arrangements and support for water service provision in rural areas

The overall goal of this programme is to support sustainable water service delivery for rural communities.

Specific objectives of the programme are to:

- Specify an institutional framework which would support the provision of levels of water services that rural communities want and for which they are willing to pay.
- Ensure that Water Service Authorities (WSA) and Water Service Providers (WSP) are well-equipped to manage community water supply and sanitation systems.
- Develop effective strategies for promoting an integrated approach to development initiatives for rural communities.
- Develop and evaluate different management models for rural water service delivery.

Improvement of the health of rural people through the promotion of adequate sanitation and hygiene practices

The overall goal of this programme is to support the improvement of the quality of life for rural communities through the promotion of adequate sanitation and hygiene practices.

Specific objectives of the programme are to:

- Establish an appropriate balance between the cost of sanitation services and consumer demand.
- Improve the co-ordination of the implementation of sanitation programmes by ensuring that roles and responsibilities of all role players are clearly defined.
- Develop guidelines for involving community-based institutions in the planning and implementation of sanitation programmes in rural areas.
- Develop innovative approaches for influencing positive behavioural change and social marketing of sanitation.
- Develop alternative financing mechanisms for household sanitation projects.
- Develop key performance indicators for successful sanitation programmes.

During the year under review, the WRC initiated a new project which focuses on developing guidelines for the operation and maintenance for water supply schemes that are based on local knowledge and experience. This study will develop a methodology for developing locally-based solutions rather than imposing external solutions that are foreign to rural communities.

Completed projects

Water resources and sanitation systems source-book with special reference to KwaZulu-Natal

(No 384) University of Natal – Department of Economics

This project involved the development of a computerised bibliographic database and source book. The objective was to provide quick access to South African literature. The central theme concerns water and sanitation in the broadest sense, incorporating material usable by a wide variety of disciplines.

The bibliographic database covers 93 years of South, and in certain cases, Southern African literature (1900–1993). The database is divided into 25 different parameters and contains 11 432 entries, all of which are in some way related to water and sanitation. The database is available on either diskettes or on CD-ROM, and is arranged alphabetically by author and also in terms of individual parameters. Users can search by author (if known), by journal, by some identify-

ing characteristic, or by user-selected key words. No highly specialised computer skills are required to use the database.

Over 70 libraries and other sources of information (such as consulting engineering firms) in KwaZulu-Natal, were visited during the information retrieval phase of the project. An interesting feature of the database is the historical record of intellectual endeavour which is made apparent by scanning titles of papers and other material found on the database. Older material is useful in identifying trends, and for before/after environmental case studies. Compilation of the database has also revealed the extent to which material (and not only the older literature), has been forgotten and all but "lost". It is apparent, however, that no-one can be aware of all South African material which is available in a specific field. A bibliographic database is one means of trying to keep track of the flood of literature which is being produced in South Africa.

The source book, which is not a textbook, has a multidisciplinary theme. The aim of the source book (consisting of 6 volumes) is to provide core information on selected topics. Most chapters list important primary references for further reading, and the addresses of some organisations which are active in the particular field. The source book consists of 20 chapters divided into data chapters and discussion chapters. Data chapters provide highly concentrated information, whilst discussion chapters integrate material from all parts of the book in an attempt to provide an overview analysis. The book should be especially useful for those who are unfamiliar with a given topic, and who wish to know more, but who are unsure about where to begin to find South African material. Most chapters or parts of chapters have a counterpart in the database.

Cost: *R433 800*
Term: *1991-1998*

Development of a training programme on community water supply management for village water committees

(No 435) CSIR – Division of Water, Environment and Forestry Technology

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

Community acceptance of a water supply scheme is usually far greater if the community is involved in the management and decision-making processes right from the beginning of the project. Hence, it would be desirable if the elected committee could undergo some management training before the project is initiated in order to enable them to make decisions based on a clear understanding of the short- and long-term consequences of these decisions. A need has been recognised to offer courses which are specific to community water supply management and which are directed at the level of the village management committees. Many problems are presently encountered by water committees. Hence, the objective of the study was to determine a suitable training programme to address aspects of community management of water supply and sanitation.The findings from the study indicate that:

- Water committee management training can play an important role in the establishment of an "enabling environment" in which rural communities can successfully take control of their own water and sanitation development projects. The ultimate result will be the establishment of more sustainable supply systems and the reduction of water and sanitation investment risks. The proportion of the cost of a water project which is required for training is minimal, but the effect, in terms of sustainability, can be profound.
- In the development of successful community management teams, the following aspects should receive particular attention:
  - Provision of training and resources to create an effective "enabling environment" for the development of water and sanitation projects.
  - Motivation of communities to assess and identify their needs.
  - Adoption of a participatory approach as opposed to a directive approach by government and other agencies.
  - Encouragement of communities to become involved in the decision-making processes of all aspects of the project.
  - Appropriate training courses, which incorporate both management and technical skills, should be available.
  - The establishment of national and regional training centres for water and sanitation, and the concomitant co-ordination of training activities in these sectors.
  - Promotion of the role of women at all levels of water and sanitation development projects, including community management.
  - The evaluation of the committee training course developed for KwaZulu-Natal with a view to its improvement and establishment in other centres as soon as possible.
  - Clarification of the role of government in the promotion of training and the provision of other community support systems.

The main issue emanating from this study was the development of a water committee training course in conjunction with the KwaZulu Training Trust (KTT). This is perhaps the first course which is designed specifically for water committees from developing communities, and would require improvements and modifications as feed-back is received, regarding its effectiveness.

Cost: *R135 000*
Term: *1992-1994*

Sludge build-up rates in septic tanks, biological digesters and pit latrines in South Africa

(No 544) CSIR – Division of Building Techology

Pit latrines, on-site digesters and septic tanks are being increasingly installed as appropriate alternatives to full water-borne sanitation. The bacterial digestion process on which the operation of these systems is based, is never a hundred percent efficient. Therefore, a layer of undigested sludge accumulates in the digestion chambers of all these systems. This means that a tank fills up over time and has to be desludged. For this purpose, it is necessary to have a proper indication of the rate of sludge accumulation in a specific type of system operating under certain conditions.

Various problems which affected the research were tank-emptying routines, lack of reliable information on the number of users, improper emptying of tanks as well as political instability in certain areas. Despite these problems, sufficient information was obtained for the purpose of establishing acceptable design guidelines.

The study yielded some important aspects on which recommendations could be based. These include:

- User education is of crucial importance in order to ensure the correct operation and maintenance of sanitation systems.
- Correct installation of sanitation systems should be enforced by quality control on-site.

- Pits for ventilated improved pit latrines should be as deep as possible in order to reduce desludging frequency, given site conditions and cost constraints.

Cost: *R250 100*
Term: *1993-1995*

Development of a decision-support system for the selection of the most appropriate sanitation option for developing communities

(No 586) Umgeni Water

The specific aim of this project was the development of a decision-support system which would facilitate the selection of the most appropriate sanitation option by integrating available information and expertise according to sound scientific and socio-economic principles.

Robust and effective site sanitation planning and reporting aid (SSPRA) software has been developed to assist planners and decision-makers in the selection of appropriate sanitation technologies. This system is not formally linked to a geographic information system (GIS), but it has been provided with a spatial dimension in the form of the regional zoning map. This map also provides a contextual basis for site-based sanitation selection. The SSPRA software is accompanied by a comprehensive user manual to provide the user with information that is required to use the system effectively.

Cost: *R300 000*
Term: *1993-1996*

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

(No 603) CSIR – Division of Water, Environment and Forestry Technology

Deep- and shallow-well handpumps are used extensively for rural community water supplies over large parts of South Africa. Very often, however, these installations fail to meet the requirements even though they are considered to be one of the simplest community water supply technologies. These failures may be due to:

- Inadequate pump design
- Poor pump selection
- Poor pump installation
- Inadequate maintenance

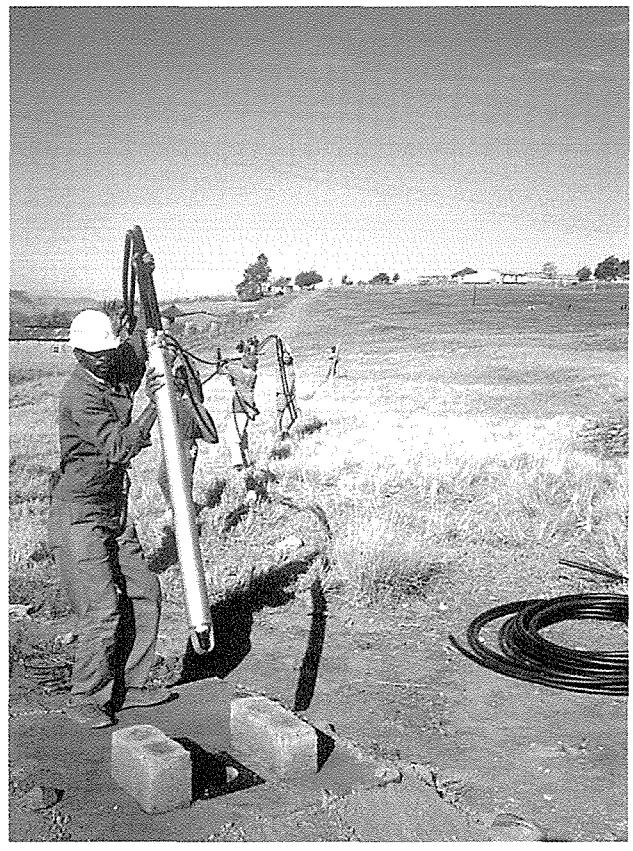
It has, however, been demonstrated in other parts of the world that high failure rates are not inevitable and that these schemes can be transformed into reliable low-cost solutions through the adoption of the so-called village level operation and maintenance (VLOM)-concept, where appropriate design technologies and implementation policies are systematically included. This concept not only assists in the selection of handpumps specifically designed for village-level operation and maintenance, but also addresses the benefits of community participation and ownership. The training and employment of community operation and maintenance staff, and the reduction of a community's dependence on centralised support systems are vital to this concept.

The study indicated that 10% of the South African population (2 million people) are dependent on the estimated 10 000 handpumps which exist in this country. This can be equated to an investment of about R400 million, and the study estimates that between 40% and 50% of the handpumps are not working at any one time.

The consolidated findings from the literature survey, the analysis of South African borehole and handpump installation records and the surveys of the handpump stakeholders indicate that three broad areas of project implementation have to be carried out competently in order to achieve effective community handpump systems. The three broad areas are:

- **The development of the borehole and the measurement of recovery rates**

  The development of the borehole is an essential component of the implementation of effective community water supply programmes using handpumps. When the cost of drilling unsuccessful holes is included, the development of the borehole can be expected to cost between 65% and 70% of the total cost of the project (The literature sometimes quotes a figure as high as 90%, but in these cases, insufficient resources would have been



The development of effective community water supply systems using deep- and shallow-well handpumps.

devoted to institutional capacity-building and skills training). The importance of the development of the borehole combined with its cost, emphasises the care that needs to be taken during this phase of project implementation.

- **The selection and installation of the handpumps**

  The handpump users survey, and to a lesser extent the purchasers survey, indicate that users prefer lever-operated piston pumps to wheel-operated piston pumps and rotary-screw type pumps. For low heads, up to about 12 m lift, indications are that direct action pumps may be preferred. The users survey also makes it clear that the user seeks a high delivery rate pump instead of one that is "easy to use". In other words, a short tough task is preferred, with the provision that children be able to pump some water.

- **Ensuring adequate village, local government and private enterprise institutional and skills capacity**

  From a South African viewpoint, a disturbing outcome of this study was the divergence between South African and "rest of the world" community water professionals as to their confidence in the ability of handpumps to provide an effective service. This bodes ill for a sustainable service level since it is essential that implementing agents and local authorities have a positive attitude towards handpumps if such projects are to be sustainable. Communities appreciate their handpumps and know that with better project implementation and maintenance these handpumps could deliver a better service. However, in the present climate of high expectations and a few rural communities paying anything for water, the demand for individual yard connections is high, and an additional major threat to the wider acceptance of handpumps is a fear that making handpump systems more effective will jeopardise their hopes of obtaining a higher level of service at a later stage.

Cost: *R340 000*
Term: *1994-1996*

Land-based effluent disposal and use: Development of guidelines and expert-systems-based decision support

(No 698) CSIR – Division of Water, Environment and Forest Technology

Effluents and soils were identified as factors which help in the process of making decisions on the applicability of a specific effluent on a specific land. The identification of the effluent takes into account health-related aspects, the risk of pollution to the water source and the effects of it on plants. The identification of the soil relates to the ability of soils to attenuate the contaminants in the effluents.

A framework and procedure were drawn up according to the permitting procedure for sludge application to land in South Africa (WRC Report No TT 85/97).

The three stages of the permitting procedure are :

- The effluent treatment stage/land-use screening
- The suitability of the site conditions
- Sustainable land application rates, specifying applicable design planning and management options.

The suggested procedure is presented in greater detail in the programme to lead the user of the programme to specific criteria such as effluent/crop type/land-use acceptability; and effluent/crop, climate and site criteria.

The user is guided through the process in order to be able to determine whether the combination is acceptable or not and whether it conforms to health guidelines. If this is acceptable, it is indicative of restrictions or protective measures.

The second set of criteria helps in the identification of further overriding criteria, limiting conditions and relevant corrective measures. It takes the user, step-by-step, through information gathering, derivation of results and reporting requirements.

It is a complex procedure to go through all the steps. The software provides decision-support tools which permit officials and others, who are involved in tasks relating to effluent irrigation to land, to make decisions which support long-term sustainability.

ELADS (Effluents to land-application decision-support) software is the expert systems-based decision-support software developed. It could be used not only for sewage effluents, but also for organic effluents, to some extent for nitrogenous effluents and effluents containing potentially toxic trace elements. It could be modified to accommodate any site, soil or effluent-related limits specified by new regulations (WRC Report No TT 125/00).

Cost: *R259 992*
Term: *1995-1997*

Preparation of standard engineering drawings, specifications and guidelines for ventilated improved pit latrines in South Africa

(No 709) CSIR – Division of Building Technology

According to the National Sanitation Policy of 1996, the ventilated improved pit toilet (VIP) is considered to be the acceptable basic level of sanitation service that is supported by government. This project aimed to develop standards and guidelines that would assist those responsible for sanitation programmes in order to ensure that the VIP they install would meet health and user requirements.

The following conclusions were drawn from this study:

- Regular maintenance of VIP toilets is essential in order to ensure proper functioning.
- Pit emptying is often a problem if toilets are not specifically designed to facilitate this process.
- The literature yielded certain guidelines on maximum population densities for single-pit and twin-pit toilets. However, attention is drawn to the problem of progressive loss of ventilation as the number of dwellings increase.
- VIP toilets, when correctly designed, operated and maintained, have proved to be an acceptable, cost-effective, hygienic and environmentally-friendly sanitation option.
- This research contributed to the preparation of a publication entitled *Building VIPs: Guidelines for the Design and Construction of Domestic Ventilated Improved Pit Toilets*. This publication was published and distributed by DWAF.

Cost: *R90 000*
Term: *1995-1997*

Guidelines for the upgrading of existing rural water treatment plants

(No 738) CSIR – Division of Water, Environment and Forestry Technology

A large number of rural water treatment plants do not produce the quality or quantity of water that they were meant to produce. Some of the reasons are inappropriate treatment systems installed, lack of knowledge of basic water treatment principles, inadequate maintenance of equipment, financial constraints, lack of community involvement during conception and insufficient information on how to upgrade the treatment systems using simple, cost-efficient measures. The aim of the project was to draw up guidelines for upgrading existing small water treatment plants, thereby creating a better standard of living by using existing facilities optimally.

The guidelines can be used by policy-makers and planners when considering alternatives for providing or improving the water supply to small users and rural communities. It will provide them with the necessary information in a concise form to show that upgrading of existing treatment plants offers a cost-effective way of improving the water supply to the communities. Local authorities, hospitals, forestry stations and communities can use the practical guidelines to upgrade their plants effectively. The guidelines specifically point out the advantages, disadvantages and possible pitfalls of the various treatment options. Key guidelines for selection and operation of the treatment options are given. Available databases on water treatment plants in the country as well as information-gathering during the study show that of a total number of 880 treatment plants in the country, 587 (or 67%) have capacities of less than 2,5 M*l*/d (2 500 m^3/d) and, therefore, fall in the category of small water treatment plants.

Cost: *R194 000*
Term: *1996-1999*

Water supply to rural and peri-urban communities using membrane technologies

(No 764) University of Stellenbosch – Institute for Polymer Science

The overall aims of this project were to demonstrate and further the technology that evolved through a demonstration plant operated at a small Cape community during 1995. This included research into the development of a package capillary ultrafiltration (UF) membrane filtration unit which would be used to provide affordable, safe drinking water from sub-standard surface or sub-surface resources for use by rural and farming communities, schools and medical clinics.

The membrane pilot plants, containing locally manufactured capillary membranes, were operated on three types of raw water: medium-coloured soft Cape water, highly-coloured soft Cape water and Inanda Dam eutrophic water from the Umgeni system. Two of the three plants supplied potable water under controlled conditions to small communities during this period. Excellent removal rates were obtained for colour (>90%), iron (>95%) and turbidity (down to <0.5 NTU after treatment). Micro-organisms such as coliforms, faecal streptococci and *Escherichia coli* were completely removed, but some residual plate count organisms remained in the treated water. The runs were completed over an extended period of more than four years and showed that ultrafiltration can be a viable option to produce water of a potable quality.

Cost: *R429 000*
Term: *1996-1999*

Preparation of a booklet for new owners of sanitation systems that will contain the essential operation and maintenance requirements of sanitation systems

(No 771) CSIR – Division of Building Technology

The specific objectives of the research project were the following:

- Preparation of a booklet that could be given to people when they moved into an urban area. The booklet would inform them of the essential maintenance requirements of a sanitation system.
- The distribution of the booklet would assist in reducing the abuse and failure rate of sanitation systems.

The research produced a draft booklet on *How to use and care for a VIP toilet*. However, when the draft booklet was tested at community level, it was found to be unsuitable for the target groups because the messages in the booklet were inappropriate. The project contract was terminated because the project team did not have the necessary expertise to prepare a booklet that could be understood easily by the target group.

Cost: *R76 000*
Term: *1996-1997*

An information booklet on drinking water for creating a greater awareness among the general public

(No 772) CSIR – Division of Water, Environment and Forestry Technology

In many developing communities, there is a need for information on the important issues that relate to the supply of drinking water. Information on various sources of drinking water that can be treated for drinking purposes, and the importance of ensuring appropriate water quality has been addressed to a certain extent in this project. The aim of the project was to produce an information booklet on drinking water which will, hopefully, make the general community more aware of their consumption of water.

This booklet provides basic information on the possible sources of water, and addresses questions such as: What do we use water for? and Why is water important? It also looks at rainfall, prevention and removal of pollution, and water treatment. In addition water distribution systems and costs associated with water treatment are discussed. A case, therefore, is put forward as to why we should pay for water. This booklet provides useful information when used with other sources of informative education regarding drinking water.

Cost: *R68 000*
Term: *1996-1999*

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

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

In a survey carried out by DA Still of the CSIR in his M.Sc. (Eng.) thesis at the University of Cape Town (1991), it was found that there are between 2 000 and 4 000 indigenous communities in South Africa in drought-stricken or arid areas without a potable water supply, and without electricity. Many of them travel long distances in order to fetch their drinking water.

The local manufacture of affordable solar stills will meet the demand of relieving the potable water shortage in remote arid areas without incurring the infrastructure costs of providing pipelines, electricity supplies, and pumps. At the same time, a new industry and training centre would be established in South Africa, with the potential for growth to expand to other countries in Africa and to parts of the world which encounter similar problems.

Hence, the objective of the study was to investigate the feasibility of utilising locally-available materials for the construction of stills, so that such construction would be an affordable technology option. The findings of the study show that:

- Solar stills are the subject of renewed research interest worldwide, mainly due to the suitability of the technology to provide desalinated water to smaller communities in arid, drought-stricken areas, combined with its environmentally-friendly application.
- Significant experimental progress has been made in lowering the manufacturing cost of locally-manufactured basin solar stills. A reduction of 85% in distilled water cost compared to that of benchmark imported stills was achieved. This was done by addressing the biggest cost contributing factor, i.e. replacing the

aluminium solar still frame with special plywood. Cardboard frame stills failed under the environmental test conditions.

- The up-front capital cost of present solar stills is high, especially if additional infrastructure for batteries is required. It is clear that the complete design has to be investigated further, if the cost goal of R0.02/*l* distilled water is to be achieved.
- The quality of the distilled water is good and, in practice, feed water blending can be carried out to further increase the water production volumes. On average, TDS values of lower than 10 mg/*l* were achieved when different feed waters, such as seawater and very brackish water, were used.
- There are a number of factors that influence still operation. These factors include meteorological and geographical influences, construction material characteristics and feed water quality.
- The practical implementation of solar stills in the target areas will be a direct function of the degree of involvement of the end-user (local authority/household). Aspects such as training of users in still operation and maintenance are of crucial importance to the long-term success of this technology.

Cost: *R60 000*
Term: *1997-1998*

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

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

While it is increasingly recognised that women have crucial roles to play in water supply and sanitation projects, there is inadequate awareness of how to promote optimal participation of women in this process. The main concern is how to approach, train and support women for these levels of involvement.

The study has identified the following factors that hinder participation of women:

- **Decision-making** – In all case-study areas, men played a prominent role and were perceived by both men and women as leaders and decision-makers.
- **Culture** – The cultural norms and values of rural villages played a major role in the participation and decision-making process. Men were regarded as being superior to women. It was observed that in communities with less traditional cultural norms, people were more flexible with regard to the formal participation of women as decision-makers.
- **Roles and responsibilities** – Women showed a tendency to expect men to interact with development agencies because men were perceived as being better able to deal with outsiders. The workload of women precluded their participation in training courses.
- **Training and education** – In all area studies, men were more literate than women. Consequently, women could not occupy decision-making positions in project committees because most of them were illiterate.
- **Attitudes and awareness** – The misunderstanding of roles and responsibilities by both genders played a major role in the decision-making process in water supply and sanitation projects.
- **Barriers to the empowerment of women** – The main obstacle to women's empowerment was their lack of confidence and low self-esteem. This was exacerbated by the attitudes of men, which were linked to the traditional culture and belief that men are superior to women.

The study has proposed the following strategy for the empowerment of rural women in the field of water supply and sanitation:

- **Policy and process** – DWAF should identify and address potential constraints to the implementation of its policy on gender and water.
- **Implementation plan** – Changing attitudes and perceptions regarding gender in water supply and sanitation will require a number of interventions such as gender awareness programmes and building of a 'culture' of gender-sensitive approaches within the water and sanitation sector.
- **The empowerment programmes** – Special empowerment programmes for women should be developed in order to improve their literacy and leadership.

Cost: *R263 000*
Term: *1997-1998*

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

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

In spite of lessons learned from the international drinking water supply and sanitation decade, hygiene education is often poorly handled in developing countries and, for this reason, the sustainability of the projects is not feasable. The aim of hygiene education is to bring about change in health-related behaviour.

The study showed that the level of general knowledge regarding hygiene practices was high in all case study areas. However, the practice of appropriate hygienic lifestyle was hampered by poverty and a lack of access to basic water supply and sanitation services. It was found that rural communities lacked a specific knowledge regarding causes, transmission and prevention of water-related and faeces-related diseases. The level of knowledge on the treatment of these diseases was high because of their prevalence in these communities. This research has produced the following manuals:

- *A Manual on Knowledge, Attitude and Practice (KAP) Study for Hygiene Awareness in the Rural Areas of South Africa* (K5/819)
- *The KAP Tool for Hygiene* (TT 144/00)
- *Hygiene Awareness Workshop* (TT 145/00)

Cost: *R370 000*
Term: *1997-1998*

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

(No 830) Phillip Pybus Consulting Engineer

Fundamental and central to the reconstruction and development programme (RDP), is the empowerment of beneficiaries of basic services in the development process, enabling them to make informed choices. It appears that, although a great many consulting engineers working in the field of community water supply and sanitation are paying attention to the principles of community participation, the community's level of empowerment is not as high as it ought to be. In fact, most of the training appears to be directed towards the implementation stages of the project and not to the ability to conceptualise and understand what the choices are.

The purpose of this research was to test the hypothesis above and to establish how engineering information, for example, concerning the level of service, can best be given so that the community leaders can make a decision based on sound knowledge of the technicalities of the situation.

In an analysis of the major factors that negatively affect communication between consultants (specifically engineering) and communities, it was found that the majority of factors stemmed from a lack of

integrated and comprehensive project planning. A number of good reasons may be identified for this, one of which has been the traditional emphasis that this project phase is largely executed "at risk". There is a fairly natural tendency by consulting firms to minimise such "at risk" expenditure. However, the result of this is that vital questions are not asked and essential communication exercises (such as participative research and awareness creation) are not effected. The findings of this study show that:

- A situational assessment of community needs had been done frequently on the basis of discussions with a small group of people. This was usually conducted with a local or a district authority or, in some instances, the project steering committee (PSC) (that may or may not have been elected on a representative basis). Efforts had not been made to promote participatory approaches such as, for example, participatory appraisal in the initial needs appraisal process.
- It is accepted that the PSC is a particularly important component of any project. However, there is an inordinate and, inappropriate emphasis on the role and responsibilities of the PSC to the extent that it becomes the sole focus of the project. There is an intrinsic assumption that communication and interaction with the PSC is synonymous with communication and interaction with the community. Additional assumptions are made about the extent to which they can and will provide feedback to the community as well as the degree to which the PSC can (or should) be responsible for mobilisation and awareness programmes within the community.
- One of the most serious problems identified during the study relates to the fact that affordability and the willingness to pay for services are not given sufficient attention. The degree to which communities have been able to exercise informed choice about service levels and costs is related directly to their willingness to pay for services.
- A typical and common finding in all the projects is that training (the process of transferring specific functional skills and knowledge to bring a person to an agreed standard of proficiency) is seen as being synonymous with capacity-building. While extensive training had taken place, commensurate capacity-building activities related to the mobilisation of communities and the creation of community-wide awareness had not been addressed.
- It was found that the assumption was often made that once people have access to information, they can make an informed choice. Issues, however, are complex and the decision-making process cannot simply involve the sharing of technical information and the eliciting of a uniform response. It is essential to understand the overall context in which decisions are made. Information sharing, consultation and communication will not work if there is just a flow of content (particularly if it is one-way from external sources to the community). Information-sharing needs to be related to people's lives and must be built on the internal community knowledge system.
- It has been noted that the major challenge in initiatives to promote water supply and sanitation at community level is one of institutional strengthening and human resource capacity-building for the management of sustainable development. While project implementation aims at the development of infrastructure for sustainable water supply and sanitation services, the ability of role-players at local level to manage the system on an ongoing basis (including cost recovery) forms an integral component of such sustainability.
- It became very apparent that the engineers wished to make contact with the communities. Where the appointment was made through an implementing agent, a split-level of responsibility occurred. The engineers were obliged to report to the implementing agent whilst they were trying to meet the wishes of the communities. The implementing agent was represented by another engineer and not by a community facilitator. Under no circumstances was a development support communicator appointed to act as a go-between for the engineers and the communities.
- The engineers tended to view the projects in mechanistic terms and neglected the human context of establishing the needs of the community first and then translating these into real terms.

The findings from this study are supported by an excellent set of guidelines (Report No TT 133/00) , aimed at improving communication processes between practitioners and communities in water and sanitation development projects (A further set of three guidelines are in the process of being printed).

Cost: *R160 000*
Term: *1997-1998*

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

(No 875) Wagner Systems (Pty) Ltd.

The project set out to integrate a unique method of energy conversion with appropriate technology in order to develop a low-cost, solar-powered power unit, operating on the Stirling cycle, and driving an integrated water pump. Furthermore, optimisation of the design and the construction process was investigated in order to ensure that conditions in developing countries and rural areas would not inhibit utilisation of this technology.

During the course of the project a low-cost Stirling motor has been designed and built. The low ΔT design (working between 30°and 70° C) has a solar radiation area of 6 m^2, and does not rely on parabolic dishes, solar concentrators or a tracking system. Problems were encountered in scaling the motor up to this size, necessitating the introduction of various innovative modifications in order to allow the motor to operate at air pressures of only 7 to 10 millibar above ambient. In spite of these innovations, problems were still experienced, e.g. sealing problems, necessitating expensive material and workmanship; weight problems, resulting in low operating speeds due to inertia forces; and strength requirements, resulting in reduced solar radiation collection areas.

During tests of the prototype, it became obvious that the efficiency of the low ΔT Stirling motor was too low (due to the latter two problems mentioned above) for exploitation for pumping purposes. Furthermore, reflection losses at lower solar radiation angles were very pronounced and unavoidable, aggravating the low efficiencies of the motor. The temperature range of 30° to 70°C proved to be too narrow for utilisation in a solar-powered Stirling cycle motor for pumping purposes.

Cost: *R246 800*
Term: *1997-1999*

Development of standards and mechanisms for quality management in the water and sanitation training sector and evaluation of the effectiveness of methodology and technology developed in the research project

(No 880) National Community Water and Sanitation Training Institute

The provision of clean water and sanitation is indispensible to the success of the government's RDP. In line with this, DWAF policy is to ensure safe, basic water supply and sanitation services to all South Africans. Following the new constitution, the role of central government is to ensure that services are provided, while the onus of providing these services lies with the local government. While the backlog of supply is most noticeable in the rural areas, the lack of capacity of local government to control and manage these services effectively was seen to be even greater.

During this project, following an initial needs analysis, a training programme was developed to build capacity at local government level to manage the provision of water supply and sanitation services. The courseware development went through a number of iterations in which courses were presented. Feedback was obtained as to what else was needed, and this was addressed before the revised courseware was presented to the next group.

The product of this project is a cohesive unit of 34 modules, addressing all aspects relevant to the provision of the services by local government.

These modules fall into the following 7 broad categories:

- Local governance
- Project planning
- Project implementation
- Operation and maintenance/sustainability
- Human and financial management
- Water resource management
- Environmental sanitation and waste management

Volume 1 of Report No K5/880 gives the background and overview. The other 7 volumes present the courseware as detailed above. **Volume 1** is the only volume that will be covered here. It deals initially with the background to the water supply and sanitation sector in the country. A survey of policies and legislation is presented in a manner that identifies the job descriptions of the role-players. The following chapter covers the development of the learning programme, and then the detail of the modular learning material is given. There follows a chapter aimed specifically at the course facilitator, which outlines how to disseminate the material to adults. The principles of adult education are explained clearly.

The published report covers the background to and overview of the project and lists the various training modules developed. The training modules themselves have not been published.

Cost: *R650 000*
Term: *1997-1999*

Improving water use, sanitation practices and hygiene education for primary-school children in South Africa – Phase II

(No 960) University of the Western Cape – Public Health Programme

There is a need for a long-term programme of action to ensure that sound health education around water and sanitation issues is disseminated through the curriculum and teacher-training programmes within the National Department of Education. Schools should be the major focus for the promotion of positive hygiene practices because children can act as informal educators in their communities.

The following conclusions were drawn from this study:

- Water and sanitation provision at public schools, particularly in rural and peri-urban areas, were generally grossly inadequate.
- Although health and hygiene awareness was fairly reasonable, actual practice did not coincide with the knowledge.
- Both the context and practice of health and hygiene awareness were similar in both home and school environments. This pointed to the need for an integrated approach to solving both the infrastructure as well as the learning deficits.
- Maintenance of water supply and sanitary facilities was the major problem for urban, peri-urban and rural schools.

The study recommended that a curriculum review should focus on the development of teaching materials and methods that can reconcile the gap between understanding of health and hygiene knowledge and their practices within different contexts.

Cost: *R344 000*
Term: *1998-1999*

New project

Development of a methodology and guidelines for the design of community-based O&M systems based on local capacity and practice

(No 1130) Mvula Trust

Evaluations of new water projects done by several agencies have highlighted serious problems with the operation and maintenance (O&M) of water supply schemes. These studies showed that the O&M systems that had been implemented were generally unresponsive to user needs. This highlights the importance of basing the development of O&M guidelines on local knowledge and experience within communities.

The proposed research will explore different methods that communities used to manage their water supply schemes prior to the implementation of new water projects sponsored by government and other development-funding agencies. This study will document local knowledge and experience which will be used in future as a basis for the development of O&M guidelines.

Estimated cost: *R546 000*
Expected term: *2000-2001*

Research projects

Completed

- **384** Water resources and sanitation systems sourcebook with special reference to KwaZulu-Natal(University of Natal – Department of Economics)
- **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)
- **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)
- **603** Development of effective community water supply systems using deep- and shallow-well handpumps (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)
- **709** Preparation of standard engineering drawings, specifications and guidelines for ventilated improved pit (VIP) latrines in South Africa (CSIR – Division of Building Technology)
- **738** Guidelines for the upgrading of existing rural water treatment plants (CSIR – Division of Water, Environment and Forestry Technology)
- **764** Water supply to rural and peri-urban communities using membrane technologies (Univ of Stellenbosch – Institute for Polymer Science)
- **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** An information booklet on drinking water for creating a greater awareness among the general public (CSIR – Division of Water, Environment and Forestry Technology)
- **792** Solar still batteries in arid rural sites without electricity supply to provide potable water from brack, salty water (McCracken Solar Stills Company (Pty) Ltd.)
- **817** Development of strategies for empowerment of women in water supply and sanitation projects (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)
- **830** Level of communication between communities and engineers in the provision of engineering services (Philip Pybus CE)
- **875** Development of an appropriate, low-cost, solar-powered Stirling motor for water pumping (Wagner Systems (Pty) Ltd.)
- **880** Development of standards and mechanisms for quality management in the water and sanitation training sector (National Community Water and Sanitation Training Institute)
- **960** Improving water use, sanitation practices and hygiene education for primary-school children in South Africa – Phase II (University of the Western Cape – Public Health Programme)

Current

- **520** Guidelines on appropriate technologies for water supply and sanitation in developing communities (CSIR – Division of Water, Environment and Forestry Technology)
- **598** Appropriate management of urban runoff in South Africa (University of Witwatersrand – Water Systems Research Group and and CSIR – Division of Water, Environment and Forestry Technology)
- **631** Assignment of a financial cost to pollution from on-site sanitation, with particular reference to the PWV (University of the Witwatersrand – Department of Civil Engineering)
- **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 sewage treatment using the advanced algal high rate oxidation pond (AHROP) (Rhodes University – Department of Biochemistry and Microbiology)
- **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 Bophuthatswana – 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 North West – Departments of Nursing Science, Chemistry and Agriculture)
- **734** Development of a strategy for disseminating information from the hydrogeological mapping programme to village water committees (Water Systems Management)
- **767** Sustainability and affordability of community based integrated waste and wastewater management for dense, informal urban settlements (SRK (CE) Inc.)
- **770** Handbook of water disinfection processes (CSIR – Division of Water, Environment and Forestry Technology)
- **786** Application of visual settlement planning (ViSP) computer software applications technology in South Africa: Building the capacity of local communities in urban development (University of Cape Town – Department of Civil Engineering)
- **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)
- **828** Field evaluation of alternative disinfection systems for small water supply schemes (CSIR – Division of Water, Environment and Forestry Technology)

- **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)
- **861** Development of guidelines for the management of rural groundwater resources (CSIR – Division of Water, Environment and Forestry Technology)
- **885** Removal of nitrogen from ventilated improved pit latrines (VIP) systems by nitrification and denitrification processes (Technikon Pretoria, and NRF)
- **886** Development of a framework for the calculation of a monthly tariff payable in stand-alone community water supply schemes (Mvula Trust)
- **902** Fog water collection: Implementation of an operational prototype system (University of the North – Department of Geography)
- **925** Assessing the causes and pathways of water-borne disease in rural settlements with limited formal water supply and sanitation (Umgeni Water)
- **962** Water-supply management for small communities: Development of expert-systems-based decision-support software and a guidelines manual (CSIR – Division of Water, Environment and Forestry Technology)
- **976** Continuous flow air lift groundwater pump for rural applications (Green Energy Systems cc)
- **981** Incorporation of water, sanitation, health and hygiene issues into Soul City, a multimedia edutainment vehicle (Soul City)
- **991** Capacity-building and training needs of district councils and transitional rural councils in the management of community water and sanitation services in the Eastern Cape (University of Fort Hare – Department of Development Studies)
- **995** Monitoring leachate and biogas emissions from existing experimental field cells (University of the Witwatersrand – Department of Civil Engineering)
- **996** Community management of natural, human and financial resources relating to basic water supply projects (Lynette Dreyer and Associates)
- **1020** Development of generic and sectoral competencies in the water supply and sanitation training sector (National Community Water and Sanitation Training Institute (NCWSTI))
- **1032** Cost improvement of solar still units for general use by rural communities in remote Southern African locations (McCracken Solar Stills (Pty) Ltd.)
- **1052** Assessment of the attended coupon-operated access-point cost- recovery system for community water supply schemes (Lima Rural Development Foundation)
- **1053** Benchmarks and key performance indicators in water and wastewater services (P Pybus Consulting Engineer cc)
- **1070** Development of small-scale ultrafiltration systems for the provision of potable water at point source (ML Sultan Technikon – Department of Chemical Engineering)
- **1087** Assessing the impact of gender in water and sanitation provision and maintenance (Networks for Development)
- **1099** Developing guidelines and methodology to implement operation and maintenance in rural water supply programmes (In-Touch Community Development and Project Management)

New

- **1130** Development of a methodology and guidelines for the design of community based O&M systems based on local capacity and practice (Mvula Trust)

Continuous flow air-lift groundwater pump utilising compressed air generated by a wind-driven rotor.

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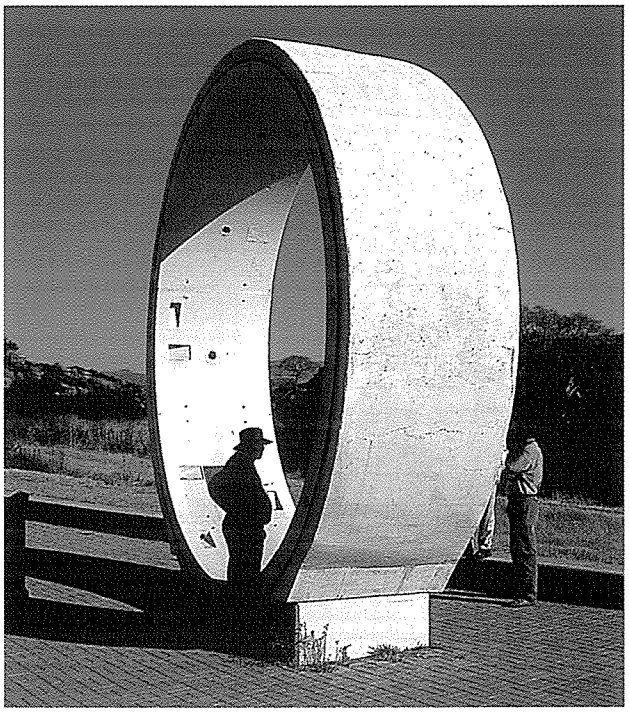
3 Water services: Institutional and management issues



The developmental issues that confront South Africa are numerous and multifaceted. National priorities have changed with the introduction of democracy, and now include the alleviation of poverty.

In the endeavour to contribute to this national objective, the WRC has been expanding its research efforts in the field of Community Water Supply and Sanitation (CWSS). An output during this period was the production of a strategy document called **Water Supply and Sanitation Research With An Impact On Development** (WASRID) which would guide researchers and the WRC in areas where research investment and capacity were required. It also provides the basis for addressing priority areas requiring support and allows for some co-ordination in this field. The current research plan for CWSS research is now more than five years old. During this time much has been achieved and significant progress in the sector has been made, both at the policy level and at the implementation level. These developments also allow the sector to reflect on the past experiences. A significant development in this regard was the conference which was held in East London during March 1999. Outputs of the conference reflected, firstly, a need for water and sanitation and, secondly, a change of rationale as far as these fields are concerned.

A significant output of the conference was that the focus needed to be changed: The focus of the previous five years had been on rural water supply service issues. The result is that water and sanitation issues in peri-urban areas were lagging. The backlog in the latter area needs to be addressed. The challenges and complexity of the urban question in this area have been compounded by new legislation and the fact that local government lacks the capacity to deliver services to its constituencies. It also became evident that the capacity needs in the urban sector varied from those of the rural sector, although there is a great deal of overlap. The current demarcation process will bring new challenges to the water sector. Experience over the past five years has also shown that the sustainability of water services is dependent mainly on strong institutional and managerial support. It is evident that many failures of schemes over the years are a direct result of a lack of such support.

It was, therefore, imperative that the importance of institutional and management issues in water services be afforded high priority and support. It is with this objective that this new research field has been created and should contribute towards developing research capacity in this crucial area in order to meet the necessary requirements of the sector. This field will provide focus and co-ordination of management issues affecting water services. Key studies have already been initiated relating to benchmarking and relating key performance indicators, corporatisation of water institutions, asset management, information management of water services and water user associations. All these studies are aimed at improving the capacity of the sector to operate in a transparent, efficient and viable manner. The findings and outputs of these studies will contribute to developments in the regulation of water services, education and training and better services for all.

Highlights

Shallow sewerage pilot project

An initiative to find appropriate and affordable sanitation solutions for underprivileged and poor urban communities is beginning to bear fruit. A partnership involving Durban Metro Water Services (DMWS), the WRC and Water and Sanitation Services South Africa (WSSA), was forged at the beginning of the year in order to test the concepts of shallow sewerage or Brazilian Condominial systems in the Durban area and to provide innovative solutions that could be applied to the rest of Durban and to other parts of South Africa.

The shallow sewerage pilot project (WRC Project No 1146) was implemented in two low-income communities: Emmaus and Briardale. Owing to the innovative technical, social and institutional approaches and the communities's response and commitment to the project, the physical construction has been very impressive. The project successfully provided sanitation to 250 households within 12 months. The cost of extending Durban's sewerage systems in order to meet the needs of all residents would have been prohibitive had conventional technology been used. Preliminary findings indicate that financial gains of the shallow sewerage project allowed capital cost savings of 52%. Further research is continuing.

Completed projects

Institutional structure for the management of a rural water and sanitation supply scheme involving five local authorities

(No 958) Association for Water and Rural Development (AWARD)

The main objective of the project was the establishment of a sustainable water management system involving the co-operation of local government, community water committees and non-governmental organisations.

The study has highlighted the importance of involving rural local government in participatory processes that provide a clear understanding of the concept of decentralisation. Achieving cost-recovery and decentralisation of services cost money. Therefore, there is a need for an adequate long-term financial commitment. In regions with a low economic base, limited financial support should be provided by the National Government. The study emphasises the importance of ensuring that the establishment of a water board is linked directly to that of a water service authority. Whilst a water board and a water service authority have different responsibilities, there is an intrinsic link between the two institutions, the viability of one is directly dependent on the success of the other.

Information dissemination and participation are essential prerequisites for ensuring cost-recovery and the sustainability of new institutions. In particular, communities must endorse local government choices in the form of water service provision.

Cost: *R120 000*
Term: *1998-1999*

Development of a rapid capacity-building programme for management of water and waste services at district council and local authority level

(No 982) University of Port Elizabeth – Institute for Development Planning and Research

There is a need to develop innovative ways of improving the scope of water services and authorities so that they can deliver services more efficiently. The proposed rapid capacity-building programme was conceptualised as a process where specific needs regarding training, service delivery and management are identified and addressed.

This research has developed a model for rapid capacity-building which focuses on the formation of a 'hub' or a centre where all kinds of information, such as contact information for experts and organisations in the area and guidelines for certain procedures are held. In order that this centre function optimally, a communication system must exist so that communities within the service area of the centre have easy access to the facilities that exist. The ultimate vision would be to link the communities to the centre electronically.

Rapid capacity-building is possible in terms of two options: The first option is to provide the required capacity by using existing external expertise. This is a high-cost, low-risk option. The second option is to empower local people. This a low-cost, high-risk option, which will not deliver adequate water and waste services under the prevailing critical conditions. It is suggested that in the short-term, existing expertise could be used to provide information which is needed to manage and maintain water services at community level. In the medium- to long-term, activities concerning education and training can be launched in order to build capacity within communities.

Cost: *R100 000*
Term: *1998-1999*

Benchmarks and cost comparisons in water and wastewater treatment

(No 984) Phillip Pybus (CE)

South Africa is entering a phase of massive infrastructure expansion, particularly in the provision of water supply and sanitation services. This will entail the design, construction and operation of a number of works, large and small, and for both potable supplies as well as for wastewater treatment. It is important that the issues of cost and effectiveness of performance are approached conscientiously and consistently so that the parties involved can benchmark what they are doing so as to make their designs and operations fully competitive and operationally cost effective. Benchmarking and key performance indicators are bound to become important management tools in the water service sector in the near future and they will also assist with regulatory aspects.

The aim of the research was to ascertain from the local authorities, designers and water boards the nature and extent to which they benchmark their activities. If such a system were in place, the logistics thereof needed: e.g. which activities and parameters are being benchmarked, with whom and how frequently. The findings are as follows:

- None of the respondents had established benchmark values for the key areas of their operations.
- A number of the engineers expressed interest in the establishment of a list of key performance indicators so that they had a yardstick to measure performance and in some cases, to compare performance. The cost of the water seemed to be a popular indicator, although local differences and the effects of escalation could distort any comparisons that might be evident. Non-dimensional indicators would have to be established.
- The interviews showed that there is a need for guidelines in order to establish a limited set of metric benchmarks that could easily be applied. Not one could name immediately the key areas of performance of the local authority in the delivery of water and sanitation services.

It was clearly evident from this study that there is a lack of understanding and knowledge of the concepts of benchmarking and key performance indicators in the water sector. This status justifies the need for more intensive activity in this area, so as to generate sufficient knowledge and capacity in the sector. The concepts are set to become key management tools in the water service industry in the future.

Cost: *R37 000*
Term: *1998-1999*

Computerised human-resource planning system for water service institutions

(No 993) Stewart Scott (Pty) Ltd.

The research project was aimed at developing a management tool to help managers to implement integrated human-resource planning of water service institutions. The project focuses on the human resources that are required in order to support the infrastructure, as well as the organisational structure requirements of various sizes of water service institutions.

The computerised human resource planning and management system (HRPMS), which was developed for water service institutions through this project, includes facets of both a management information system (MIS) as well as a decision-support system (DSS). The management component of the HRPMS includes portions of the job analysis and employee profile modules. The planning DSS component includes the employment equity, benchmarking, forecasting

human resource requirements as well as the provision of data/ statistics that are required for business plans as stipulated by the Water Services Act. The reporting facilities provided by the HRPMS facilitate management, planning and decision-making.

Cost: *R160 000*
Term: *1999*

New projects

Identifying examples of successful cost-recovery approaches in low-income, urban and peri-urban areas

(No 1131) Sigodi Marah Martin Development Consultants

The principle that the user pays for services has been accepted as a basis for the provision of water supply and sanitation services to both rural and urban communities. However, one has to consider basic human needs, poverty and the implementation of appropriate life-line tariffs. The factors influencing cost-recovery based on a willingness to pay are also well-known. They include perceptions regarding improved standards of service, clear and cost-efficient arrangements for billing and payment, effective sanctions for non-payment, transparent administration and accountable community leadership. Although these aspects have been documented, local authorities are succeeding, to varying degrees, to successfully apply cost-recovery schemes. Whenever cost-recovery is not achieved, the sustainability of service provision is in jeopardy.

Instead of placing emphasis on the problems, this study will focus on solutions by recording "success stories" of cost-recovery schemes based on case studies. Experiences of local authorities with successful cost-recovery approaches can give guidance in the endeavour to at least balance the budget for water supply and sanitation services. Improved means of collection and payment of water charges will, therefore, have an impact on the financial survival and the eventual viability of local authorities.

The aims of the research are to:

- Audit selected successful cost-recovery water service provision.
- Establish the institutional, social, economic and political contributions to successful water service provision.
- Identify the determinants of successful cost-recovery programmes as a pointer to show the way forward.
- Formulate guidelines for the water service sector.
- Unpack all of the above issues and develop strategies for use by local authorities and other service providers to progressively overcome the obstacles.

Estimated cost: *R438 000*
Expected term: *2000-2001*

Pilot initiative to implement shallow sewerage technology in Durban. (Proj No 1146).

Innovative partnership to improve water and sanitation services in deprived urban and peri-urban areas: KwaZulu-Natal pilot project, Inanda-Ntuzuma, Durban, Edendale, Pietermaritzburg

(No 1139) Business Partners for Development (BPD), Durban Metro Water, Mvula Trust, WRC, Pietermaritzburg TLC, Generale des Eaux, Umgeni Water

The BPD project is an innovative approach initiated by the World Bank cluster on water, in an attempt to address water and sanitation issues in urban and peri-urban areas in developing countries. Conceptually, it is about bringing together the private sector, the public sector, the non-governmental sector and civil society, in order to address water and sanitation needs. KwaZulu-Natal is one of 5 pilot projects in the world. The rationale is that the sharing of experiences among the participants of these projects will contribute towards improved service delivery in the future.

The Durban Metro and the Pietermaritzburg areas are two components of the project that would address issues related to service delivery, viz. cost-recovery, water-loss management, affordability and levels of services, technical options, customer management, education and awareness etc., so as to provide a sustainable service to these communities. The study has a significant service delivery component.

An important aspect which is relevant to the sector is the sharing of experiences within the partnership that would benefit local and international understanding. The key aspect is complemented by aspects that transform service delivery from a beneficiary/recipient approach to a customer approach where the customer becomes part of the development process. The project is a learning and exploratory exercise and findings will provide answers to a global question on how to provide services to poor urban areas and informal communities. Outputs from this BPD project will contribute greatly at a national policy level as it addresses all matters of social, financial, technical and institutional importance. It will also assist the other urban local government sectors in the country. The objectives of the pilot project are to:

- Demonstrate a partnership approach in service provision to developing areas which can be adapted on a larger scale within urban areas, both nationally and internationally.
- Share and disseminate experience gained from this project, regarding aspects of a partnership approach.
- Develop an innovative customer management system.

- Investigate the applicability of GIS tools linked to customer management in previously disadvantaged and informal areas.
- Develop an education and awareness strategy to materials pertaining to water conservation, health and hygiene.

Estimated cost: *R880 000*
Expected term: *2000-2001*

Option of corporatisation for establishing new water service providers

(No 1141) Palmer Development Group

Corporatisation is an alternative to total privatisation of municipal services. The process allows a municipality to function in a financially viable manner, without losing total control over its function and enables them to forge partnerships with the private sector. Global trends are characterised by a move towards privatisation. However, corporatisation could be a suitable option for developing countries, especially where equity of services is vital. The concept has already been embraced by many large municipalities in the country (Durban, Johannesburg, etc.), indicating that an innovative process is being implemented in the country. Corporatisation is essentially a process of transforming an existing public sector service provider into a company, which would typically be wholly or partially owned by local government. In contrast to the concession option for municipal service partnerships, the corporatisation option is "home-grown" and is based on a progressive process of ring fencing and commercialisation, rather than a once-off deal to bring in an "outside" company.

Durban shallow sewers, Briardale inspection chamber. (Proj No 1146).

Corporatisation has a particular advantage for South African conditions in that it can be used to form co-operative service provision arrangements among neighbouring local authorities. This allows smaller local authorities to benefit from economies of scale and to attract better quality management. The challenge is to transfer this experience to small and medium local authorities, especially the rural authorities, where institutional, financial and social factors are crucial to sustainability. However, it is evident that there is a shortage of practical insight into this topic and there is a need for co-ordinated research in order to gather local and international experience on corporatisation, to interpret this for current local conditions, and to transfer this knowledge to all water service authorities.

The overall aim of this research is to investigate the suitability of corporatisation for municipal service provision in South Africa, and to increase awareness of the corporatisation option within the water service sector.

Estimated cost: *R170 000*
Expected term: *2000*

Information management for the water service sector, with specific reference to the regulatory system

(No 1142) Palmer Development Group

There is currently an urgent need to deal with regulatory issues in the water service sector. DWAF and other government departments (Constitutional Development in particular) are in the process of addressing regulatory strategy, but more initiatives are necessary.

In implementing such a strategy, information plays a key role. The regulator requires information in order to monitor the performance of water service providers and/or the water service authorities who appoint them. This information, which includes volume, format and management, is crucial to the effective functioning of the regulator. Current legislation and environment provide this opportunity to the water service sector through the proposed National Water Services Information System. The success of this system depends on the benefits that it provides to water service institutions and the enthusiastic participation of the information generators. Besides, the systems will co-ordinate activities in a fragmented industry and will contribute to improving performance of the sector through benchmarking and performance indicators.

This project is intended to address the information requirements of the industry as a whole through research, in order to establish industry requirements and international 'best practice'. One of the key contributions of the study is that it aims to have close consultations with the user groups in order to facilitate interaction between DWAF and the user groups. The outputs of this consultative approach will be of greater value through the buy-in and knowledge development of the sector. The aims are to:

- Review regulatory policy/strategy within the water sector, by interacting with DWAF, other government departments, representatives of local government and water service industry representatives.
- Undertake an international review of management reporting and information systems, as used by regulators and organisations representing water services. Based on the international review and an understanding of local policy objectives and institutional constraints, there is a need to identify information management options for the various user groups and for the South African water sector.

- Prepare proposals on management information strategies for each user group, detailing how management reporting and information systems might function, and what would be required to put them in place. Proposals will include recommendations relating to key performance indicators and the manner in which they should be used.
- Hold workshops with stakeholders (including those regulating and those to be regulated) in order to get feedback on the proposals.

Estimated cost: *R180 000*
Expected term: *2000*

Pilot initiative to implement shallow/simplified sewerage technology in Durban

(No 1146) Durban Metro Water Services

Sanitation, owing to the major impact that it has on health and on the quality of life, is a service with a high priority. The level at which such sanitation services are provided, and the arrangements for implementing the associated projects, are possibly the most debated and contentious issues in the field of urban service provision. The importance of looking at sanitation options between on-plot systems and full water-borne systems is evidenced by the results of a survey of local authority research needs which was commissioned by the WRC, where it was identified as an issue of high priority. In this endeavour the WRC initiated a desk study to establish the applicability of shallow sewerage technology for South African conditions. The technology has been widely and successfully applied in many countries. In Brazil and Pakistan it has become a norm. One of the key findings emanating from the WRC study is that shallow sewer systems provide a viable intermediate sanitation alternative, with a cost which ranges between that of VIPs and conventional sewerage. They may be preferable to VIPs in denser (greater than 35 dwelling units/ha), formal and informal peri-urban settlements. They are unlikely to be a viable alternative to VIPs in rural settlements because densities are generally too low. Shallow sewerage also provides a less expensive alternative to conventional sewerage in low to medium income formal urban residential areas. A significant advantage is that shallow sewer systems are appropriate where water usage is between 30 and 60 *l*/cap·d (i.e. pour flush toilets with yard tanks or yard taps), which may be too high for VIPs and too low for conventional sewerage. The main recommendation emanating from the study was that the technology required was to be handled as a pilot project.

With this as a stimulus, Durban Metro Water Services (DMWS) indicated an interest in taking the recommendations further. The WRC report and the willingness of DMWS and Water and Sanitation South Africa (WSSA) culminated in this pilot technology with the aim being to:

- Test the technical functioning of the technology.
- Assess the viability of the technology as an alternative to conventional sewerage systems.
- Investigate and test methods to delegate operation and maintenance through partnerships among local authority, service providers and communities due to the nature of the technology.
- Capture the experiences of the pilot implementation for dissemination and as criteria towards improving implementation of future initiatives.
- Monitor and evaluate the technical aspects on an ongoing basis.

Estimated cost: *R600 000*
Expected term: *2000-2001*

Research projects

Completed

- **958** Institutional structure for the management of a rural water and sanitation supply scheme involving five local authorities (Association for Water and Rural Development (AWARD))
- **982** Development of a rapid capacity-building programme for management of water and waste services at district council and local authority levels (University of Port Elizabeth – Institute for Development Planning and Research)
- **984** Benchmarks and cost parameters in water and wastewater treatment (Philip Pybus (CE))
- **993** Computerised human-resource planning system for water service institutions (Stewart Scott (Pty) Ltd.)

Current

- **897** Improved management of assets in the water supply industry with regard to possible privatisation (University of the Witwatersrand – Water Systems Research Group)
- **959** The institutional arrangements and support facilities required for sustainable community water supply (Water Systems Management)
- **1053** Benchmarks and key performance indicators in water and wastewater services (P Pybus (CE))

New

- **1131** Identifying examples of successful cost-recovery approaches in low-income, urban and peri-urban areas (Sigodi Marah Martin Development Consultants)
- **1139** Innovative partnership to improve water and sanitation services in deprived urban and peri-urban areas: KwaZulu-Natal pilot project, Inanda-Ntuzuma, Durban, Edendale, Pietermaritzburg (Durban Metro Water Services, Mvula Trust, Pietermaritzburg TLC, Compagnie Generale des Eaux, Umgeni Water)
- **1141** Option of corporatisation for establishing new water service providers (Palmer Development Group)
- **1142** Information management for the water service sector, with specific reference to the regulatory system (Palmer Development Group)
- **1146** Pilot initiative to implement shallow sewerage technology in Durban (Durban Metro Water Services)

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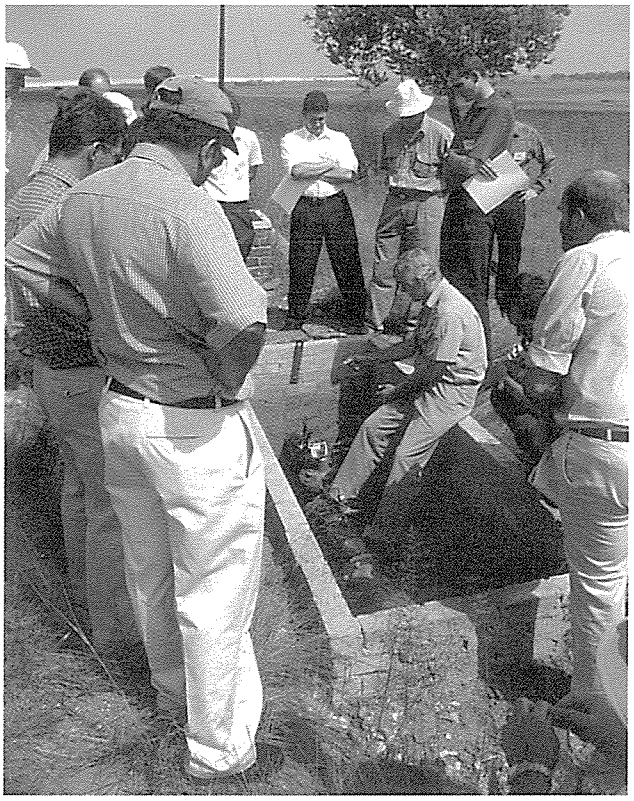
4 Integrated urban water management

This new field has emerged as a direct result of the conclusions drawn by international and local agencies that sanitation cannot be considered to be a stand-alone issue as it had been erroneously considered to be in the past.



These past practices have undermined the sustainability of urban sanitation in developing countries, and the contributing factors are issues such as inadequate human sanitation; poorly planned on-site sanitation; water-borne untreated sewage; inadequate planning, management and maintenance of sewers and inadequate refuse and solid waste disposal. Developed countries are not free from this malice because their long-term problems relate to the mixing of waste streams; sludge handling problems; costs of services; inefficient water usage; secondary pollution due to nutrients and toxins, etc.

Therefore, the way forward lies in the development and implementation of an integrated approach to urban water management (including waste management), IUWM. In the IUWM approach, consideration is given to the collective impact of all possible water-related urban processes (of which the management of human excreta or sewage is only one) on issues such as human health; environmental protection; quality of receiving waters; urban water demand; affordability; land- and water-based recreation and stakeholder satisfaction. Individual processes are then planned and managed in a way that the collective impact, with due interaction of processes, is optimised as far as possible.

This new research field has the long-term view of ensuring that greater planning and integration would occur in the management of urban water and complements the field of **Water Services: Institutional and Management Issues**. This new field will focus mainly on the technological issues of water research management, such as water distribution networks; sewers, wastewater management, solid waste and urban runoff, and aims to address them in a manner which will promote a more effective and integrated approach to urban water management.

The emphasis of this integrated approach has already been addressed by our new water and environmental policies and the greatest challenge is to implement these policies. It is hoped that this new field will stimulate thinking and activity in this approach and contribute towards the long-term sustainability of urban water management.

Completed projects

Graded standards for landfilling in South Africa: Establishing appropriate affordable standards for disadvantaged communities

(No 670) University of the Witwatersrand – Department of Civil Engineering

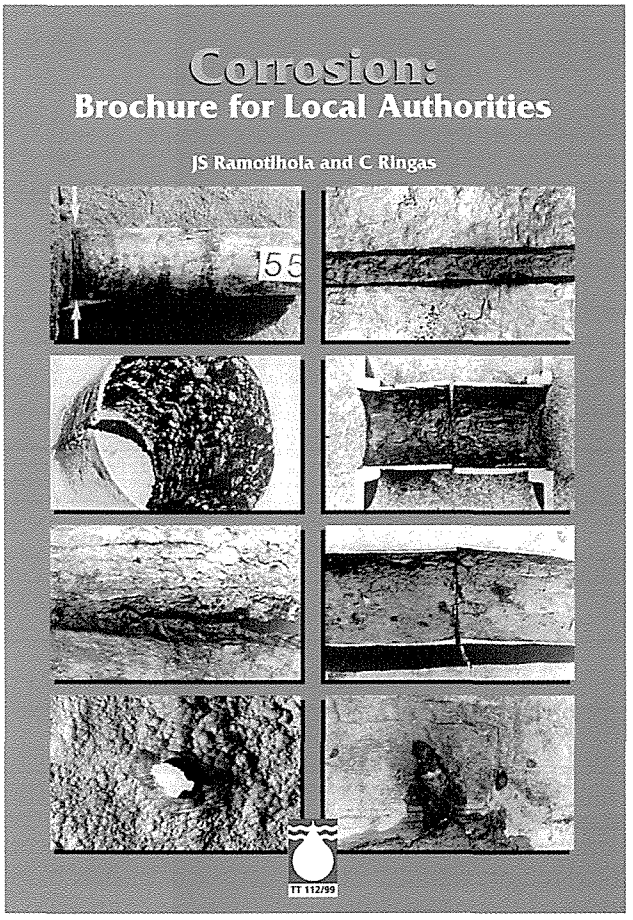
The new *Minimum Requirements for Landfilling in South Africa* was introduced by DWAF during 1994. It includes a set of standards that is graded according to the type of waste, the size of the landfill and the climatic conditions at the landfill site. The minimum requirements differentiate waste into "general" and "hazardous" categories. However, it has been well-established that the waste generated by a disadvantaged community differs considerably from that produced by an affluent community. Almost all of the research on the decomposition mechanisms, products, pollution potential and energy potential of refuse has been done on refuse from affluent American and European communities. The small amount of research done in South Africa has concentrated on large landfills serving cities, where the refuse comes from predominantly affluent areas.

As the South African population consists mainly of poor people who live in disadvantaged communities, much of the refuse produced is "poor" refuse. Because of the different composition of this "poor" refuse, and particularly its lower organic content, it is suspected that the pollution potential and the energy potential are both lower than those of "rich" refuse. If this is the case, then the minimum requirements may be more onerous than is necessary. On the other hand, it is not known at present if the minimum requirements

for small landfills are truly adequate, or if they need to be enhanced. This study aimed at answering some of these questions. Findings indicate that:

- An investigation of five unlined landfill sites in South Africa has shown evidence of limited, localised contamination within the soil adjacent to the landfills. The landfills studied were primarily those serving small country towns and were situated in both water-deficient (B–) and water-surplus (B+) areas of the country.
- Evidence of contamination was detected at most of the sites, although this contamination was limited to an area very close to the toe of the landfill, i.e. there was no evidence of an extensive contaminant plume being emitted from the landfills. In many cases contamination was confined to the upper 0.5 m of the soil profile. Based on previous work at the Linbro Park landfill in Johannesburg, this was ascribed to spillage of refuse from delivery vehicles on access roads.
- It is difficult to separate the effects of previously poor operational procedures, poor siting and climatic effects when giving reasons for the existence of soil contamination at the sites. The results do seem to indicate that even at landfill sites where sanitary landfilling procedures were not followed in the past (a poor level of waste compaction and lack of daily covering) or where sites were poorly chosen (e.g. allowing refuse disposal into water), contamination from the landfills is still very localised. This is probably because leachate, when it occurs, is generated in small quantities and is dispersed far beyond the limits of the landfill.
- A waste characterisation and generation study of waste derived from three economically and environmentally different communities illustrated large differences in waste composition and rates of generation. Waste from low-income communities that use coal as a fuel (Ratanda and Wattville) comprised more than 50% of undried mass of ash and dust, with the putrescible content never exceeding 20%, regardless of the season of the year. Waste from medium-income communities (Heidelberg and Benoni) had more than 60% of undried mass of biodegradable matter. However, waste from a third low-income community (Mdantsane), that uses kerosene as a fuel, had a very similar composition to that of the medium-income communities.
- Waste-generation rates for the communities of Heidelberg, Ratanda and Mdantsane varied considerably, with Heidelberg producing 1.6 kg/person·d (a figure boosted by the ash in the waste), and Mdantsane producing less than 0.2 kg/person·d. Comparisons with waste-generation rates for other developing countries showed that the generation rates recorded for Mdantsane were not unusually low for very poor communities.
- Monitoring of the leachate from the small field cells for the first three years of the study has indicated a definite difference in quality. The high biodegradable content waste (B) from Benoni, produced leachate with higher contaminant loads than the low biodegradable content (b) waste from Wattville. However, the differences in loading are not exceptionally big and there appears to be only limited justification for differentiating between B and b wastes based on this evidence.

Cost: *R297 500*
Term: *1995-1997*



Production of a corrosion brochure for local authorities

(No 787) CSIR – Division of Materials, Sciences and Technology

Recent research has shown that the external corrosion of buried metallic pipelines is a major concern for water supply authorities. The science of corrosion is an extremely complex subject. Corrosion occurs in a variety of forms, each requiring a different protection strategy.

To enable water supply authorities to effectively develop a suitable corrosion-protection strategy, a concise guideline brochure, based on the results of the earlier research, has been produced. The main aim of the brochure is to guide them in the identification of corrosion characteristics and the appropriate remedial measures that one can adopt in order to inhibit or prevent further corrosion. Even a small increase in the lifespan of a pipeline will lead to savings of millions of Rand per annum.

The brochure highlights cost-effective ways in which external corrosion can be minimised. The brochure can also be useful to repair teams working in the field, and contains colour photographs showing the different forms of corrosion in order to assist field teams to correctly identify the cause of the failure. Appropriate repairs can then be carried out. The brochure also describes how each local authority can build up its own database, thereby assisting in the long-term strategy of each local authority by ensuring that correct corrosion-prevention strategies are used.

Cost: *R60 000*
Term: *1996-1997*

New projects

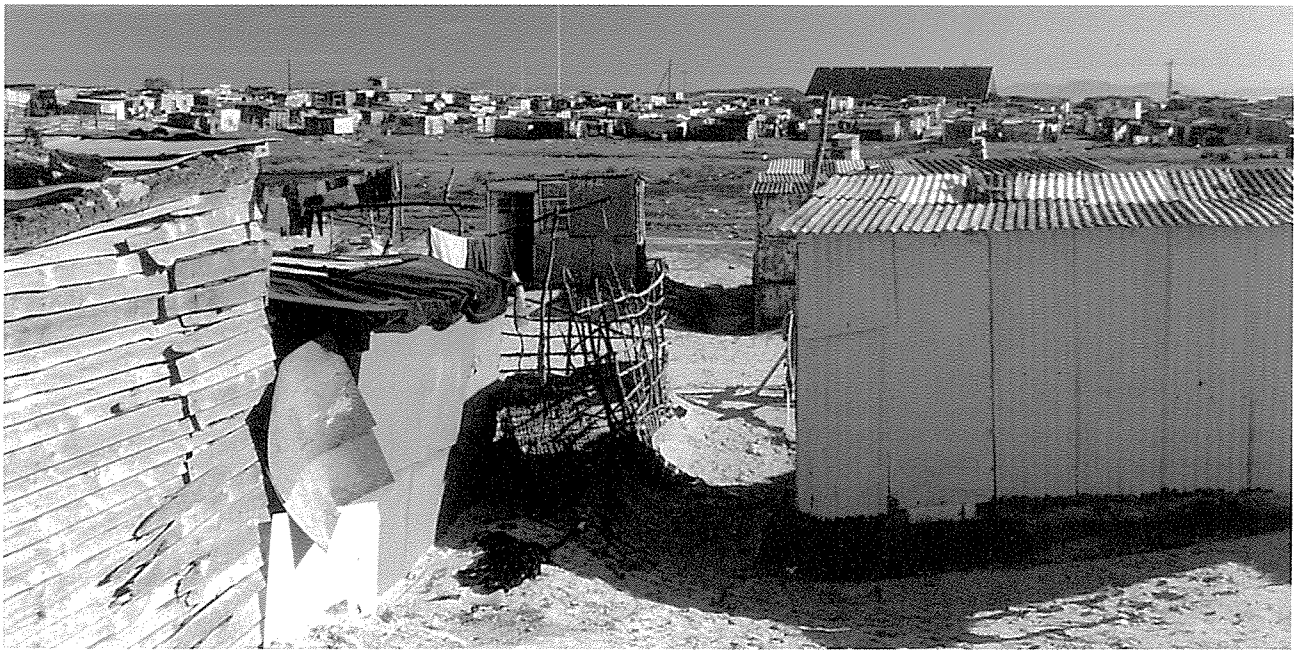
Application of combined services metering in a pilot community of Mount Pleasant

(No 1100) Eskom

Pre-payment metering has had limited success, despite its obvious advantages to both authorities and consumers. Perhaps the biggest failure in the development of pre-payment metering to date has been the inability of the water and electricity authorities to combine their resources to the mutual benefit of both parties. A second limitation has been the stunted communication abilities of most of the existing pre-payment meters. A third limitation has been the limited added value that has been derived from these meters to date. A fourth consideration is the lack of emphasis with regard to on-line communication, for real-time benefits and for the ease of data processing.

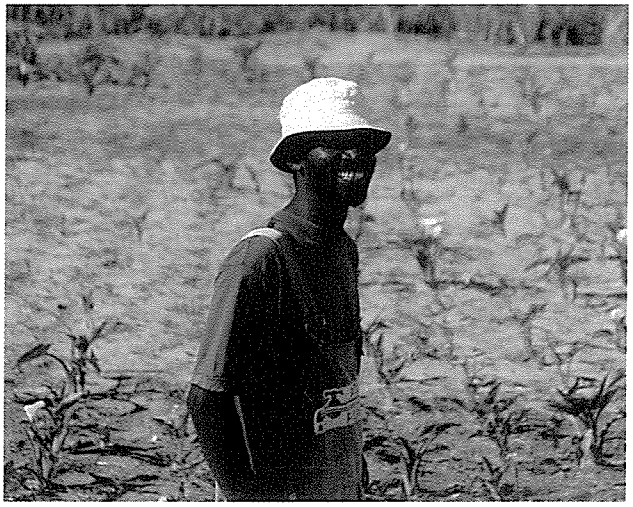
Furthermore, there is a perception that advanced metering systems have limited applicability in the homes of low consumers of water or electricity. However, it is unlikely that this perception has been substantiated by the full suite of costs and benefits, e.g. the social and environmental externalities, the opportunity costs, the cumulative and synergistic impacts, and other socio-economic realities that are typically ignored by those who constrain themselves to line-function barriers.

The project aims to assess the benefits of providing the community with a combined water and electricity pre-payment meter with bi-directional communications, including value-added services. The focus of the project is to introduce value-added services to the customer via the communications channel. Research has identified the rejection of pre-payment metering as being fundamentally a social problem which can only be addressed by convincing consumers that a remote link with their house offers more benefits



The informal settlement of Sabata Dalindyebo Square, Khayelitsha, bordering the arum lily site.

Ms Ntombizanele Christina Matomela, a permanently employed gardener, getting ready to weed. (Cultivar: Indigenous white arum lilies). (Proj No 1054).



Mr Mapa Joseph Ngcume, a permanently employed gardener with indigenous white arum lilies in the background. (Proj No 1054).

than disadvantages. Ultimately, this development will minimise meter fraud and non-payment.

Mount Pleasant, one of the suburbs of Hermanus, has been chosen as the pilot site. It is a small community (404 houses) which currently has both water and electricity reticulation. As originally envisaged, the project aims to provide the community with a combined water and electricity pre-payment meter with bi-directional communications. The success of the concept should be applicable throughout South Africa and it is expected that a substantial amount of commercial activity will occur via this project as it is progressively introduced to communities. The pilot study is being undertaken in partnership with Hermanus Municipality, Eskom, DWAF and the National Water Conservation Campaign.

Estimated cost: *R455 000*
Expected term: *2000-2002*

Effects of leak repairs and direct billing of tenants in high-rise inner-city buildings

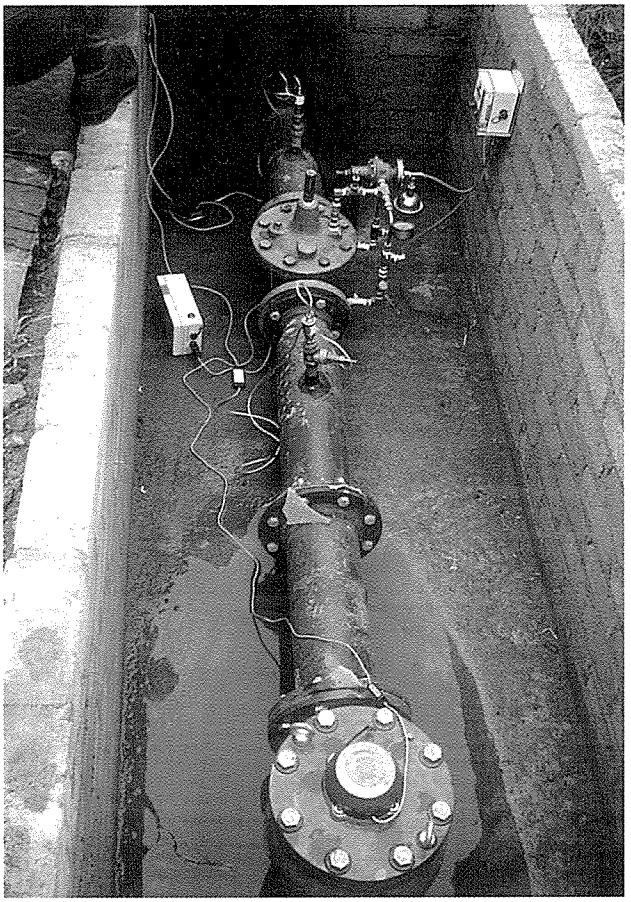
(No 1143) Greater Johannesburg Metropolitan Council (GJMC)

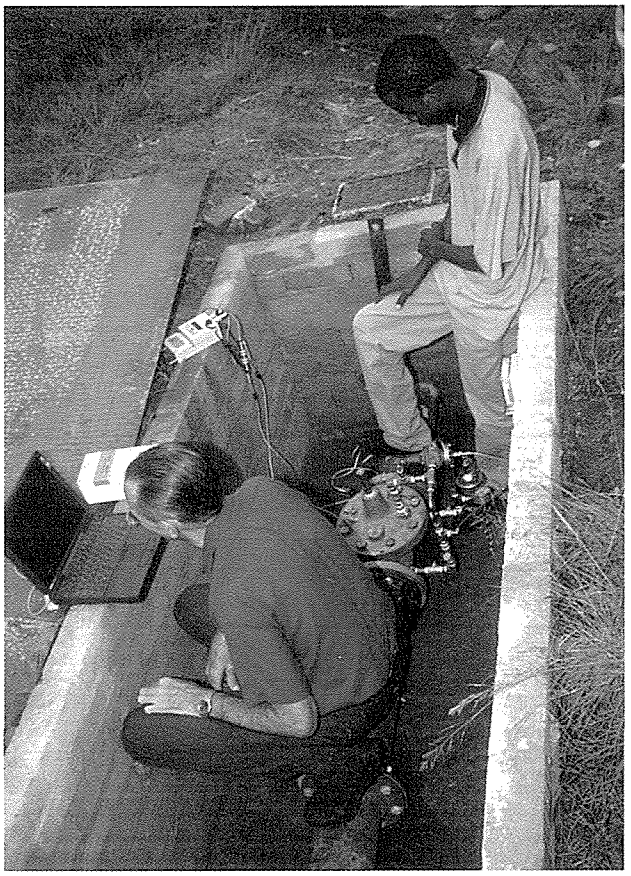
Over the past few years there has been a sudden population migration to the inner city urban hives. The inner-city population is one which is relatively new, having previously been excluded from the inner-city residential environment due to apartheid legislation. Linked to this development there has been inner-city decay, resulting in poor environments, unsanitary conditions, neglect of maintenance of buildings, overcrowding, etc. The water service sector has been significantly affected by this development, with high water losses and consumption recorded in these areas. The situation is common to many of the metropoles of the country. The proposed pilot project falls within the part of the inner city which is included in a bigger Western Joubert Park Precinct Pilot Project that has education, social development, residential renewal and rehabilitation as focal points. The effects of the proposed project are required to be closely monitored, together with the broader social and physical results of the proposed interventions, in order to make recommendations as to possible local authority legislational or policy changes with regard to service delivery and billing systems.

The proposed pilot project will test the effects of leak repairs and direct billing on water conservation and on levels of payment. However, a central issue will be testing the social impact of education programmes on inner-city residents. Fifteen buildings have been chosen in the Inner City of Johannesburg, specifically in an area which is the focus of other initiatives that are aimed at social and physical development, directed at relatively new inner-city populations. The project aims to:

- Document baseline data relating to water consumption, levels of payment for services and attitudes and awareness of residents in some inner-city buildings.
- Establish monitoring, reporting and data management systems as the indicators of the project.
- Develop educational systems and documentation around services issues and report on the effects of the interventions on social attitudes and awareness.
- Report on the effects of the interventions on water consumption and on levels of payment in the pilot buildings.
- Indicate to the Greater Johannesburg Metropolitan Council the direction in which policy should be changed with regard to service delivery and billing systems and/or services supporting education programmes.

Estimated cost: *R440 000*
Expected term: *2000-2001*





Water leakage: Pressure-management pilot studies at Krugersdorp and GJMC.

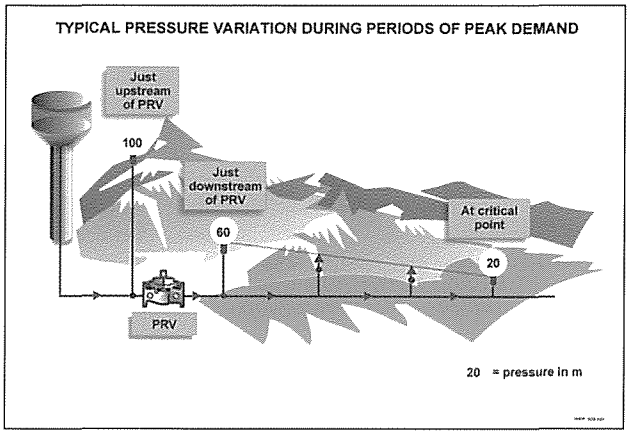
Evaluation of the application of genetic algorithms in the planning, design and management of water supply systems

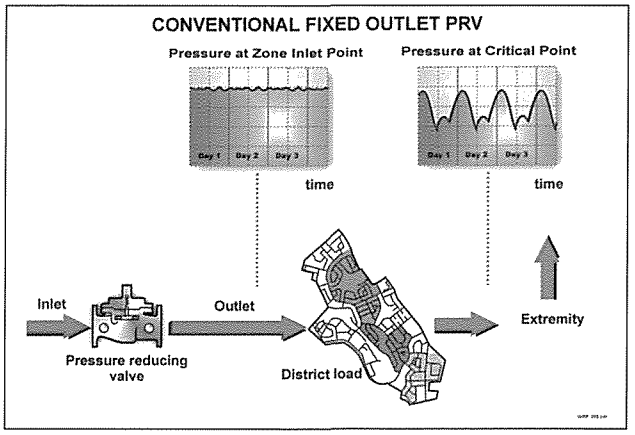
(No 1144) University of Pretoria – Department of Civil Engineering

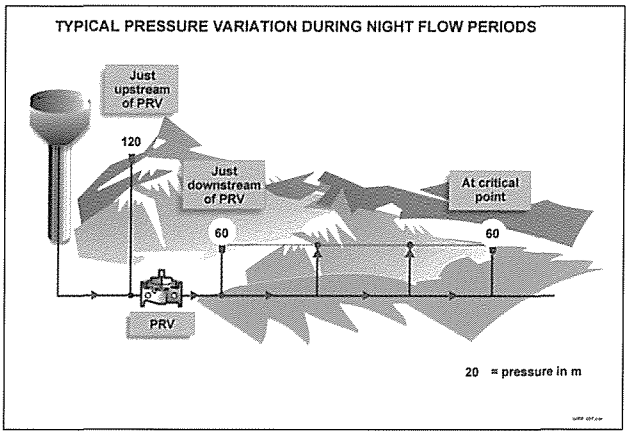
Since the government has determined the objective of supplying safe water to all the citizens of South Africa, the quest for optimal utilisation of scarce capital has been promoted strongly. Techniques like stochastic assessments, linear programming and multi-objective analyses have been used to evaluate and optimise different characteristics of water supply schemes. Preliminary indications suggest that the degree of accuracy that can be achieved by genetic algorithms is much better than in other algorithms. Genetic algorithms are being recognised as a powerful procedure and their application in water supply warrants investigation.

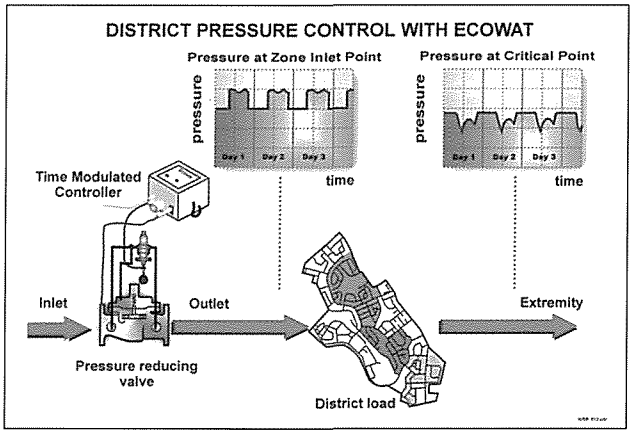
The technique of genetic algorithms has been applied, for instance, in the evaluation of new wing forms for Boeing Aircraft as well as for a number of other uses. In complex water distribution systems, the alternative options, when evaluating the extensions to water supply systems, become numerous and, therefore, a procedure to evaluate the alternatives is required. Genetic algorithms provide a procedure for the evaluation of all possible solutions and their application in the water supply field should be evaluated.

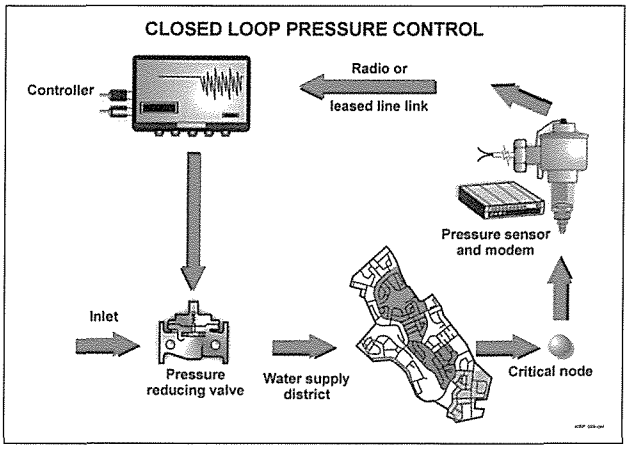
The study can be considered to be an exploratory study to test the applicability of the concept. It aims to evaluate the application of

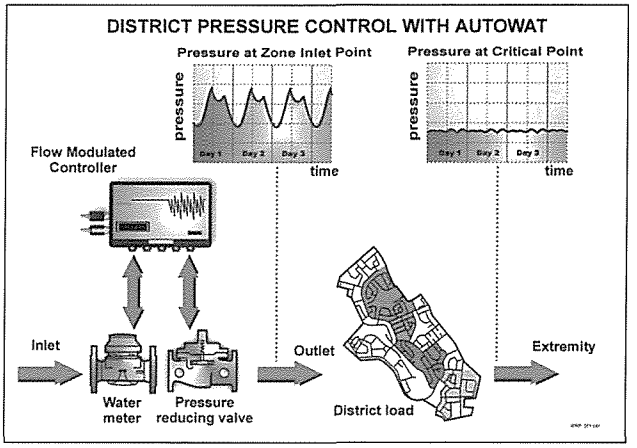












Concepts of pressure management.

genetic algorithms in the optimisation of different components of the water supply scheme. A successful outcome will justify further research and development of genetic algorithms, which will provide a new tool for improving the performance of the water service sector.

Estimated cost: *R117 000*
Expected term: *2000-2001*

Benchmarking of leakage for water suppliers in South Africa

(No 1145) WRP (Pty) Ltd.

Leakage is an important component of unaccounted-for water (UAW) in distribution systems. The current situation in the water service sector is alarming. It is estimated that an average of 28% of all potable water supplied in the country is lost, costing the sector and the communities billions of rands. In comparing these statistics to international figures, these levels could be considered to be very high.

To address the current situation with regard to water losses, UAW is significantly emphasised in the Water Services Act. The Act makes it a requirement for service providers to indicate losses in their system. This requirement will be further concretised by the pending *water regulations, which will make a water auditing report compul*sory, through the SABS – 0306. This will force service providers to reduce losses to acceptable limits.

Leakage levels are rapidly becoming a major concern in South Africa. There are no guidelines or benchmarks available to indicate acceptable limits or a system that provides constant updates for the sake of comparison. Another problem is that most organisations tend to express their leakage levels in terms of percentage of water input to the distribution system. Although this is the simplest method of expressing losses, it is also the most unreliable method. In order to overcome this problem, it is necessary to derive a methodology that can be applied to a wide range of water suppliers from rural to high-density urban areas. The methodology must take various key indicators into account, including length of mains, density of connections, operating pressure, etc. The aims of the project are as follows:

- To evaluate current leakage benchmarking approaches in South Africa.
- To establish a suitable methodology for benchmarking leakage in South Africa.
- To liaise with similar initiatives being undertaken elsewhere in the world in order to ensure that an internationally-recognised methodology is adopted.
- To promote the use of the approach through close liaison with the various water companies.

Estimated cost: *R195 000*
Expected term: *2000-2001*

Research projects

Completed

- **670** Graded standards for landfilling in South Africa: Establishing appropriate affordable standards for disadvantaged communities (University of the Witwatersrand – Department of Civil Engineering)
- **787** Production of a corrosion brochure for local authorities (CSIR – Division of Materials, Sciences and Technology)

Current

- **598** Research on appropriate management of urban runoff in South Africa (University of Witwatersrand – Water Systems Research Group and and CSIR – Division of Water, Environment and Forestry Technology)
- **717** Impact of urbanisation and industrialisation on the environment (Vista University – Department of Chemistry (Mamelodi Campus))
- **779** Use of chloramination and sodium silicates to inhibit corrosion in mild steel pipelines (Rand Water – Scientific Services)
- **898** Economic model for leakage management (BKS (Pty) Ltd.)
- **985** Development of a stochastic technique for the optimisation of pipe and reservoir systems (Rand Afrikaans University – Department of Civil and Urban Engineering)
- **995** Monitoring leachate and biogas emissions from existing experimental field cells (University of the Witwatersrand – Department of Civil Engineering)
- **997** Water leakage: Pressure management model (WRP (Pty) Ltd.)
- **1054** Cultivation of high-value aquatic plants in restored urban wetlands for income generation in local communities (Abbott Grobicki (Pty) Ltd.)

New

- **1100** Application of combined services metering in a pilot community of Mount Pleasant (Eskom)
- **1143** Effects of leak repairs and direct billing of tenants for water in high-rise inner-city buildings (Greater Johannesburg Metropolitan Council)
- **1144** Evaluation of the application of genetic algorithms in the planning, design and management of water supply systems (University of Pretoria – Department of Civil Engineering)
- **1145** Benchmarking of leakage for water suppliers in South Africa (WRP (Pty) Ltd.)

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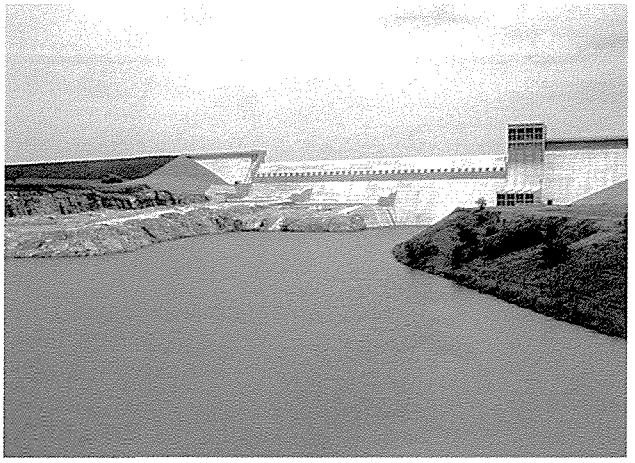
5 Potable water treatment

Issues such as optimisation and development of cost-effective treatment methods for the best water quality production, minimising risk from treatment processes and substantial changes occurring in distribution systems and the challenge of providing safe water to rural communities, have remained priority areas in this field of research.



A view of the Driekoppies Dam near Malelane – recently completed.

These priority areas will be addressed more effectively and timeously in future because of major improvements resulting in an appropriate and well-designed research agenda which uses a rigorous planning and management process incorporating external peer review.

Our goal is that all our applied projects stem from a proactive and comprehensive approach to assessing the research needs of the water supply community. The ability to obtain and use relevant input regarding ongoing and emerging issues for research is seen as a corner-stone of our success. Research responses to community water supply issues are conceptualised within a framework which encompasses five strategic goals that guide the field of **Potable Water Treatment**:

- Improve drinking water **distribution, infrastructure and processes** therein, for the reliable delivery of high-quality water to the consumer via a tap. This specifically looks at aggressive waters, corrosion, biogrowth, post-precipitation, etc.
- Protect the consumer from risks associated with chemicals, particularly **organic chemicals**. The importance of natural organic matter (NOM) in terms of its reactions with disinfectant and removal processes is receiving international attention. Progress has been made on basic research, while in future the emphasis will be on the characterisation of the individual compounds.
- Improve **water treatment processes** in order to obtain optimum water quality and system reliability. New initiatives in this area include the development of a new ozonizer technology and the use of particle counting in order to optimise filter performance.
- Protect the drinking water consumer from **microbial risk**. Current research includes biofilm inhibition and improved disinfectant-dosing equipment.
- Provide science, technology and management support to **small water treatment systems** in order to improve the supply of water to rural communities. This area received a boost in that the problem of fluoride in rural water supplies could possibly be eliminated by the use of easily available clay bricks. An integrated approach to rural water supply could prove to be a huge step forward. The integration of a water supply project with catchment management and income-generating projects is receiving attention.

Completed projects

Evaluation of full-scale flotation-filtration and chlorine dioxide plants

(No 280) Free State Gold Fields Water Board

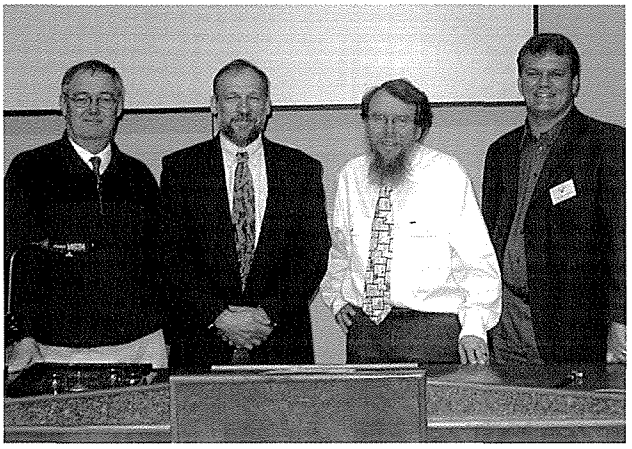
The project aimed at investigating the comparative efficiencies of chlorine and chlorine dioxide in the treatment of eutrophic water in a lime-based drinking water treatment process in the middle Vaal River.

It was shown that chlorine dioxide was a better oxidant than chlorine, when applied to the Balkfontein Water Treatment Plant, in terms of the following:

- Improved flocculation was achieved.
- Improved removal of algae and algae-related colour took place.
- Formation of trihalomethanes was reduced on the production line using chlorine dioxide, compared to the line using chlorine as an oxidant.

Early indications were that different algal species are retained with different efficiencies by the sand filters. Certain algal species specifically seem to be "problem" algae in this regard. These algae seem to penetrate the whole treatment process and end up in the final water to the consumer. No final report will be published because of delays in completion of the final report, during which time a follow-up project (Project 567 – **The occurrence and distribution of algal species and related substances in a full-scale water treatment plant**) will surpass and include the research conducted under this project.

Cost: *R141 500*
Term: *1989-1992*



The four lecturers at the WRC-funded particle counting workshops – Johannes Haarhoff, John Tobiason (University of Massachusets), Desmond Lawler (University of Texas) and Tony Ceronio.

Corrosion performance of various non-metallic piping materials and coatings in potable water

(No 381) CSIR – Division of Materials, Sciences and Technology

The effect of mining operations and the rapid industrialisation of the PWV and Klerksdorp areas have inevitably led to an increase in the mineral pollution of the Vaal River. This river supplies the greater part of Gauteng and Klerksdorp with water. The introduction of water from the Tugela River and the Lesotho Highlands Water Scheme has also had a significant influence on the quality of water from the Vaal River. Changes in water quality have a profound effect on the performance of existing pipework and on the selection of materials for future pipework, especially for the transportation of potable water.

In the Johannesburg municipal area, as in other parts of the world, steel is by far the popular choice for pipe material. It is well-known that even though potable water is treated, corrosion of bare steel occurs readily. This is often due to electrochemical corrosion mechanisms and occasionally due to microbiologically-influenced corrosion.

Whilst there are many methods which can be used for corrosion protection, it has been found that for most applications it is cost effective to apply a protective material to the internal pipe surface. Choosing the right coating for an application is very often a process of elimination rather than selection. This study aimed at determining the performance of coatings. This investigation resulted in two individual reports:

Report 1: *Corrosion Performance of Various Non-Metallic Piping Materials and Coatings in the PWV Region.*

The main results and findings are as follows:

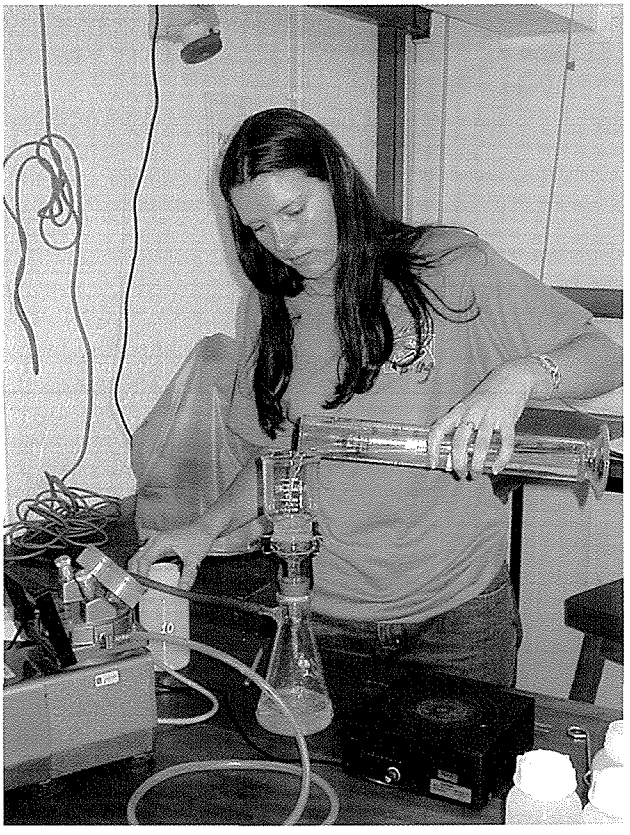
- After 42 months of testing the performance of non-metallic coatings, the findings were somewhat varied and it was possible to rank their corrosion resistance performance.
- Some of the coatings performed well, namely polyamide-cured epoxy resin-based materials.
- Uncoated carbon steel showed signs of corrosion in the form of tuberculations of the surface and pitting of the substrate. This aspect indicates that all steel pipelines used to convey potable water should be internally lined.
- The performance of all plastic piping was satisfactory and no obvious deterioration of these materials could be detected. The presence of a corrosion product had no effect on the integrity of non-metallic piping materials.
- The mortar-lined pipe samples performed well after 42 months of testing. The presence of corrosion products seemed to have originated from the other pipe materials in the systems.
- HDPE-lined steel piping performed well under the test conditions.
- The performance of the epoxy coatings was variable. The performance of the polyamide-cured epoxy coatings was good as was the hot applied solvent-free aliphatic amine-cured epoxy.

Report 2: *Exposure of Generic Coating in Raw South African Dam Waters.*

After three years of exposure in the Vaal, Kleinplaas and Roodeplaat Dams the following conclusions were made:

- Metal-coated panels, i.e. galvanised and zinc- and aluminium-sprayed panels, that have been over-painted, have performed poorly.
- The performance of unpainted metal-coated panels has varied with some unanticipated severe failures.
- The performance of organic coatings on mild steel panels has been good.
- The performance of generic coatings from different manufacturers varies.
- Where 3CR12 panels are completely exposed, the resistance to corrosion has been excellent, but sometimes where oxygen is excluded, e.g. at mountings, deep pitting has occurred.

Cost: *R688 000*
Term: *1991-1995*



A student doing laboratory work.

Ozonation in the production of potable water from polluted surface water

(No 446) University of Pretoria – Department of Chemical Engineering, Rand Water – Division of Water Utilisation Engineering and Scientific Service

The Vaal River is eutrophied, polluted and mineralised because of the extensive utilisation of the water through household, mining, agricultural and industrial activities. This water, therefore, requires appropriate treatment processes for the production of potable water. The objective of the project was to investigate the influence of ozonation on the coagulation, flocculation and filtration processes for the removal of inorganic and organic suspended material, with specific reference to the lime/silica process used.

The results showed that the Vaal Dam water did not respond positively to ozonation with regard to improved flocculation effects as is commonly experienced in international surface waters. However, overall coagulant demand is lowered because of the positive coagulation effect which ozone has on the "difficult"-to-flocculate Klip River water, thereby off-setting some of the ozonation costs. In addition, the positive effects of ozone on organics and algae in the raw water will improve the quality of treated water and lower activated carbon requirements in providing a better finished water quality than is currently the case.

Cost: *R79 000*
Term: *1993-1996*

Occurrence and distribution of algal species and related substances in a full-scale water purification plant

(No 567) University of the Free State – Department of Botany and Genetics

The aim of the project was to obtain information on the connection between morphological and physiological characteristics of phytoplankton species and its effect on the efficiency of algae removal by water purification processes such as oxidation, flocculation, sedimentation, filtration and flotation. The eutrophied middle Vaal River water was the subject of this study.

The results indicate that the efficiencies of coagulation, flocculation, sedimentation, flotation and sand filtration at one of the middle Vaal River water treatment plants are affected by a complex array of conditions, processes, substances and organisms. These include the nature and origin of inorganic and organic substances as well as suspended particles, i.e. colloidal and algal entities. It is significant that the "problem" algae penetrate the coagulation, flocculation and phase-separation processes of a water treatment plant. A number of these "problem" algae were identified during the project. The project, involving joint research work between a German research group of the Wahnbachtal River Association near Bonn and the South African research team, was of mutual benefit to both countries.

Cost: *R579 000*
Term: *1993-1996*

Treatment of eutrophic waters using pre- and intermediate ozonation, peroxone and Pica carbon

(No 694) Umgeni Water – Scientific Services

The project aimed at providing some guidelines for the treatment of South African eutrophic waters using oxidation and activated carbon filters. Both laboratory and pilot-plant-scale investigations were conducted. Various ozonation options, as well as comparative studies on standard and a new type of activated carbon to limit regeneration frequency, were considered. It was found that granular activated carbon, especially in combination with ozone, can be applied effectively in the adsorption of taste and odour compounds released by algae, as well as pesticides (atrazine) from surface water. However, little biological activity was detected on any of the activated carbons evaluated. When used on its own, ozone concentrations of 0.1 to 0.4 mg ozone per mg dissolved organic carbon (DOC) can result in 40% to 60% removal of colour, which can be increased to over 90% when conventional treatment is used after ozonation. Hydrogen peroxide which was used in conjunction with ozone generally resulted in the same effect as that achieved with ozone alone. However, this occurs at a lower ozone dose. Peroxide to ozone ratios in excess of 0.3 do not increase the benefit derived from ozone alone. Preliminary guidelines for the use of ozone and activated carbon for the treatment of a typical South African eutrophic water are provided, as well as a protocol for the evaluation of such pilot systems.

Cost: *R600 000*
Term: *1995-1997*

Water meters: Influence of various fittings and installation configurations on accuracy

(No 948) (SABS)

With the new National Water Supply Regulations requiring proper water audits and the pending Code of Practice for Unaccounted-for Water within Distribution Systems, it is essential to know the effect on accuracy of fittings used for the installation of water meters. This will enable municipalities and contractors to be aware of the correct procedure. At a later stage the Code of Practice can be amended accordingly. Hence, the main aim of this study was to determine the influences of these fittings on the accuracy of the water meter. Based on the tests undertaken of different installations and configurations, the following were the findings:

- That, at an installation of 45° to the vertical, an inferential meter severely under-registers the quantity of water passing through it. The explanation for the severe under-registration at lower flow rates for inferential meters of the 45° orientation may be due to the increase of the mechanical friction between the rotor and the shaft bearings, as the points of support of the rotor are no longer the bearing areas only as designed. All the inferential meters had large shifts from the signature curves at flow rates below the transition flow rate. Tests carried out on this configuration showed the curve of every inferential meter deviating towards errors greater than 10% at flows near the minimum flow rate. The presence of a valve upstream of both inferential and volumetric meters shifted the error curve marginally from the signature curves and, therefore, did not affect their accuracy severely.
- The above-ground fittings did not affect the curves for both types of meters tested to enable one to draw any conclusions. The piston meters proved that some models were sensitive to upstream flow conditions and orientation from the vertical and other types were not.
- The problems that arose, owing to the suitability of some of the meters chosen as standard comparison meters, resulted in the observation that meters are already type-approved under the existing South African Bureau of Standards (*SABS 1529-1, 1994*). The fact that type-approved meters failed the standard SABS test, raises queries regarding the test methodology and the SABS mark system.

Cost: *R200 000*
Term: *1998*

New projects

Evaluation of powdered activated carbon (PAC) for the removal of taste- and odour-causing compounds from water and the relationship between this phenomenon and the physico-chemical properties of the PAC and the role of water quality

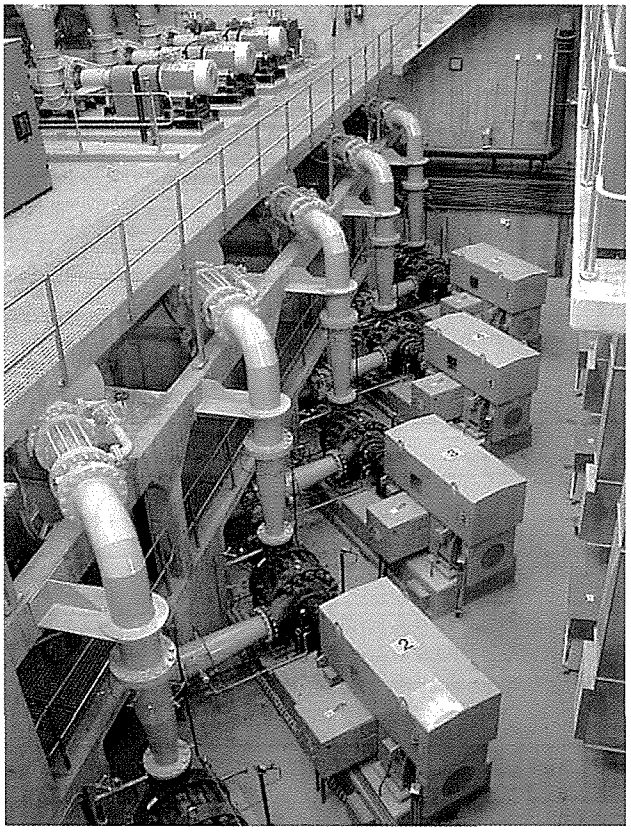
(No 1124) Rand Water – Process Development

The presence of nuisance compounds like geosmin and 2–Methylisoborneol (MIB) in drinking water often leads to consumer complaints. Unfortunately, toxic compounds like microcytin may go by unnoticed. Very few water treatment plants in South Africa are equipped to remove such troublesome compounds as unit treatment processes for the removal of taste and odour compounds and other metabolytes are usually not installed. This is because the problems normally occur sporadically or seasonally. There is seldom any associated health risk and treatment costs are high.

Since PAC is required intermittently, the selection of the correct type of material could present a problem as water quality may change, and may have an influence on the adsorption of the nuisance compounds. In the absence of available information, it is important to establish the possible relationship between the physico–chemical properties of PAC and the removal of taste- and odour-causing compounds from water and to also investigate whether water quality could influence the efficiency of removal.

The aims of this project include setting guidelines for the evaluation of PAC for the removal of taste- and odour-causing compounds like geosmin and 2–MIB from water. It will also look at the relationship between the physico–chemical properties of PAC and the removal efficiency of taste- and odour-causing compounds from water. Finally, it will try to establish whether compounds exist which mimic geosmin/2–MIB with regard to the removal by PAC and which are cheaper and easier to evaluate. The whole process will be evaluated nationwide.

Estimated cost: *R400 000*
Expected term: *2000-2001*



A view of the recently inaugurated high-lift pump station at the Vaalkop Water Treatment Plant of Magalies Water.

Small water treatment systems: A case for development of an approval/certification system

(No 1125) Options to Solutions

It has been highlighted both in WRC Project 828, **Upgrading of rural water treatment systems**, and during the Appropriate Practice Conference held in East London from the 15th to the 17th March 1999, that, in an effort to provide all households in the country with a reliable supply of clean, safe drinking water, a large number of small water treatment systems (SWTSs) have been installed. To the dismay and disappointment of many communities, a large proportion of these systems stopped operating after a short time. This clearly shows that some form of intervention, aimed at only allowing systems of a certain predictable mean time before failure (MTBF) to be installed, is required. Some overseas countries, faced with a similar problem, have been seen to take steps, such as the use of a registration and approval system for SWTSs in order to combat such a problem. This has been shown to be effective.

A prototype approval system, similar to the USA's National Sanitation Foundation (NSF) needs to be developed. Statistical techniques should be applied in order to identify the critical factors affecting the performance of such SWTSs. Once these critical parameters have been identified, an appropriate approval/certification/evaluation system for local application can be developed. This may result in further development of specific environmental simulation tests aimed at proving the reliability of the systems.

The aims of the project are, therefore, to establish whether the prior use of an approval/certification system would have resulted in better sustainability of small water treatment systems and to critically evaluate the approval/certification system, to develop guidelines for proper application thereof and to build a case for nationwide adoption.

Estimated cost: *R 290 000*
Expected term: *2000-2001*

Development and evaluation of new South African ozoniser technology for removal of pathogenic organisms, possible enteric viruses indicated by bacteriophages, and tastes and odours present in Hartbeespoort Dam water

(No 1127) PARC Scientific

Water supply from the lower Crocodile River system, where the eutrophied and heavily polluted Hartbeespoort Dam is a good representation, reaches a large number of people from developed and developing communities. Increasing demand compels capacity enlargement of existing purification systems and the planning of future plants. The continually decreasing quality of raw water, as manifested by e.g. unpalatable taste and odour of the water, and the many reported sewage spills, necessitate the upgrading of the treatment processes. A heavy organic pollution load presents problems with conventional chlorination, and provides a feed medium for residual bacteriological growth. The situation potentially presents a considerable health risk.

Ozone is efficient in the removal of pathogenic organisms, enteric bacteriophages resistant to conventional means, and tastes and odours from eutrophic waters. This project aims to develop an optimised, energy-efficient, modular power supply, compatible with the locally-developed, new technology ozone generators. Furthermore, a set of requirements, scaling parameters and operational procedures, to allow for the design of a full-scale ozonation system, permitting efficient ozonation for the removal of pathogenic organisms, possible enteric micro-organisms indicated by bacteriophages, and tastes and odours from typical eutrophied and heavily polluted waters, will be developed. This project should result in a model of parameters and improvements which are required to enable construction of full-scale, commercial, South African ozoniser systems. The price structure may introduce ozonation as a viable alternative in many applications in order to address the deteriorating water quality situation in the country.

Estimated cost: *R398 000*
Expected term: *2000-2001*

Development of guidelines for the disposal of water treatment sludges to land

(No 1148) University of Natal – School of Applied Environmental Sciences

South Africa's turbid waters give rise to the production of huge quantities of sludge during the water treatment process. Chemical precipitants are added to the turbid waters to promote flocculation. Once flocculated, the solid fraction which settles under gravity is transferred to drying beds, while the supernatant is filtered and clarified for domestic consumption. The dewatered solids (sludges) are regarded as industrial wastes and must be disposed of accordingly. The traditional method of sludge disposal has been by landfilling, but given the economic constraints associated with landfill maintenance, alternative methods of sludge disposal have to be considered. A disposal option which is gaining increased acceptance internationally is the application of sludge directly onto land.

Land disposal is based upon the fundamental tenet that the physical, chemical and biological properties of the soil can be used to digest the applied waste without inducing negative effects on soil quality, groundwater or plant growth. Sludge could have two opposing physical effects on soils, viz. the polyelectrolyte could improve soil structure, or the fine silt and clay could lead to structural degradation. Chemically, the behaviour of heavy metals and the high phosphorus fixing ability of the sludge also give rise for concern. These concerns will be evaluated as part of this project.

Estimated cost: *R650 000*
Expected term: *2000-2002*

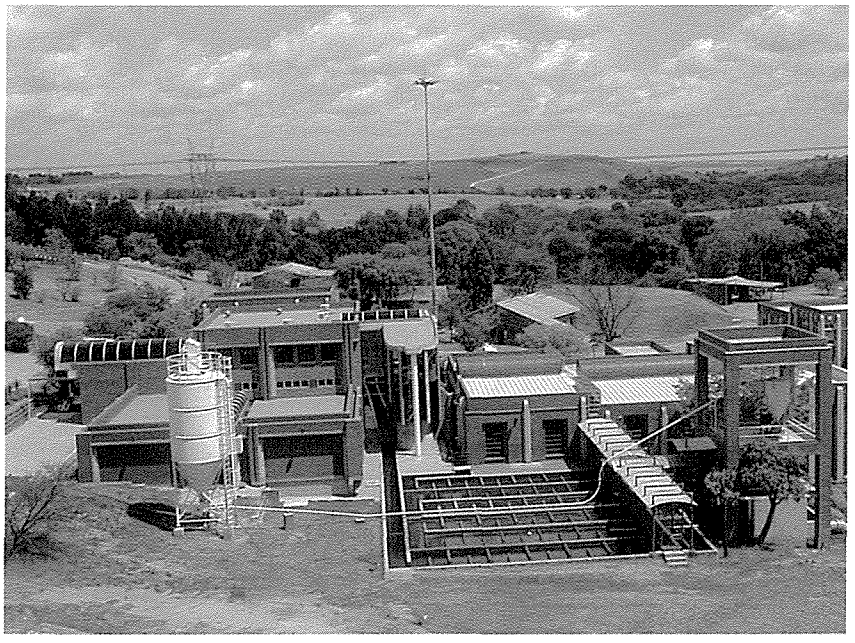
Fluoride removal from water with unconventional low-cost media

(No 1183) Rand Afrikaans University – Department of Civil and Urban Engineering

The excessive presence of fluoride in isolated rural parts of South Africa is well-known and documented. Its removal is a high priority for water managers, as evidenced for example by the workshop on its removal hosted by the WRC in March 1999. In a review presented at this workshop, one alternative approach to fluoride removal (other than the usual methods of chemical precipitation, or ion exchange/adsorption on conventional media) is a method reported from Sri Lanka. Here the water is percolated through a bed of clay brick fragments with reported success. The health and cost benefits of such a low–cost method are obvious, and especially so to rural South Africa.

Despite the enormous appeal and potential of this technology, a two–stage approach to the problem is proposed due to the high risk of the project. This first stage (this project) will only include the necessary exploratory work to determine whether the technology holds any potential at all. Should the reported success from Sri Lanka be duplicated, then one should advance to a second, more exhaustive stage, backed by the necessary scientific evidence. Hence, the aims are as follows: To make a rapid assessment of the potential of clay brick for the removal of fluoride from rural water supplies and to assemble the necessary fundamental information to formulate a rational, well-motivated follow–up research proposal, should the technology show sufficient promise.

Estimated cost: *R90 000*
Expected term: *2000-2001*



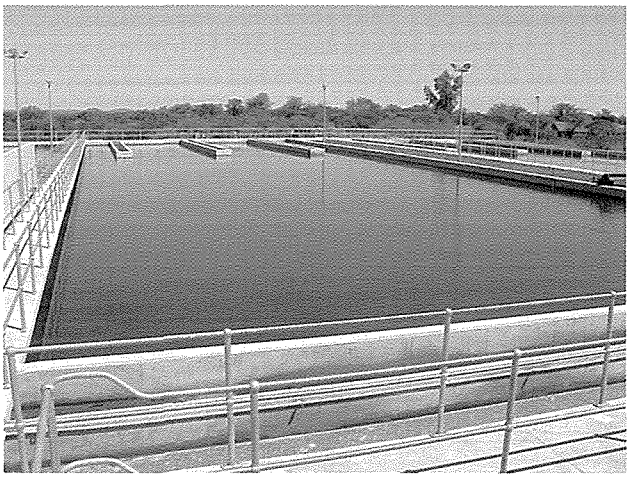
The Rietvlei Water Treatment Plant – national winner for engineering excellence in 2000, with the decision based on the pioneering and innovative use of GAC for advanced treatment.

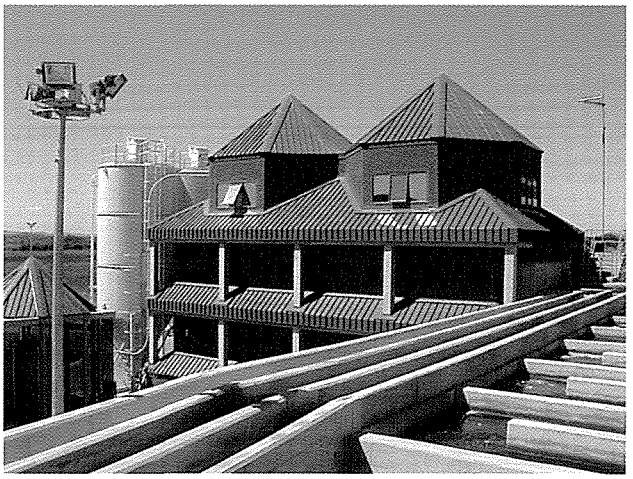
Assessment of procedures used in Southern Africa to evaluate chemicals used in water and wastewater treatment

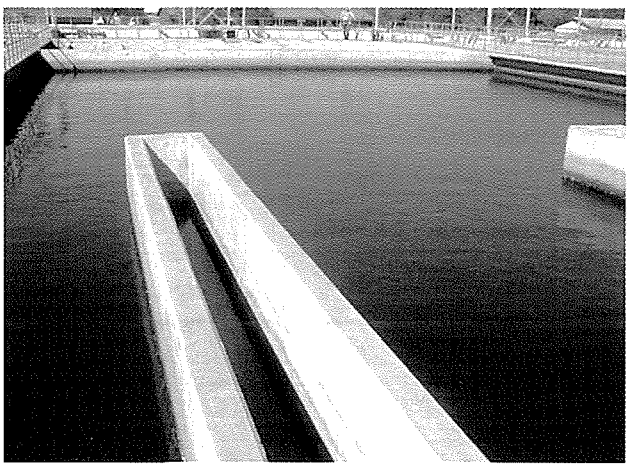
(No 1184) Umgeni Water – Department of Process Services

A large number of chemicals are used in the production of potable water and in the treatment of wastewater effluents. In potable water treatment, chemicals such as inorganic salts and polymeric organic coagulants are used for primary coagulation, as coagulant aids and for sludge dewatering; lime and soda ash allow for pH correction and water stabilisation; caustic soda is used for pH adjustment; powdered activated carbon (PAC) can remove taste and odour compounds and micropollutants such as atrazine; bentonite aids coagulation; and ammonium hydroxide is used in chloramination.

At present there are some recommended tests available for the assessment of some of these chemicals such as the *SABS 459–1955 Standard Specification for Lime* which is used for chemical and metallurgical purposes. However, the tests described in this specification are, for the most part, outdated gravimetric procedures which are particularly time-consuming. In the case of polyelectrolytes used for primary coagulation during potable water treatment, there is currently no legislation or regulation system available in this country to control the use of these chemicals and no standard tests are available to measure the effectiveness of these chemicals for coagulation.







Three views of the new sedimentation tanks at the Vaalkop Water Treatment Plant.

This lack of standard tests in the water and wastewater chemical industry makes it difficult to assess or compare these products and this can have negative health and environmental implications. A handbook containing standard tests, which have been properly evaluated and which, for the most part, can be performed using relatively simple equipment, would be of great benefit to the entire water industry. The main aims of this project are to:

- Assess the various procedures used in Southern Africa to evaluate the different chemicals used in water and wastewater treatment.
- Identify the critical determinants for the evaluation of these chemicals and to recommend standard procedures.
- Produce a handbook for all Southern African water and wastewater authorities which can be used for the evaluation of the chemicals used in water and wastewater treatment. This handbook would set out standard procedures for the assessment.

Estimated cost: *R89 000*
Expected term: *2000-2001*

Design manual for small water treatment plants for rural communities with specific emphasis on community involvement and the use of indigenous treatment technologies

(No 1185) Chris Swartz Engineering

A large number of small water treatment systems installed in South Africa are subject to failure during their lifetime. According to feedback at a recent conference held in East London (*Appropriate Practice Conference, March 1999*), of a number of more than 50 small treatment systems that were installed in Southern Africa, only a small percentage are performing according to the requirements and can be considered to be successful water supply projects. This implies that a failure to gain the support and participation of the communities during the initial stages of successful water supply projects may result in failure of the system. It is of utmost importance that the communities accept the technology and that the technology should work for the community.

A number of guideline documents have been drawn up about various aspects of rural water supply, and on the different technologies used in rural water treatment plants (WRC Report *Nos. 231/1/93, KV 58/94, TT 68/95, 449/1/95, 450/1/97*, and *354/1/97*; various *Technical Guides* by the CSIR's Division of Water Technology). However, none of these guides specifically address the pitfalls that should be guarded against when designing small treatment systems, and which often lead to failure. There is, therefore, a need for a comprehensive design manual for small rural water treatment plants, which specifically identifies pitfalls to be avoided in the design of these plants, and which contains the very important guidelines on how to obtain community support and participation in the project. Because many of the treatment systems designed by engineers for rural applications are over–designed or inappropriate (too sophisticated; community does not accept the technology), the aim is also to provide guidelines on how the "simpler" and indigenous technologies can be used to ensure community participation, cost reduction and sustainability of the systems.

Estimated cost: *R95 000*
Expected term: *2000*

Research projects

Completed

- **280** Evaluation of full-scale flotation-filtration and chlorine dioxide plants (Free State Gold Fields Water Board)
- **381** Corrosion performance of various non-metallic piping materials and coatings in potable water (CSIR – Division of Materials, Sciences and Technology)
- **446** Osonation 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 – Scientific Services)
- **567** The occurrence and distribution of algal species and related substances in a full-scale water purification plant (University of the Free State – Department of Botany and Genetics)
- **694** Treatment of eutrophic waters using pre- and intermediate ozonation, peroxone and Pica carbon (Umgeni Water – Scientific Services)
- **948** Water meters: Influence of various fittings and installation configurations on accuracy (SABS)

Current

- **624** Personal computer-based procedure for the estimation of irrigation requirements of crops in Southern Africa (MBB (CE) Inc.)
- **648** Application of computational fluid dynamics to improving the design and operation of water and wastewater treatment plants (University of Natal – Department of Chemical Engineering)
- **662** Evaluation and optimisation of a cross-flow microfilter for the production of potable water for rural and peri-urban areas (University of Natal – Pollution Research Group)
- **679** Compilation of a computerised, diagnostic system for algal-related water purification problems (Rand Water – Scientific Services)
- **734** Development of a strategy for disseminating information from the hydrogeological mapping programme to village water committees (Water Systems Management)
- **829** Systems for the abstraction of surface water through river sand-beds (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)
- **873** Chemical and microbiological evaluation of the performance of commercially available home treatment devices (Rand Water – Scientific Services)
- **898** Economic model for leakage management (BKS (Pty) Ltd.)
- **919** Optimisation of an automatic backwashing filter for the cost-effective production of potable water for rural areas (University of Natal – Department of Civil Engineering, and Umgeni Water – Scientific Services)
- **920** Evaluation of a filter washwater recovery plant to establish guidelines for design and future operation (Rand Water – Scientific Services)
- **921** Water quality deterioration in potable water reservoirs relative to chlorine decay (Rand Water – Scientific Services)
- **922** STASOFT IV – A user-friendly computer program for use in the treatment of municipal water supplies (University of Cape Town – Department of Civil Engineering)
- **923** Supercritical fluid regeneration of activated carbon applicable to water fraternity (Potchefstroom University – Centre for Separation Technology)
- **924** Characterisation and chemical removal of organic matter in South African coloured surface waters (Chris Swartz Engineering)
- **963** Trouble-shooting guide for the domestic consumer (Rand Water – Scientific Services)
- **998** Modelling of flocculation, thickening and sedimentation in water treatment (Potchefstroom University for CHE – School for Mechanical and Materials Engineering)
- **1023** Inhibition of biofilm regrowth in potable water systems (University Fort Hare – Department of Biochemistry and Microbiology)
- **1024** Evaluation of phase removal processes at full-scale SA water treatment plants in terms of particle size and number (Rand Afrikaans University – Department of Civil and Urban Engineering)
- **1025** Investigation into the use of particle size analysis for monitoring and optimising plant performance for the production of potable water (Umgeni Water – Process Facility Department)
- **1026** Consolidation and transfer of limestone-mediated stabilisation technology for small to medium scale water users (CSIR – Cape Water Programme)
- **1027** Development and assessment of the limestone-mediated sidestream stabilisation process, with emphasis on use thereof by Rand Water for stabilisation of Lesotho Highlands scheme water (CSIR – Division of Water, Environment and Forestry Technology))
- **1041** Support, maintenance and debugging of WATREX – Expert system for water treatment plant design (Sutherland Associates)

New

- **1124** Evaluation of powdered activated carbon (PAC) for the removal of taste- and odour-causing compounds from water and the relationship between this phenomenon and the physico-chemical properties of the PAC and the role of water quality (Rand Water – Process Development)

- **1125** Small water treatment systems: A case for development of an approval/certification system (Options to Solutions)
- **1127** Development and evaluation of new South African ozoniser technology for removal of pathogenic organisms, possible enteric viruses indicated by bacteriophages, and tastes and odours present in Hartbeespoort Dam water (PARC Scientific)
- **1148** Development of guidelines for the disposal of water treatment sludges to land (University of Natal – School of Applied Environmental Sciences)
- **1183** Fluoride removal from water with unconventional low-cost media (Rand Afrikaans University – Department of Civil and Urban Engineering)
- **1184** Assessment of procedures used in Southern Africa to evaluate chemicals used in water and wastewater treatment (Umgeni Water – Department of Process Services)
- **1185** Design manual for small water treatment plants for rural communities with specific emphasis on community involvement and the use of indigenous treatment technologies (Chris Swartz Engineering)

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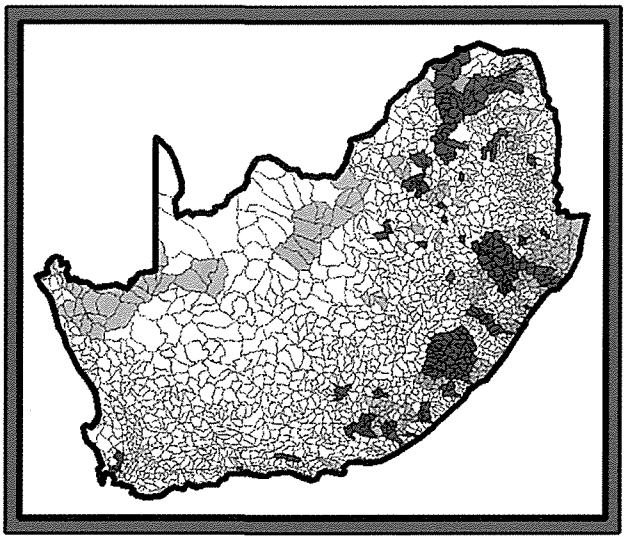
6 Health-related water issues

Until 1999 health-related water research was being addressed under a variety of WRC research fields. Its importance, however, led to health-related water issues which are now being recognised as a research field in its own right.



Identified faecal pollution risk areas for the implementation of the National Microbial Monitoring Programme (NMMP).

Health-related water research must focus on protecting the quality of water in a resource. Polluted and/or toxic water could lead to chronic ill-health, acute disease or even sudden death, especially when ingested through drinking or consumption of food. The focus on prevention of water-quality deterioration which can be health-threatening, would have the added advantage of reducing the time, energy and funds needed for purification and disinfection of affected waters and treatment of symptoms of water-related diseases.

To address causes instead of symptoms, the WRC is taking a holistic, multidisciplinary approach to finding solutions to problems associated with the decreasing quality of our water resources. Several workshops, starting in October 1999 and continuing to the end of 2000, have been held with the aim of developing a strategic plan for the research field. The main focus of the strategic plan is to develop a comprehensive understanding of the origin of pollution, the effects thereof on water quality, water treatment, water usage and the ultimate effects of poor water quality on animal and human health.

In executing the strategic plan, a key approach will be to identify the origin of pollutants. This requires the availability of methods for detecting and quantifying the amounts present. There may be a need to develop and test basic analytical methods and/or to investigate simpler, cost and time-effective methods which will allow early detection of pollution and prevention of serious consequences in terms of human and animal health.

Because the majority of our water resources are already polluted in one way or another, attention must also be paid to remediation of problems. The effects the pollutants may have on animal and human health need to be addressed through risk assessment studies in order to be able to make decisions on the most cost-effective remediation processes.

The strategic research plan will be executed through individual projects, "closed" programmes and "open" programmes. Individual projects could address isolated problems or focus on pilot studies. "Closed" programmes consisting of individual multidisciplinary projects of a fixed term, will address specific short-term problems that are experienced. The "open" programmes will be used to identify real, immediate or emerging problems in order to understand and gain data on the extent thereof, investigate the remediation steps to be initiated or identify the proactive precautions which will be taken.

It is of crucial importance that programmes in this field are not handled in isolation: care must be taken to ensure a multidisciplinary approach and to include and involve all relevant sciences in solving the problems. The intention of the proposed strategic plan is to ensure such involvement by including a set of criteria as a check list for all projects and programmes.

A further aim of research in the field is to deliver user-friendly end-products which make a difference to the attitude of all South Africans in caring for water sources, rather than polluting them and, thereby, contributing to the deteriorating quality that ultimately leads to ill-health and declining prosperity.

Completed projects

Development of procedures for biodegradability testing of organic chemical compounds

(No 611) CSIR – Division of Water, Environment and Forestry Technology

The aim of the project was to evaluate short-term screening tests for the biodegradability of chemical projects and pollutants in water and effluents and the modification of the most suitable tests for application in South Africa. The main results were:

- Water samples from the Apies River and Daspoort sewage works were found to be suitable for use as environmental (OECD) and sewage (ISO) inocula in the tests. This situation will virtually simulate conditions which are prevalent in the aquatic environment.
- With the inocula mentioned above, typical chemical compounds in some of the industrial effluents of South Africa were then tested and the following results were obtained:

– Aniline and lauryl sulphate were found to be readily biodegradable in all the tests.
– Diethylene glycol was difficult to biodegrade and was shown only to be readily biodegradable in the DOC reduction test with activated sludge, and only when a low test concentration was used.

- Stearic acid was readily biodegradable in the oxygen depletion, but not in the CO_2 reduction tests.
- Mixtures of chemicals, when aniline was used as a reference chemical, were not toxic at the test concentrations.
- Abiotic degradation could not be demonstrated with mixtures of aniline (reference chemical) and chemical compounds because of test concentrations which were not toxic.
- Effluent from a food industry showed abiotic degradation.
- Toxicity was not found in the river water and effluent at the concentrations tested.
- Summary of results: The biodegradability tests on the river water and effluent showed that the CO_2 production test was positive for all the samples tested, while the DOC reduction and oxygen depletion tests were only positive in a few instances. The DOC reduction test gave low values of biodegradation with river water.

Cost: *R251 533*
Term: *1994-1995*

Qualitative and quantitative evaluation of oestrogen and oestrogen-mimicking substances in the water environment

(No 742) Rand Water

A literature survey to identify substances which were claimed to be oestrogen-mimicking was undertaken. The 142 substances which were identified were then scrutinised to identify the substances that would most probably be found in South Africa.

The criteria used during this process were to trace industries that manufactured the substances, and thereafter, to analyse their effluents. When significant levels of the listed substances were found in the effluents, the surrounding water sources were tested for these substances.

From these analyses, it was found that several water sources were contaminated with endocrine disruptors. The drinking water which was analysed by the available methods did not appear to have sufficiently significant levels of these substances to put the users at risk.

Cost: *R255 000*
Term: *1996-1998*

Quality of Domestic Water Supplies Volume 2: Sampling Guide

(K8/274) BKS (Pty) Ltd.

The first draft *Assessment Guide* for assessing the fitness for use of water for domestic purposes was published jointly by the DWAF, the Department of Health and the WRC in 1996.

The Guide was widely distributed amongst interested and affected parties and a workshop was held in February 1997 to consult with a selected group of users on the applicability of the Guide.

At this workshop it was obvious that more refinements needed to be made to the document. During the workshop the idea of a series of guidelines was initiated by the WRC. It was accepted and the *Quality of Domestic Water Supplies Volume I: Assessment Guide* was published in 1998, with a second print-run in 1999 of 14 000 copies.

Soon after the publication of the *Assessment Guide*, requests for the *Sampling Guide* were received. The technical team went through the same procedures as with the *Assessment Guide* and a peer-review workshop was held on 29 April 1999 with a selected user-group.

The *Sampling Guide* is an extension of the *Assessment Guide* and the information content is therefore compatible. The *Sampling Guide* is divided into four parts:

Part 1: General information on the objectives and concepts of domestic water quality sampling.
Part 2: Planning of the sampling programme.
Part 3: Preparing for the sampling exercise.
Part 4: Sample collection.

Cost: *R132 000*
Term: *1997-1998*

Creating the infrastructure required to commence with the National Microbial Monitoring Programme

(K8/349) CSIR – Division of Water, Environment and Forestry Technology

The consultancy project was a continuation of Project No 824 and had the following objectives :

- Select areas that might present a high human health risk of faecal pollution in South Africa.
- Initiate monitoring on a pilot scale.
- Recommend procedures for a national-scale monitoring programme and produce an implementation manual including such procedures.

These objectives have been achieved. The next step is the actual implementation of the Programme to create a sound foundation for all the aspects that are necessary for the commencement of actual monitoring in two selected high-risk areas during 2000 and include an awareness campaign based on currently available information. Areas were selected according to pre-determined criteria and the necessary capacity and infrastructure were created within each area. The implementation manual was tested during this period for its user-friendly nature. Clarity of the procedures and methods described in the manual were applied. This paved the way for the follow-up project, which commenced in 2000, entitled: **Pilot study to demonstrate implementation of the National Microbial Monitoring Programme** (No 1118).

Cost: *R100 000*
Term: *8 months (1999)*

New projects

Development of guidelines and a human health risk assessment for *Legionella* levels in water

(No 1104) CSIR – Division of Water, Environment and Forestry Technology

Legionellosis is a lung disease that could be transmitted via cooling towers used in industries as well as by air conditioners in buildings.

The *Legionella* action group was established because of uncertainties about the methods used for *Legionella* detection in water. The WRC funded 3 workshops (Johannesburg, Durban and Cape Town) to create an awareness of the occurrence of *Legionella* in cooling water. The need for standard analytical techniques and guidelines for industry on assessing the quality of cooling water were among the issues raised by industries at these workshops. South Africa does not have guidelines for industry regarding accepted levels of *Legionella* in cooling water.

The WRC previously funded a research project to evaluate available methods and to recommend a standard method applicable for South African conditions: No 927: **Detection methods for studying the ecology of *Legionella* in cooling water systems**. In the recommendations it was mentioned that industries need guidance on infectious doses and that the country needs legislation to ensure safe environments in the work-place and in areas surrounding industries.

This project will address these needs. Its aims are, therefore, to:

- Establish guidelines for safe *Legionella* levels which will assist industry in the maintenance of cooling water and will serve as a guide for the timeous treatment of cooling waters to maintain acceptable Legionella levels and to prevent outbreaks of legionellosis.
- Assess the levels of *Legionella* in cooling water which may pose a human health risk.

Estimated cost: *R55 000*
Expected term: *2000*

Development of a field kit for microbial water quality assessment in small and rural communities

(No 1105) CSIR – Division of Water, Environment and Forestry Technology

The WRC recently funded a project to evaluate the H_2S strip test for use as a rapid indicator of the quality of drinking water in rural areas.

The H_2S strip test is highly recommended for use as a screening test to highlight potential community health problems. This determination of microbial pollution of water is very useful and the kit is a visually striking means of explaining the microbial quality of water to communities. The management team of the *Quality of Domestic Water Supplies Guidelines* series has included this method in the *Analytical Guide* (*Volume 3*).

It is, however, advisable to first make sure that the method is applicable to all areas, especially those experiencing extreme temperatures. The suitability of the kit for use by environmental health officers, community water committees and individuals as a rapid and reliable screening test to indicate poor microbial water quality must also be evaluated.

The test kit could be useful as an education tool for illustrating microbial pollution. It could also be of value to stimulate awareness of communities to microbial pollution of their drinking water that could have detrimental health effects.

The aim of this project is, therefore, to test the proposed field kit with environmental health officers for its use in managing small water supply systems, particularly in areas where water monitoring would not normally take place. A major component of the project involves technology transfer.

Estimated cost: *R70 000*
Expected term: *2000*

Pilot study to demonstrate implementation of the National Microbial Monitoring Programme

(No 1118) CSIR – Division of Water, Environment and Forestry Technology

Project (No 824): **Selection of procedures for faecal pollution monitoring to describe health risks** and consultancy project (K8/349) **Creating the infrastructure required to commence with the National Microbial Monitoring Programme** (NMMP) were predecessors of this project. The main product of these projects was an implementation manual for the National Microbial Water Quality Monitoring Programme (NMWQMP).

This project that demonstrates the implementation of the NMMP is regarded as an important link between the concepts described in the implementation manual and full-scale implementation of the monitoring programme. An added advantage of the project would be its ability to 'kick-start' the implementation process and thus form the first building blocks in the phased-implementation approach proposed in the manual.

The full-scale implementation of the NMMP is of high priority to DWAF, since the establishment of national monitoring systems is a requirement of the Water Act (Act 36 of 1998).

The aim of this project is, therefore, to test and demonstrate the viability of the concepts and procedures described in the implementation manual for NMWQMP, through the monitoring of surface water resources in selected high-risk areas, on a pilot scale.

Estimated cost: *R303 000*
Expected term: *2000-2001*

Risk of insecticide (Pyrethroid) resistance for malaria control in South Africa

(No 1119) Agricultural Research Council – Unit of Pesticide Impact

Pyrethroid, an organophosphate pesticide, replaced the use of DDT as an indoor application for the control of malaria. Pyrethroid is also used as a pesticide in agricultural areas surrounding Ubombo in KwaZulu-Natal and could, therefore, be present in surface water. Recent studies have shown that mosquitoes in the Ubombo area have developed signs of resistance to organophosphates. Such resistance could have developed via the exposure of the larvae to pyrethroids in the water environment. If this is the case, it could have vast implications for the malaria control programme.

Malaria is one of the diseases identified as being of high priority and has been included in the top 10 research topics of the National Health Research Programme of the Department of Health. The high incidence of fatalities occurring in South Africa as a result of malaria is of great concern. Resistance of strains of vectors to pesticides and parasites to prophylaxis has become apparent, placing both inhabitants and tourists in certain areas at risk.

It is, therefore, important for South Africa to take pro-active steps to address the possible problem of loss of control over malaria in these vulnerable rural areas. The proposal contains a large educational component and aims to involve communities and build capacity with regard to the safe use of pesticides.

The aims of the project are, therefore, to:

- Establish the patterns of agricultural pesticide use by emergent farmers and determine the association of pyrethroid residues in water.
- Determine the potential of these residues to cause build-up of resistance to pyrethroids in malaria vector larvae.
- Develop a protocol for sampling, analysis and interpretation whereby areas at risk can be investigated for resistance potential within a short period.

Estimated cost: *R150 000*
Expected term: *2000*

Assessment of Domestic Water Supplies. Volume 5: Management Guide

(No 1123) BKS (Pty) Ltd..

The *Management Guide* is one of a series of five proposed guideline documents aimed at assessing the quality of domestic water supplies. The series draws together the results of many research projects and the collective knowledge of experts in the field. It aims to present information in a manner which is scientifically credible, but at the same time, easy for lay people to comprehend. In this way it is hoped that the Guide will stimulate community members to become involved in the management of their own community water supplies.

The first of these documents that was published, *Quality of Domestic Water Supplies. Volume I: Assessment Guide*, was successfully introduced into many spheres of South African society. It is already accepted as the official document which is used to assess

domestic water supplies.

It is foreseen that the *Management Guide* will fulfil as important a need as did the first document. Publication is a matter of urgency.

The aim of this project is to produce a document (*Volume 5*) that will give guidance on water quality management with regard to the planning of a new water supply scheme, the implementation of a proposed water supply scheme, and the operation of an existing water supply scheme for domestic use.

Estimated cost: *R115 000*
Expected term: *2000*

Incidence of enteric pathogens in domestic water, water sources and stools of residents of urban and rural areas in the Venda region of the Northern Province

(No 1126) University of Venda – Department of Biochemistry and Microbiology

The Northern Province lacks laboratories to assess microbiological water quality and microbial pollution of domestic water supplies and water sources. Data are not available to promote public awareness of pollution and the detrimental effects on health.

One of the objectives of this proposal is to get the local communities involved in the various aspects of water management, conservation and pollution control by stimulating the development of a microbiological analytical centre in close proximity to the communities. Capacity-building is thus a strong component of this proposal. A well-equipped laboratory with microbiologists who are capable of determining health risks and associated water treatment needs will be of benefit to the University as well as to the Northern Province and its inhabitants.

The aims of the project are to:

- Explore the use of viruses as indicators of water quality and determine the anti-biograms of isolates in order to provide updated information on their susceptibility patterns and the extent to which enteric bacterial infections influence the incidence of diarrhoea and dysentery amongst infants in urban and rural regions in the Northern Province.
- Determine the incidence of enteric pathogens in domestic water and water sources.

Feedback will be provided to communities on findings and implications regarding the microbiological water quality.

Estimated cost: *R350 000*
Expected term: *2000-2002*

Assessment of the risk of infection associated with viruses in South African drinking water supplies

(No 1164) University of Pretoria – Department of Medical Virology

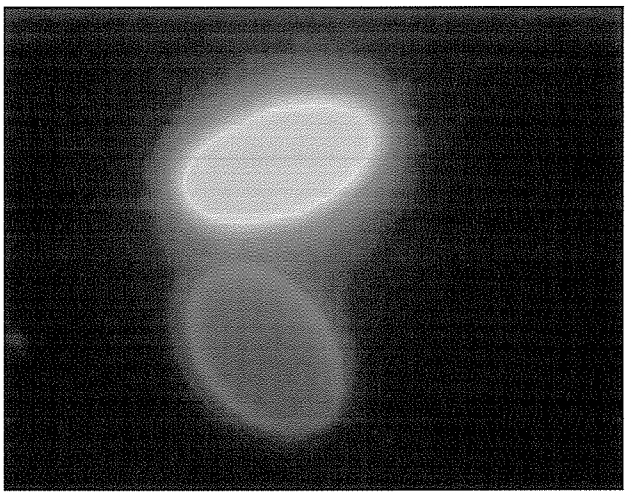
South Africa lacks information and general data on the risks associated with viral infection via drinking water supplies in South Africa. Because methods available for the detection of viruses are tedious and expensive, no viral detection methods or limits were included in the section on Microbiological Quality in the recently published *Quality of Domestic Water Supplies. Volume I: Assessment Guide*. The Department of Environmental Health is concerned about the lack of data regarding water-related viral diseases. This project will address both the need for simpler, more economic, but effective viral detection methods and the lack of data and information on viruses in drinking water.

The proposal includes an extensive component of technology transfer and capacity-building to those institutions that are interested in establishing laboratories in which virology analyses and research could be conducted as a service to neighbouring communities. The availability of information acquired will be of special value to enable environmental health officers to take the necessary steps to combat outbreaks of water-borne diseases.

The aims of the project are to:

- Develop simpler, more economic new techniques for the detection of small numbers of viruses in large volumes of drinking water, and to assess the value of indicators of the virological quality of drinking water.
- Generate new data which are essential for guidelines on drinking water quality and monitoring programmes and water treatment and disinfection processes.
- Provide first-hand information on the risk of viral infection which is associated with drinking water supplies in typical developed communities, developing communities, rural communities and informal settlements.
- Provide first-hand information on the incidence of a comprehensive spectrum of enteric viruses in selected representative drinking water supplies in South Africa.

Estimated cost: *R1 000 000*
Expected term: *2000-2002*



Photomicrograph of a TMR-FDA stained viable *Giardia* cyst and a TMR stained non-viable *Giardia* cyst viewed under oil immersion by epifluorescence microscopy, fitted with a triple band filter with excitations of 400/450/510 nm. (Current Proj No 825).

Research projects

Completed

- **611** Development of procedures for biodegradability testing of organic chemical compounds (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)
- **K8/274** *Quality of Domestic Water Supplies Volume 2: Sampling Guide* (BKS (Pty) Ltd.)
- **K8/349** Infrastructure required to commence with the National Microbial Monitoring Programme (CSIR – Division of Water, Environment and Forestry Technology)

Current

- **727** Effects 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)
- **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)
- **743** Health impact of waterborne viruses and methods of control in high risk communities (University of Pretoria – Department of Medical Virology)
- **821** Bacterial pathogens in groundwater (University of Durban-Westville – Department of Microbiology)
- **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)
- **827** Detection methods for studying the ecology of *Legionella* in cooling water systems (University of Pretoria – Department of Microbiology and Plant Pathology)
- **925** Assessing the causes and pathways of water borne disease in rural settlements with limited formal water supply and sanitation (Umgeni Water)
- **926** Assessment of the extent of oestrogenic activity in Western Cape water resources (University of Stellenbosch – Department of Zoology)
- **927** Occurrence and source of *Cryptosporidium* and *Giardia* in catchment areas and wastewater works (Umgeni Water)
- **928** Molecular characterisation of F-RNA coliphages in South African water sources (University of Pretoria – Department of Medical Virology)
- **1028** Protocol for surveillance and prospective epidemiological studies of gastro-intestinal health effects due to consumption of drinking water (Rand Water – Scientific Services)
- **1029** Scope and dynamics of toxins produced by cyanophytes in the fresh waters of South Africa and the implications for human and other users (University of the Free State – Department of Botany and Genetics)
- **1030** Evaluation of alternative disinfection processes for the removal of protozoan oocysts and cysts and other micro-organisms, in the treatment of final wastewater effluents (Umgeni Water)
- **1031** Occurrence of emerging viral, bacterial and parasitic pathogens in source and treated water in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **1039** Assessing potential health risks related to the use of treated waste water for various agricultural and aquacultural activities (Technikon Free State – Department of Environmental Sciences)
- **1040** Isolation of microbial extra-cellular enzymes for possible use in dairy cleaning-in-place applications (University of Port Elizabeth – Department of Biochemistry and Microbiology)
- **1067** Water quality monitoring programme to fulfill the needs of integrated catchment management in a densely populated rural catchment (University of Fort Hare – Department of Chemistry)
- **1068** Occurrence of *E.Coli* 0157:H7 and other pathogenic *E.Coli* strains in water sources intended for direct and indirect human consumption (University of Pretoria – Department of Medical Virology)
- **1069** Determination of cytotoxicity and invasiveness of hetero-trophic plate count bacteria isolated from drinking water (Rand Water – Scientific Services)

New

- **1104** Development of guidelines and a human health risk assessment for *Legionella* levels in water (CSIR – Division of Water, Environment and Forestry Technology)
- **1105** Development of a field kit for microbial water quality assessment in small and rural communities(CSIR – Division of Water, Environment and Forestry Technology)
- **1118** Pilot study to demonstrate implementation of the National Microbial Monitoring Programme (CSIR – Division of Water, Environment and Forestry Technology)
- **1119** Risk of insecticide (Pyrethroid) resistance for malaria control in South Africa (Agricultural Research Council – Unit Pesticide Impact)
- **1123** *Assessment of Domestic Water Supplies. Volume 5: Management Guide* (BKS (Pty) Ltd.)
- **1126** Incidence of enteric pathogens in domestic water, water sources and stools of residents of urban and rural areas in the Venda region of the Northern Province (University of Venda – Department of Biochemistry and Microbiology)
- **1164** Assessment of the risk of infection associated with viruses in South African drinking water supplies (University of Pretoria – Department of Medical Virology)

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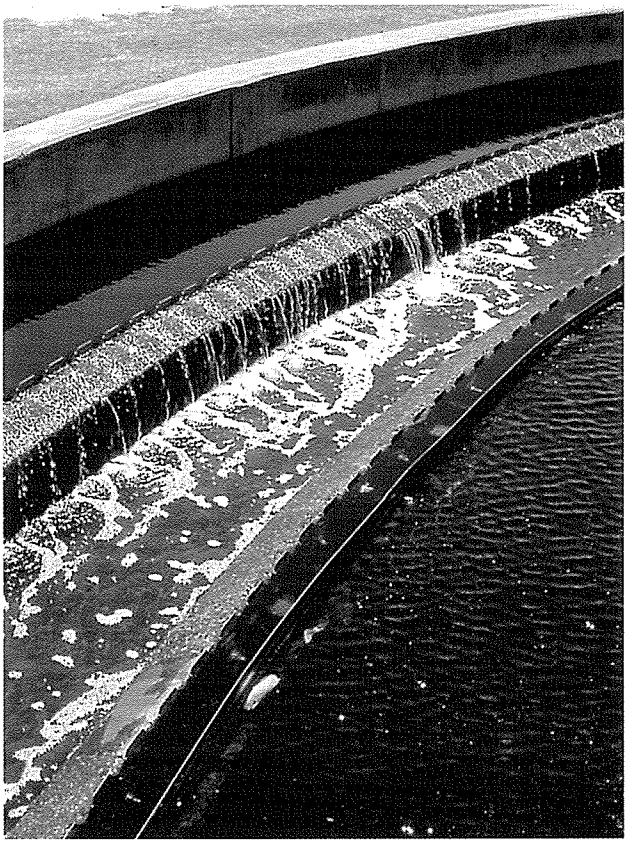
7 Municipal wastewater treatment

"Municipal wastewater treatment in the RSA must meet the concurrent challenges of providing affordable sanitation to recently-serviced sectors of the population, while at the same time, meeting the water quality requirements necessary for reuse of water for various needs and the protection of the aquatic environment"



Effective, affordable and sustainable management and treatment of sewage in the RSA faces a number of challenges in the immediate future. While many technical answers to existing problems have been provided by previous and current research, the changing socio-political-economic situation has re-defined and re-prioritised the requirements. Some of the major factors affecting national research needs are:

- Provision of water and sanitation services to previously unserviced sectors of the population will result in a rapidly increasing hydraulic and organic load on sewage treatment facilities, which must, therefore, be expanded to meet technical waste discharge quality requirements recently developed by DWAF in terms of the National Water Act. At the same time, the provision of such services must be affordable to the communities concerned.
- Low initial *per capita* water use in newly-serviced communities together with water conservation and demand management policies being applied to both domestic and industrial water use, indicate that the concentration of effluents arriving at sewage treatment works will increase.
- The quality of treated sewage discharged to watercourses (inland) and to sea (coastal) will continue to pose quality requirements based on reuse needs, the ecological reserve and marine environmental discharge requirements.
- The management, treatment and disposal of sludges from sewage treatment works are aspects of high priority.

Current and new research funded by the WRC in municipal wastewater treatment is focused on the areas indicated above, in accordance also with the Strategic Research Plan for this portfolio. Examples of the research thrusts being carried out are given below.

Innovative low-cost sanitation technology is being developed, adapted and assessed in a jointly-funded programme with Business Partners for Development, a World Bank initiative with local partners Umgeni Water, Durban Metropolitan Council, Vivendi Water and Mvula Trust. The technology which is being assessed by the Pollution Research Group at the University of Natal is the anaerobic baffled reactor, which offers good promise in terms of low capital costs, no power requirements, minimal sludge disposal requirements and a high treatment efficiency (excluding nutrient removal).

Cost-effective attainment of waste discharge standards is being addressed by on-going research into the use of "external" nitrification by trickling filters in sewage treatment trains (indicative capital and operating cost savings are in the range of 20 to 25% when compared to conventional biological nutrient removal activated sludge systems), algal improved pond systems (AIPS) and pond-enhanced treatment and operation (PETRO systems) for reduced-cost removal of organics and nutrients to the required standards.

To improve the security and cost-effectiveness of simulation packages modelling biological nutrient removal activated sludge (BNRAS) systems, collaborative engineering/microbiological work is being carried out by the University of Cape Town (Department of Civil Engineering), Technikon Natal (Centre for Water and Wastewater Research) and the University of Pretoria (Department of Microbiology) to determine the active mass fraction in BNRAS systems. Recent developments indicate that this work will be strengthened by molecular biology and simulation modelling from the University of Brisbane (Australia), funded by the Cooperative Research Centre for Waste Management and Pollution Control, based in the University of Queensland (Sydney). The overall thrust is the subject of a WRC research programme aimed at linking quantitative engineering and qualitative microbiological approaches to BNRAS systems, to determine the most appropriate microbiological, molecular and mass balance techniques for measuring the active biomass fraction in BNRAS systems, and to provide direct validation of a key kinetic rate – determining parameter (the active organism concentration) used in mathematical BNRAS models for design and operational control.

Regarding sludge treatment and disposal, major cross-cutting biotechnology is the accelerated hydrolysis of sewage sludge in the presence of sulphate-reducing bacterial systems, which is the subject of a collaborative research programme between Rhodes University

(Department of Biochemistry and Microbiology), the University of Cape Town (Departments of Chemical Engineering and Civil Engineering) and ERWAT (East Rand Water Care Company (Pty) Ltd). The technology, which is being developed at a fundamental level and is being tested on laboratory-scale and full-scale, is applicable to rapid digestion of sewage sludge and also to the renovation of high-sulphate high-volume acid mine drainage effluents to a reusable water resource.

Completed projects

Pond-enhanced trickling filter operation (PETRO®)

(No 491) Wates, Meiring and Barnard (CE) Inc. (now Meiring and Associates) and CSIR – Division of Water, Environment and Forestry Technology

The PETRO process combines the technologies of anaerobic digestion, oxidation ponds (OP) and trickling filters in a hybrid process that produces an effluent quality comparable to that produced by an activated sludge plant. Central to the success of the process is the mix of feeds to the trickling filter. Initial observation on full-scale plants, which was confirmed in the laboratory, indicated that micro-algae in the pond effluent were fixed in the Trickling Filter (TF) biofilm, where they become heterotrophic and continue to grow. Microalgal fixation in the TF means, effectively, that the PETRO process will discahrge an effluent which conforms to the General Standards.

Another initial observation was that the humus in the TF effluent settled very readily, and that the effluent itself was considerably clearer than that of the TFs used on their own. Further investigation showed that the reason for this was that the algae in the biofilm exude quantities of exocellular polysaccharides which not only have the effect of removing more algae, but also appear to act as flocculants in their own right. Investigation of the biofilm itself shows a much greater biodiversity and biomass than those found on TFs which do not have feed from an anaerobic source.

The full-scale PETRO plants studied each had 2 TFs, so it was possible to alter the loading on individual TFs without jeopardising the effluent quality. Initial experimentation in this regard indicated that a PETRO TF could treat 10 p.e.m^{-3}, as opposed to the 4 to 5 p.e.m^{-3} for stand-alone TFs. Sludge production is minimal, substantially reducing the sludge handling facilities required.

The PETRO process allows the flexibility of phased development to increase capacity as required, reducing the initial capital outlay. Its robustness makes it suitable for installation in remote areas.

Cost: *R 943 000*
Term: *1992-1994*

Development of a cross-flow microfiltration unit to improve the performance of anaerobic digesters at wastewater treatment works

(No 560) University of Natal – Pollution Research Group, Department of Chemical Engineering,

The aim of the project was to develop and demonstrate the locally-developed woven fabric tubular cross-flow microfiltration unit for the improvement of the performance of anaerobic digesters at wastewater treatment works. This will enable existing works to cope with modest increases in inflows and, hence, delay the necessity to construct new digesters.

It was found that the rate of digestion in an anaerobic digester could be increased significantly by coupling a dewatering (i.e., solids increase) device to the digester. It was also concluded from the study that the crossflow microfilter had good potential for the dewatering of sludges. However, for the specific anaerobic sewage sludge investigated, blockages, which resulted from the presence of human hairs, rendered the process impractical for the treatment of this sludge. A number of engineering-related problems were experienced with the operation of the unit. Most of these problems were related to the blockage phenomenon and the cleaning system used for cleaning the tubes in order to maintain the required water fluxes. Engineering problems related to the cleaning system could be solved satisfactorily, but not those related to the blockages.

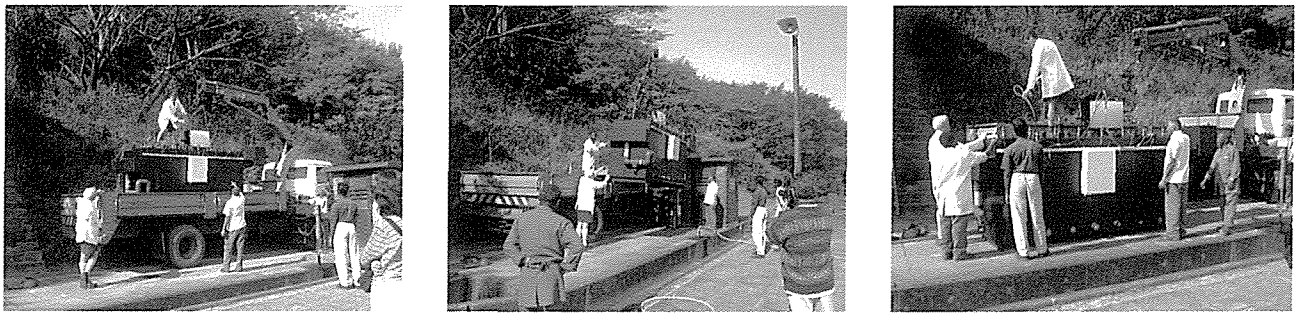
Cost: *R530 000*
Term: *1993-1996*

Modelling, design and operation of secondary settling tanks

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

Although the secondary settling tank is an important component of effluent treatment plants, its performance is often inadequate and this is essentially due to its design still being based primarily on empirical procedures which are used to assess the critical design parameter, viz., sludge settleability. The relationship between sludge settleability measures (SSMs) was checked using a large data set from different researchers around the world. The relationships between the simpler SSMs, sludge volume index (SVI), diluted sludge volume index (DSVI) and Stirred Specific Volume Index (SSVI) were not consistent among some data sets and appeared to reflect distinctly different types of activated sludge plant operating conditions.

Four steady state (SST) design procedures which recognise sludge settleability and reactor concentration were compared. It was found that even though the ATV (Abwassertechnische Vereinigung) procedure was originally based on flux theory principles, the simplifica-



Installation on-site of pilot anaerobic baffled reactor by Pollution Research Group, University of Natal, at Umbilo Sewage Works (KwaZulu-Natal).

tions and empirical changes that have been made to it over the years have made it substantially different from the flux theory. These differences, including features such as side-wall depth, geometry, tank-type baffling and inlet and outlet arrangements, influence hydrodynamic effects such as turbulent diffusion and density currents. They have a greater influence on tank performance than considered earlier in the development of the flux theory, which takes account only of sedimentation of solids.

The SST Design Program (called SEDRIC), which is written in Pascal, is capable of generating design results for the flux-based, MWRc (Modified Water Research Centre) , ATV(1976) and STOWa (Stichting Onderzoek Reiniging Water) design procedures. The program has not been officially published. However, it has found considerable circulation as freeware. Furthermore, a book, titled, *Secondary Settling Tanks: Theory, Modelling, Design and Operation* has been published by the International Association on Water Quality (IAWQ), in their Scientific and Technical Report series.

Cost: *R153 000*
Term: *1994-1998*

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

(No 820) University of Natal – Durban Pollution Research Group, School of Chemical Engineering,

This study has addressed the reduction of eutrophication through the improved removal of nitrogen compounds at sewage treatment works by enhancing biological denitrification

The following conclusions were drawn from the study:

- A comparison of the physico-chemical and biological characteristics of samples from European and South African wastewater treatment plants showed that these were fairly comparable.
- The tests conducted on the different samples showed that readily biodegradable COD fractions could be adequately characterised using the nitrate utilisation rate (NUR) method. This method is tedious and it can only be a useful tool for routine wastewater characterisation if the test could be automated.
- The accuracy of the tests appears to be compromised when enhanced biological phosphorus removal (EBPR) sludge samples are used in the NUR tests. It was found that non-EBPR (enhanced biological phosphorus removal) sludges could also consume about 4 to 5% of acetate that is present in the system for the production and replenishment of storage compounds.
- Processes such as substrate accumulation and storage may also impact on substrate removal and, hence, the determination of readily biodegradable COD components of municipal wastewater samples.

Cost: *R208 000*
Term: *1997-1998*

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

(No 822) Technikon Natal – Department of Biotechnology

Wastewaters entering a treatment plant are composed of many different and constantly changing substrates/pollutants, and only mixed microbial populations consisting of numerous species are capable of coping with such pollutants. A thorough understanding of the microbiological and related biochemical processes involved in the various aspects of wastewater treatment is necessary to support optimisation of the process and reactor design.

Principal results obtained in the study were:

At genus level, the Pseudomonads appeared to dominate the polyphosphate-accumulating bacterial community involved in biological phosphorus removal.

Acinetobacter spp. accumulated large quantities of polyphosphate from a phosphate-enriched liquid medium, but low recovery rates of this genus on solid agar media did not warrant its implication as the organism pivotal to phosphate uptake and removal from the activated sludge system.

The use of *in situ* probe hybridisation techniques showed that culture-dependent methods underestimated the total bacterial population of both full- and pilot-scale biological phosphorus-removing activated sludges by at least three orders of magnitude. This technique showed that the biological phosphorus-removing microbial population was diverse and that it was unlikely that any single species dominated biological phosphorus removal.

Experimental findings confirmed the existence of a diverse community of heterotrophic bacteria which are involved in biological nitrogen removal. Different patterns of nitrification behaviour were noted amongst heterotrophic nitrifiers with *Staphyllococcus, Micrococcus, Streptococcus, Pseudomonas* and *Bacillus* spp. all playing a role.

Cost: *R487 000*
Term: *1997-1999*

Biolog application in microbial diversity studies of activated sludge

(No 933) University of Pretoria – Department of Microbiology and Plant Pathology

The Biolog Automated Microbial Identification System was utilised in this project for the identification and characterisation of micro-organisms in the activated sludge system with a view to understanding their role in the removal of phosphates in wastewater treatment. The Biolog system is based on the different utilisation of a large number of organic compounds by the various test organisms.

The results show that, when using the Biolog system, no specific patterns could be identified for phosphate removing and non-phosphate removing systems, indicating that phosphate removal could not be related to the functionality of the aerobic heterotrophic microbial community which was determined using the Biolog system. Some limitations were identified which might make it impossible to draw a valid conclusion. However, such cases were not common. As shown by this study, the use of substrate utilisation profiles to characterise microbial communities have clear limitations, but this rapid technique remains a valuable tool for the comparison of microbial communities, provided that the data are interpreted cautiously.

Cost: *R174 000*
Term: *1998-1999*

New projects

Co-digestion of high strength/toxic organic effluents in anaerobic digesters at wastewater treatment works

(No 1074) University of Natal – Pollution Research Group, School of Chemical Engineering

There is a current shortage of high-grade landfill sites in the country. Many landfill sites that are built are not designed for saturated soil conditions. These landfills should not receive liquid effluents. Some liquid effluents with a high organic load are disposed of at landfill sites because the cost of discharging to sewer is prohibitive. However, if the organic material were to be degraded anaerobically the nett costs would be much lower. Many classes of toxic or biorefractory organic compounds can be degraded anaerobically by an acclimated association of anaerobic bacteria provided that the residence time is sufficiently long.

The specific aims of the project are to:

- Illustrate that organic liquid effluents can be disposed of and effectively treated in conventional sewage works at the anaerobic digestion stage.
- Provide a protocol for the evaluation of liquid effluents for disposal in a conventional wastewater treatment digester.
- Provide an alternative treatment system for high-strength liquid effluents that are currently being disposed of in landfill sites.

Estimated cost: *R1 260 000*
Expected term: *2000-2002*

Intermediate scale-up evaluation of the Rhodes Process for hydrolysis and solubilisation of sewage sludges in a sulphate-reducing bacterial system

(No 1169) Rhodes University – Department of Biochemistry and Microbiology

WRC-funded research into the biological reduction of sulphate in high-volume sources such as acid mine drainage has resulted in the development of process innovations and knowledge in such systems. A spin-off of this research (Rhodes University) has been the accelerated hydrolysis of complex carbon sources (e.g. sewage sludge), which is of potentially major interest to sewage treatment plant operators. In this project, ERWAT is aiming, in collaboration with Rhodes University, to undertake a pilot-scale evaluation of the process for accelerated hydrolysis (solubilisation) of primary sewage solids and their subsequent treatment in conventional aerobic treatment processes, to quantify the role of sulphur compounds as inventory reagents in the process, to derive design criteria for the process, and to evaluate application opportunities.

The main aims of the project are to:

- Undertake the intermediate scale-up evaluation of the Rhodes Process for accelerated solubilisation of primary sewage solids.
- Trace the subsequent treatment of solubilised solids passed to conventional aerobic treatment processes for final disposal.
- Evaluate the scale-up performance of processes used for sulphur and sulphide recovery as inventory reagents within the system.
- Derive process design criteria required to undertake the full-scale implementation of the process.
- Evaluate application opportunities of the process for co-disposal of sulphate-rich wastes and also secondary sewage sludges.

Estimated cost: *R700 000*
Expected term: *2000-2001*

Enzymology of accelerated primary sewage sludge solubilisation and digestion in sulphate-reducing systems

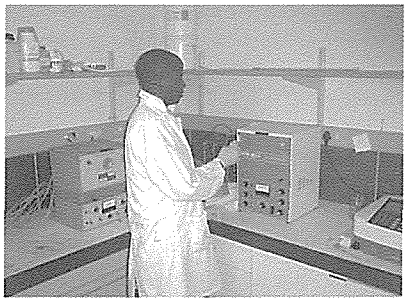
(No 1170) Rhodes University – Department of Biochemistry and Microbiology

The accelerated hydrolysis of complex carbon sources, in particular sewage sludge, in the presence of sulphate-reducing bacterial systems, is a spin-off from WRC-funded research being carried out by Rhodes University (Department of Biochemistry and Microbiology) into the biological reduction of sulphate in high-volume sources such as acid mine drainage. It is important to develop a more fundamental understanding of the observed phenomenon of accelerated hydrolysis (solubilisation) of complex organics such as sewage sludges when serving as carbon sources for sulphate-reducing bacteria, so that the overall process can be optimised and engineered effectively. Enzymological studies to identify the bio-catalysed reactions occurring, to characterise the physico-chemical factors involved (e.g. time, temperature, pH, redox potential, etc.) and to maximise the overall reaction efficiency, are important areas of investigation.

The main aims of the project are to:

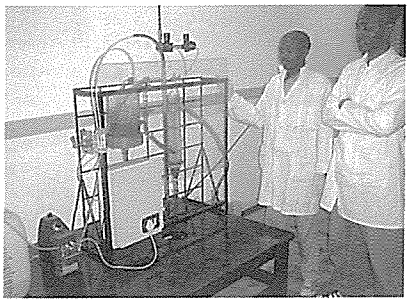
- Investigate the enzymology of accelerated primary sewage sludge solubilisation and disposal associated with sulphate-reducing bacterial systems. This includes identifying and characterising the major enzyme groups involved and determining the factors influencing their performance. Furthermore, the development and optimisation of the primary sewage sludge solubilisation process and reactor design indicators by the maximisation of enzymatic performance are also investigated.
- To construct a descriptive model of the physical mechanisms and the enzymatic role for the breakdown and digestion of the sewage sludge by investigating the action of the various enzymes (phosphatases, proteases, cellulases, sulphatases).

Co-digestion Project No 1074 at the University of Natal, Durban, Pollution Research Group.



Gas composition analysis using GC – chemical engineering student Ntsikelelo Lukope.

Serum bottle tests for determining toxicity and biodegradability of industrial effluents (initial screening tests).



Activated sludge simulation unit for testing industrial effluent – students Zama Mtembu and Ntsikelelo Lukope.

- To contribute enzymological inputs to the development of novel processes for utilising primary sewage sludge solubilisation as a carbon source for the treatment of acid mine drainage and for tertiary nutrient removal treatment processes.

Estimated cost: *R707 000*
Expected term: *2000-2002*

Determination of heterotrophic active bacteria in activated sludge using novel molecular techniques

(No 1178) Technikon Natal – Centre for Water and Wastewater Research

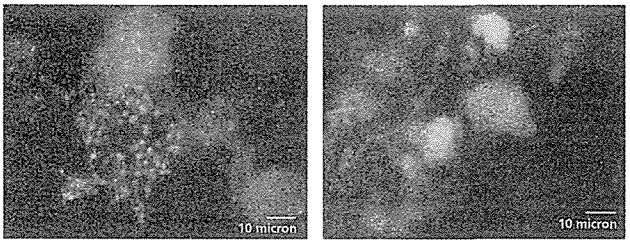
The heterotrophic active biomass component of activated sludge mediates the biodegradation processes of COD removal and denitrification and the rates of these processes are, therefore, directly related to the fraction present in the mixed liquor. To ensure that both new and existing wastewater treatment installations are designed or modified in such a way that they will adequately satisfy wastewater discharge quality and reuse requirements, the activate biomass fraction should be accurately quantified.

With the advancement and refinement of various molecular biology techniques, it has now become possible to measure the active fraction of activated sludge mixed liquors directly *in situ*. Intracellular ribonucleic acid (RNA) concentration is directly proportional to metabolic activity over a wide range and visualised fluorescence from specific binding of fluorescently labelled oligonucleotide probes, can, therefore, be correlated with metabolic activity for a particular organism. RNA content in activated sludge will be expressed as a function of total nucleic ratio (TNA), and the index (RNA/TNA) should indicate the active biomass fraction. Similarly, the fluorescent *in situ* hybridisation (FISH) index should give an indication of the ratio of metabolically active bacterial cells to the total cell number. Both parameters will assist in quantifying heterotrophic activity in activated sludge.

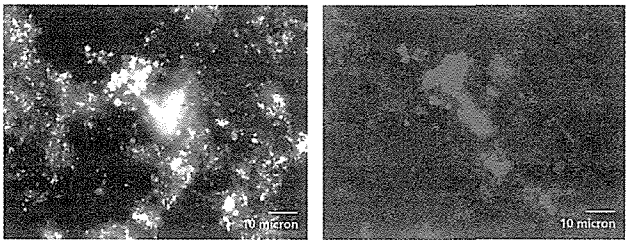
The specific aims in this project are to:

- Optimise nucleic acid extraction from activated sludge.
- Determine whether the RNA content of activated sludge is proportional to metabolic activity over a wide range.
- Determine RNA/TNA for a well-defined activated sludge pilot-plant process.
- Determine the active biomass fraction of activated sludge mixed liquor from the above-mentioned process using FISH ratios.

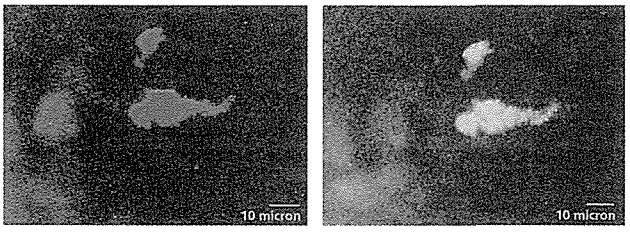
Estimated cost: *R875 000*
Expected term: *2000-2002*



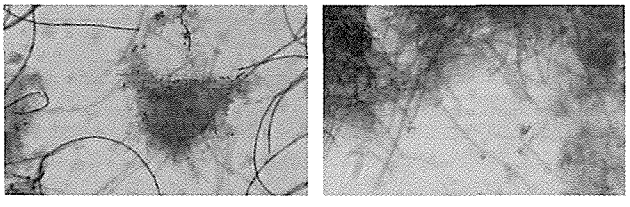
In situ hybridisation of enhanced culture activated sludge with rhodamine (red) labelled probe BET42a and fluorescein (green) labelled probe GAM42a.



DAPI stain (blue) of enhanced activated sludge (left) and *in situ* hybridisation with rhodamine (red) labelled probe ALF1b (right) for the same microscope field.



In situ hybridisation of enhanced culture activated sludge with rhodamine (red) labelled probe ACA23a (left) and fluorescein (green) labelled probe GAM 42a (right) for the same microscope field.



Filamentous organisms.

Measurement of heterotrophic and autotrophic organism active biomass in biological nutrient removal activated sludge systems

(No 1179) University of Cape Town – Department of Civil Engineering

Over the past decade significant advances have been made in the area of engineering and technology (E&T) of biological wastewater treatment systems. Likewise, significant advances have been made in microbiological and biochemical (M&B) analytical methods. The major development in the E&T paradigm is the development of mathematical models that describe biological wastewater treatment processes such as the biological nutrient removal activated sludge process. The major weakness in these models is that they are based on hypothetical active organism concentrations for the biological processes of importance in the system, viz. COD degradation by ordinary heterotrophic organisms, nitrification by autotrophic nitrifier organisms, denitrification by facultative heterotrophic organisms and biological excess phosphorus removal by polyphosphate accumulating organisms. These hypothetical active organism concentrations have achieved a measure of reliability through the consistency with which these models predict observations over wide ranges of process conditions, but have yet to be validated by direct measurement, although the models are widely used in the design and operation of activated sludge systems world-wide. It is in this area that the M&B developments can make a major contribution to validation of the hypothetical active organism concentration foundation of the mathematical models.

The specific aims in this project are to:

- Improve the reliability of mathematical models for design and operation of the biological nutrient removal activated sludge (BNRAS) system.
- Provide a platform for collaborative work between the engineering and microbiological aspects of the BNRAS system.

- Provide a better scientific understanding of the microbiological processes operating in the BNRAS system in the context of defined engineered environments.

Estimated cost: *R322 500*
Expected term: *2000-2001*

Microbial characterisation of activated sludge mixed liquor suspended solids

(No 1191) University of Pretoria – Department of Microbiology and Plant Pathology

In activated sludge systems the mixed liquor organic suspended solids fraction is made up of three components: **Heterotrophic active biomass, endogenous residue, and inert material**. In nitrifying aerobic and anoxic/aerobic activated sludge systems, a fourth mixed liquor organic suspended solids component is included, namely autotrophic active biomass. All four mixed liquor organic suspended solids components settle out in the secondary settling tank, are returned to the bioreactor(s) via the underflow recycle, and leave the activated sludge system via sludge wastage. The mixed liquor organic suspended solids has historically been measured as a lumped parameter, as volatile suspended solids, or, more recently, via COD determinations. However, only a fraction is active biomass, which has not been directly measured experimentally and compared to theoretical values.

The problem in measurement of this parameter has been the lack of suitable experimental techniques. In the literature, principally microbiological techniques have been proposed; for example, pour plate or other culturing techniques, ATP analysis, DNA analysis, using fluorescent probes for ribosomal RNA, and sequencing of ribosomal DNA. These techniques have not yet been adequately integrated with the design and kinetic modelling theory: The culturing techniques have been widely criticised for their unreliability; the RNA and the two DNA methods are still in their infancy, and the last-named four methods require sophisticated equipment and experimental techniques that are not widely available.

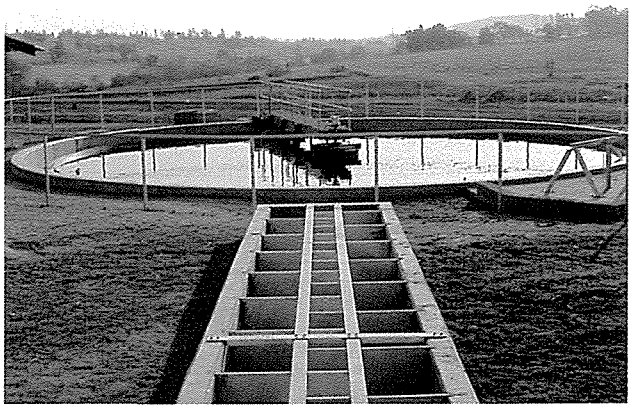
The specific aim in this proposal is to contribute towards developing a suitable method for determining the heterotrophic and autotrophic active biomass in activated sludge mixed liquor.

Estimated cost: *R88 000*
Expected term: *2000-2001*

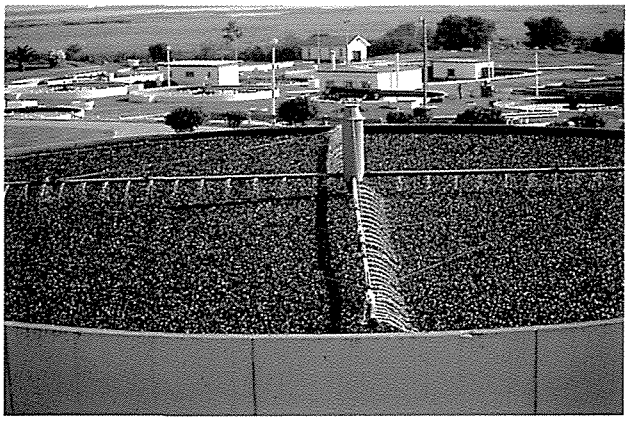
Research projects

Completed

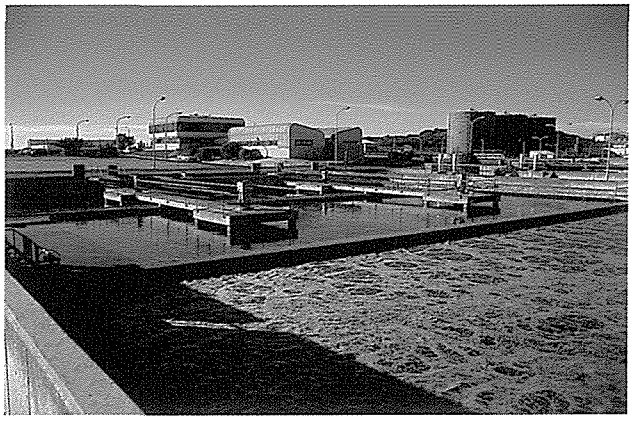
- **491** Pond-enhanced trickling filter operation (PETRO®) (Wates, Meiring and Barnard (CE) Inc. (now Meiring and Associates) and CSIR – Division of Water, Environment and Forestry Technology)
- **560** Development of a cross-flow microfiltration unit to improve the performance of anaerobic digesters at wastewater treatment works (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **620** Modelling, design and operation of secondary settling tanks (University of Cape Town – Department of Civil Engineering)
- **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 wastewater treatment processes (Technikon Natal – Department of Biotechnology)
- **933** Biolog application in microbial diversity studies of activated sludge (University of Pretoria – Department of Microbiology and Plant Pathology)



Secondary settling tank at Mitchell's Plain.



External nitrification with the aid of fixed media trickling filters (TF) to increase the capacity of biological nutrient removal (BNR) suspended medium activated sludge (AS) systems.



A biological nutrient removal activated sludge plant at Mitchell's Plain Wastewater Treatment Plant.

Current

- **248** Chemical augmentation of biological phosphate removal (Greater Johannesburg Metropolitan Council (GJMC))
- **462** Activated fixed and suspended cultures for nitrification (University of Pretoria – Department of Chemical 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)
- **606** The practical application of special waste co-disposal with municipal refuse at the Coastal Park landfill bioreactor (Cape Metropolitan Council)
- **668** Determination of dissolved organic loads in raw and other sewage waters and the determination of the relationship between COD and DOC (East Rand Water Care Company)
- **692** Treatment of wastewaters with high nutrient (N and P) but low organic (COD) content (University of Cape Town – Department of Civil Engineering)
- **713** Removal of algal and other biomass from treated wastewaters employing the PETRO® process (Wates, Meiring and Barnard (CE) Inc.)
- **739** Disinfection of purified effluent (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **775** Development of strategies for amelioration of bulking by anoxic-aerobic filamentous organisms in nutrient removal activated sludge systems (Stewart Scott (CE) Inc.)
- **799** Development and monitoring of integrated algal high-rate oxidation pond (AHROP) technology for low-cost treatment of sewage and industrial effluent (Rhodes University – Department of Biochemistry and Microbiology)
- **823** Full-scale demonstration of specific filamentous bulking control in a biological nutrient removal activated sludge plant at Mitchells Plain wastewater treatment plant (WWTP) (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))
- **929** Investigation into optimisation of high-rate biological filtration for wastewater treatment (Wates, Meiring and Barnard (CE) Inc. – Water Engineering Division)
- **934** Bio-augmentation of activated sludge for enhanced biological phosphorus removal (University of Pretoria – Department of Microbiology and Plant Pathology)
- **970** External nitrification with the aid of fixed media trickling filters (TF) to increase the capacity of biological nutrient removal (BNR) suspended medium activated sludge (AS) systems (University of Cape Town – Department of Civil Engineering)
- **971** Investigation into transforming the PETRO® process to provide for biological nutrient removal (PGJ Meiring Konsult)
- **1073** Extension of applications and optimisation of operational performance of algal integrated ponding system (AIPS) technology in appropriate low-cost treatment of industrial and domestic wastewaters (Rhodes University – Department of Biochemistry and Microbiology)
- **1075** Computational fluid dynamic support to water research projects (University of Natal – Pollution Research Group)
- **1076** Development of a novel reactor insert to upgrade anoxic reactors in biological nutrient removal wastewater treatment plants (CSIR – Division of Water, Environment and Forestry Technology)
- **1077** Use of life-cycle assessments in the selection of water treatment processes (University of Natal – Department of Chemical Engineering)

New

- **1074** Co-digestion of high strength/toxic organic effluents in anaerobic digesters at wastewater treatment works (University of Natal – Pollution Research Group, School of Chemical Engineering)
- **1169** Intermediate scale-up evaluation of the Rhodes Process for hydrolysis and solubilisation of sewage sludges in a sulphate-reducing bacterial system (Rhodes University – Department of Biochemistry and Microbiology)
- **1170** Enzymology of accelerated primary sewage sludge solubilisation and digestion in sulphate-reducing systems (Rhodes University – Department of Biochemistry and Microbiology)
- **1178** Determination of heterotrophic active bacteria in activated sludge using novel molecular techniques (Technikon Natal – Centre for Water and Wastewater Research)
- **1179** Measurement of heterotrophic and autotrophic organism active biomass in biological nutrient removal activated sludge systems (University of Cape Town – Department of Civil Engineering)
- **1191** Microbial characterisation of activated sludge mixed liquor suspended solids(University of Pretoria – Department of Microbiology and Plant Pathology)

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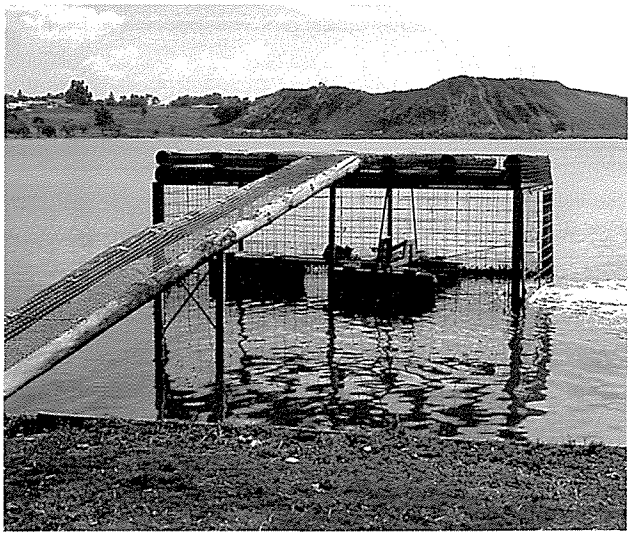
8 Water quality management

In terms of our constitution, the state has an obligation to promote an environment which supports the health and well-being of the people of South Africa. Access to water of an acceptable quality ranks high on the list of needs in this regard, while the protection of the water resource against water quality degradation and the provision of water of suitable quality to users, form corner-stones of our National Water Act.



Aspirator in Jan Smuts Lake near Johannesburg.

Impaired water quality impacts negatively on practically all water users. It is unfortunate that most water users, in turn, also impact negatively on water quality, with the result that a deterioration in quality is commonly observed after every cycle. This is the case not only for the use of abstracted water by e.g. industry and households, but also for uses on land such as by rain-fed farming or informal settlements, which cause contamination of runoff water. As water resources become more fully utilised and the surplus dilution capacity diminishes, the effects are usually manifested as water quality degradation. If left unchecked, water quality deterioration will proceed until a stage is reached when the water is no longer suitable for use.

Since South Africa is a water-scarce country with limited capacity to employ dilution as a means of managing water quality, it may, in future, be more difficult to provide users with water of an acceptable quality than providing them with the quantity that they require. For this reason, water quality managers are applying a hierarchical approach to water quality management: The first priority being pollution prevention, followed by treatment of polluted water before the practices of beneficial reuse and release into the water environment are considered.

Recognition of the problems that we share with other countries and the need to develop solutions which are adapted or designed in a unique manner for our particular situation, have over the years been the guiding principles of the WRC's research activities in support of water quality management. Poor water quality is manifested in a range of specific problems. Projects which address problems in the field of salinity, eutrophication and other water quality studies are being funded 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 by consumers or the link to salinity remains unrecognised. Salinisation is the result of the addition of a variety of salts to the water environment, an almost inevitable result of 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. A major study to develop a methodology for quantifying these costs for users in the Lower Vaal River was completed during the past year.

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 the economics of water purification and defacement of the water environment are associated with eutrophication, while certain algae also excrete toxins. In order to facilitate future research, a review and discussion document dealing with eutrophication problems was prepared recently.

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 e.g. agrochemicals, non-point sources and the use of biological indicators to identify water quality problems.

Completed projects

Management of urban impoundments

(No 633) Johannesburg Municipality and Stewart Scott Inc.

Results pertaining to the objectives were reported in an interim report, published as WRC Report No TT 77/96 entitled: *The Management of Urban Impoundments in South Africa,* **Volume I,** *Status Quo Report*. The purpose of **Volume II**, entitled: *The Management of Urban Impoundments in South Africa: Guideline Manual* (TT 119/00) is to assist those responsible for, or with an interest in, the management of water quality of urban impoundments.

The user groups identified are local authorities, developers, planners, design engineers, community-based and non-governmental organisations, academics, consultants and recreational users of urban impoundments, as well as individuals who may reside close to

or within the catchment of an impoundment.

The cause and effect relationship of water quality problems has been conceptualised in the manual via an explanation of the waste cycle in water and placed within the context of integrated catchment management.

A range of management techniques is described in order to address the common water quality problems experienced in South African urban impoundments.

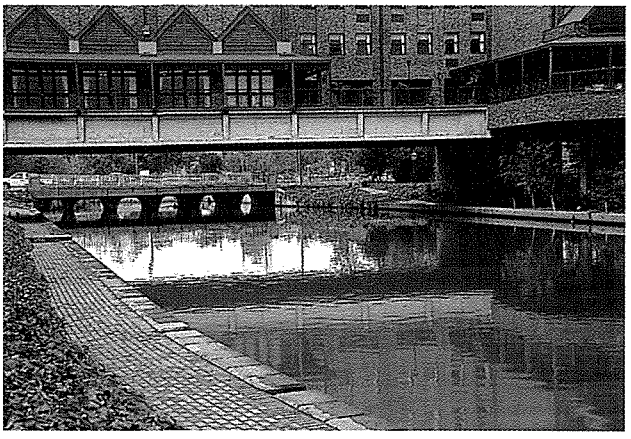
A framework for managing the impoundments examines the planning and design of the impoundment and guides the user through management techniques to address the water quality problems within the categories of catchment, pre-impoundment and in-lake management. The manual leads the impoundment manager through the processes of data collection, water quality monitoring and data assessment in order to be able to identify the type, nature and severity of the water quality problem that is experienced. Furthermore, the manager will also be able to evaluate the success of the management strategies which have been put in place.

Cost: *R617 166*
Term: *1994-1999*

Quantifying the impact of salinisation on South Africa's water resources with special reference to economic effects

(No 634) Urban Econ

As the salt content of water increases, the water becomes less suitable for most users, and additional costs are incurred. The first serious attempt in South Africa to quantify these costs was carried out as a desk study for the Vaal River by a WRC specialist consultant and published in 1987 in the so-called Heynike Report. The present study was undertaken because of uncertainties about some of the methodology and assumptions that were used in the desk study and the need for a versatile economic model that can be used to quantify the effect of salinity in monetary terms and to compare the cost-benefit ratios of alternative options. A generic methodology to determine the financial, economic and social impacts associated with an increase in salt concentration was first developed, and then applied by conducting a survey to determine the impacts of increased salt concentrations in the middle Vaal River. Conceptual formulae were developed to describe the behaviour of different sectors in the economy, viz. households, agriculture, mining, industry and services. (Background research indicated that feeder systems and the natural environment would not incur significant additional costs within the studied range of 200 to 1 200 mg/*l* TDS). An increase of 100 mg/*l* from 500 mg/*l* to 600 mg/*l* is anticipated to effect a R26 million increase in annual direct costs in the study area – approximately 85% of which would be borne by the household sector. Ratios of the indirect and induced costs to the direct costs, ranged from 1 to about 3.3.



Urban impoundments require management to ensure a safe environment.

Cost: *WRC* *R707 954*
DWAF *R860 760 (incl. VAT)*
Term: *1995-1998*

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

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

Internationally there is considerable concern about the contamination of water supplies by pesticides. In spite of a marked increase in the expenditure on and the variety of locally used agri-chemicals, there is a paucity of local research to date. The analytical capacity to determine very low levels of selected pesticides was developed at the Peninsula Technikon as part of this study. A significant spread of detections was made throughout all three areas selected for the study. Only a few of these would be cause for concern when judged by World Health Organisation standards. However, if the stricter European Union standards are used, many more detections would give rise for concern. A number of sampling points where water is used for drinking were consistently contaminated. The levels were, however, so low that they generally represented less than 1% of the acceptable daily intake. A striking and encouraging feature which emerged from farm surveys, was the relatively high level of concern of the health hazards associated with pesticides demonstrated by both farm workers and employers.

Cost: *R591 000*
Term: *1997-2000*

Selection of procedures for faecal pollution monitoring to describe health risks

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

Results of the study, related to the objectives, were:

Objective 1: To select areas that might present a high human health risk due to faecal pollution in South Africa.

This was done by screening all catchments and selecting those potentially at risk of incurring high faecal pollution. Areas with high pollution were then prioritised using data from the DWAF Water Supply and Sanitation Database and information obtained via personal communication.

Objective 2: To initiate monitoring on a pilot scale.

The pilot-scale microbial monitoring included sampling sites in rural and urban areas. Rand Water and Umgeni Water were involved during this process. The monitoring was done for a year. Thereafter, optimal sampling frequency was determined by statistical methods. Methods of data collection and transfer were also investigated.

Objective 3: To recommend procedures on a national-scale monitoring programme in the form of an implementation manual.

A draft *National Monitoring Implementation Manual* incorporating recommendations regarding data sheets and procedures was compiled and then used and tested in a follow-up consultancy project entitled: **Creating the infrastructure required to commence with the National Microbial Monitoring Programme**.

The results of this test (in terms of the consultancy, to be reported on in detail elsewhere) indicated that only minor changes were needed to the *Implementation Manual*. Consequently, the final document will be used in the implementation phase (Follow-up project, No 1118: **Pilot study to demonstrate implementation of the National Microbial Monitoring Programme**; see **Chapter 6** for details).

Cost: *R446 137*
Term: *1997-1999*

Water quality modelling of eutrophied reservoirs in South Africa

(No K8/105) University of Cape Town – Department of Civil Engineering

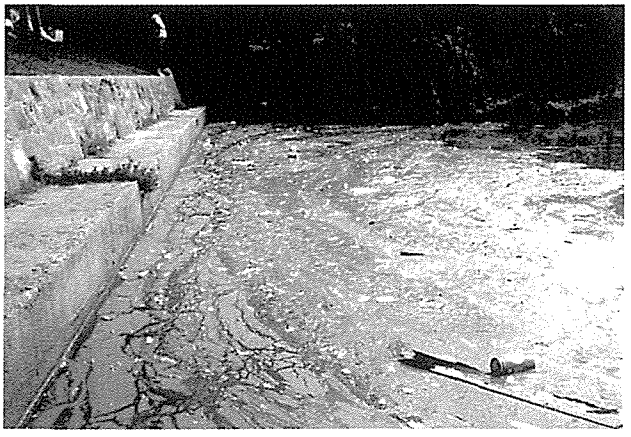
The water quality patterns in reservoirs are the result of complex interactions between several processes and driving forces. During a WRC-funded assessment of the applicability of existing hydrodynamic reservoir models for water quality management of stratified water bodies in South Africa, it was found to be necessary to modify the MINLAKE-model (developed in the USA) to reflect better the mechanisms operating under South Africa's warmer climatic conditions. Because one of the objectives of MINLAKE was to model algal succession, this consultancy project was undertaken to effect these changes and to test the modified model. The main extension to the original model was to take cognisance of the aerobic/anaerobic state of the water on various process rates, to consider the effect of temperature on process rates, and to incorporate the process of denitrification. The modified model simulated the water quality behaviour of both Roodeplaat Dam and Lake Riley in the USA (cool temperature climate) remarkably well during the test periods, and is thus expected to be valid over a wide climatic range. It is predicted that the modified MINLAKE model will assist in the pre-evaluation of the effectiveness of the treatment options aimed at changing algal dominance from unwanted blue-green to more desirable green algae.

Cost: *R39 000*
Term: *1990-1999*

Development of a framework for a research programme on eutrophication in South Africa

(No 360) Mzuri Consultants

Eutrophication remains one of the major water quality problems of South Africa. There are a few water systems that have not been affected to some extent by the problem. The potential cost implications for treatment and loss of fitness are high. Although this subject received extensive attention in the past, it has been largely neglected during the 1990s. With the aim of developing a framework for future eutrophication-related research, the WRC commissioned a review and discussion document which, after further deliberations, should culminate in the identification of those priority research areas which require further support from a South African perspective. The report presents a broad overview of concepts on eutrophication, its consequences and control. Furthermore, it represents a scan of the eutrophication problems in countries where eutrophication is regarded as a high-priority water quality issue. The situation in South Africa is dealt with by taking account of national policy and legislation, and concludes that increased attention to the problem is necessary.



Eutrophication resulting in a thick layer of algal scum.

Cost: *R60 000*
Term: *1999-2000*

New projects

Cost-effective methods for monitoring pesticide pollution in water systems: Technologies and procedures for field use in rural areas

(No 1120) University of Cape Town – Dept of Community Health

There is emerging evidence that pesticide contamination of water at relatively low concentrations is an issue of concern, particularly related to the handling of pesticides in farming practice. Relatively little pesticide monitoring takes place in South Africa because of our limited capacity for consistent high-quality analyses, the associated high costs and the dependance of local communities on distant experts. As part of a recently completed WRC project (**An assessment of the quality of water supplies in the rural Western Cape**), new pesticide analytical expertise was developed at the Peninsula Technikon. Whereas previous WRC research projects failed to detect traces of pesticides in drainage water from agricultural land, the recently-acquired expertise was sufficiently sensitive and consistent to detect small quantities of primary and breakdown products on a regular basis.

The present project will:

- Evaluate two promising new technologies that could reduce the costs and obviate the obstacles as far as the analyses for pesticides in water are concerned.
- Use these results to develop monitoring guidelines for stakeholder groups.
- *Identify the training, technical support and other needs that* should be addressed to enable these stakeholder groups to implement such monitoring.

Estimated cost: *R500 000*
Expected term: *2000-2001*

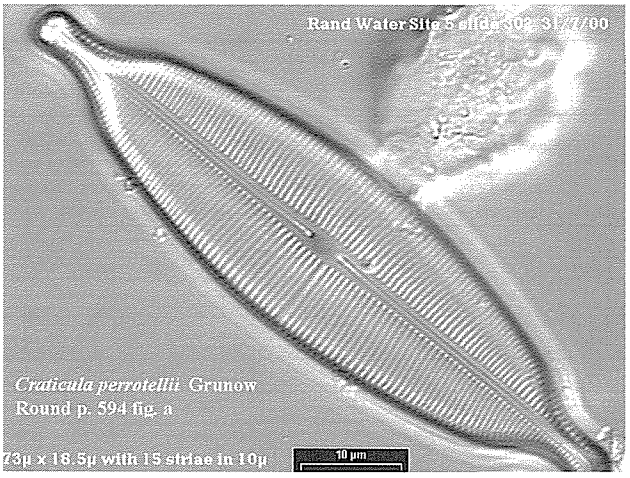
Integrated approach to biomonitoring of wastewater for the presence of biologically active agents

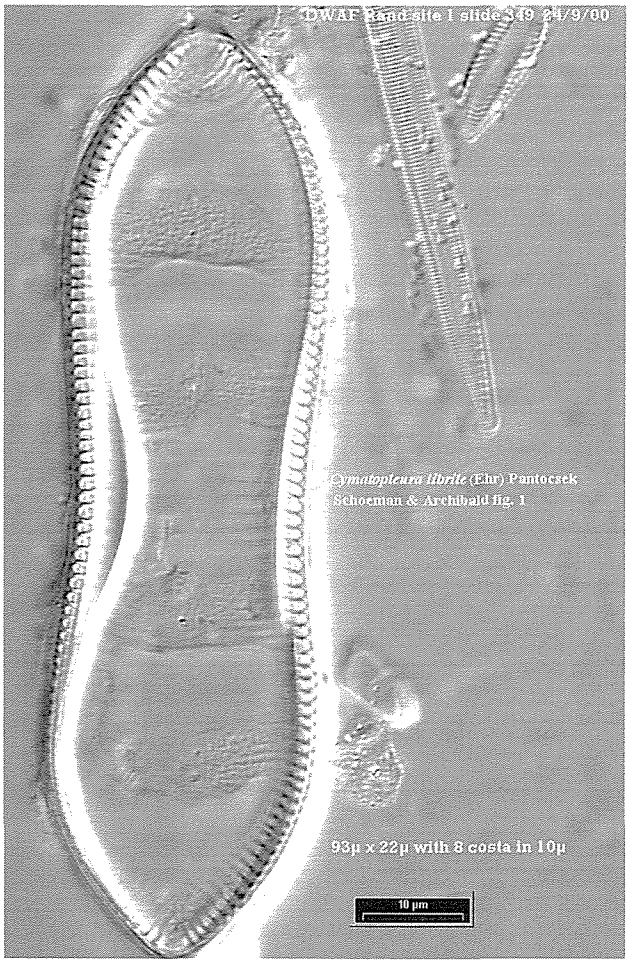
(No 1121) Highveld Biological Association

Information about water quality in South Africa is currently based largely upon routine chemical and microbiological analyses and specific research projects. There is a need for the ongoing biomonitoring of water and effluent quality which can be correlated immediately with previous information.

The work proposed in this project follows from a previous WRC-funded project where a colorimetric test was developed using mammalian tissue cell culture in a multi-well plate. The test is very sensitive to low levels of stressors, is quick (<24 hours) and, in combination with a concentration technique developed during the

previous project, can detect levels of heavy metals and certain organics at below guideline levels. The present project focuses on testing the technique on water from various sources, co-operating with various water-use agencies and developing software that will perform the necessary calculations automatically. At the moment these are done manually. Automation of the calculations will make it possible for a single-plate scanning unit to process a large number of samples daily, and will reduce the estimated cost per sample from approximately R50 to an estimated R20 to R30.





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

The aim of the project is to develop standardised low-cost methods for quantifying water quality in terms of its impact on human health. The methodologies will cover both chemical and biological agents, known and unknown. The order of priority for samples to be tested is:

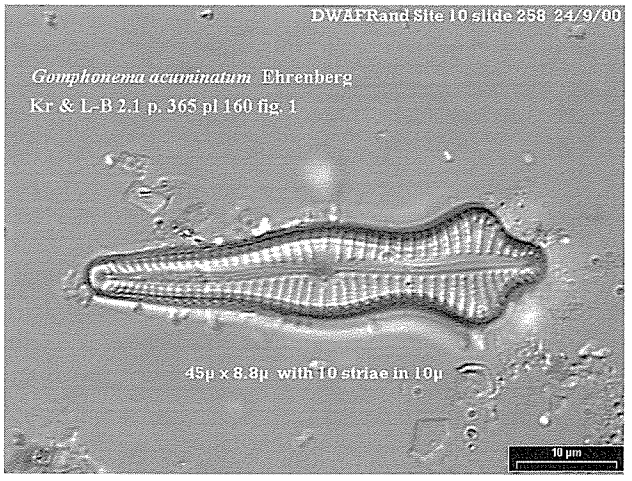
- Effluent water (drains, sewers)
- Source water (rivers, dams, boreholes)
- Water for human consumption (piped water).

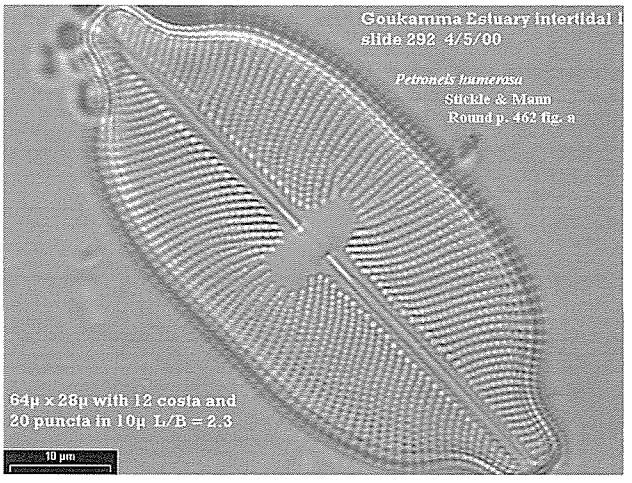
Estimated cost: *R252 000*
Expected term: *2000-2001*

Design and development of an implementation plan for a national eutrophication monitoring programme for South Africa's water resources

(No 1147) CSIR – Division of Water, Environment and Forestry Technology

Since the 1970s, DWAF and a number of organisations have been monitoring water quality in surface waters. In many cases, data have been collected which can and have been used to characterise the eutrophication status of individual river and reservoir systems. To date, there has not been a legal requirement to assess the eutrophication status at a national level, or to co-ordinate data collection, storage and reporting. However, as part of the new National Water Act, DWAF is required to establish national monitoring networks to collect relevant information on the quality of water resources. It also requires the Minister to provide guidelines, procedures, standards and methods for monitoring. Furthermore, it requires the data to be





stored in a National Information System, where they can be used for the development and implementation of the National Water Resource Strategy and Catchment Management Strategies.

This project is aimed at providing the required technical and scientific support to design and implement a National Eutrophication Monitoring Programme. It will dovetail with other networks, such as the National Rivers and Reservoir Water Quality Monitoring Network, the National Microbiological Monitoring Programme and the National River Health Programme.

Estimated cost: *R724 000*
Expected term: *2000-2001*

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- **Dr SA Mitchell** (Biomonitoring)
  e-mail: steve@wrc.org.za

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Research projects

Completed

- **633** Management of urban impoundments (Johannesburg Municipality and Stewart Scott (CE) Inc.)
- **634** Quantifying the impact of salinisation on South Africa's water resources with special reference to economic effects (Urban-Econ)
- **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)
- **824** Selection of procedures for faecal pollution monitoring to describe health risks (CSIR – Division of Water, Environment and Forestry Technology)
- **K8/105** Water quality modelling of eutrophied reservoirs in South Africa (University of Cape Town – Department of Civil Engineering)
- **K8/360** Development of a framework for a research programme on eutrophication in South Africa (Mzuri Consultants)

Current

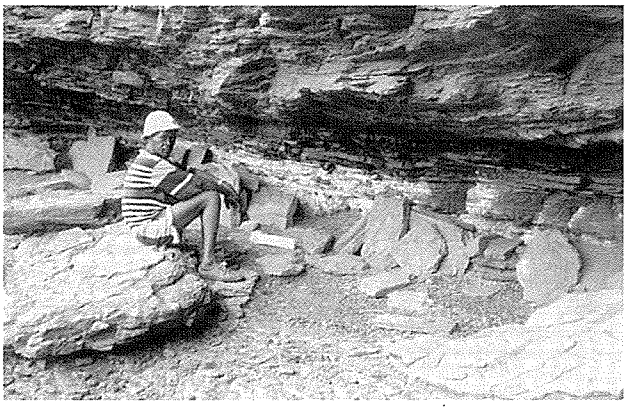
- **266** Extension of the management orientated models for eutrophication control (CSIR – Division of Water, Environment and Forest Technology)
- **369** Completion of research relating to the Disa model- A daily irrigation and salinity analysis system model (Ninham Shand (Cape) Ing.)
- **465** Detergent phosphorus in South Africa: Impact on eutrophication with specific reference to the Umgeni catchment (University of Natal – Department of Chemical Engineering and Umgeni Water)
- **522** A 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)
- **696** Development of a guide to assess non-point source pollution of surface water resources in South Africa (Sigma Beta) (CE) Inc. and 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.)
- **784** Rapid quantitative evaluation of water quality using a modified biological test: Phase 2 (University of the Witwatersrand – Department of Microbiology)
- **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)
- **950** WQ90: Development of an interactive surface water quality information and evaluation system for South Africa (Stewart Scott (CE) Inc.)
- **951** Water quality information systems for integrated water resource management: The Riviersonderend-Berg River system (University of Stellenbosch – Department of Civil Engineering and Department of Soil and Agricultural Water Science)
- **952** Biomarker assays for the detection of chronic toxicity in the aquatic environment (CSIR – Division of Water, Environment and Forestry Technology)
- **999** Evaluation of predictive models for pesticide behaviour in South African soils (Agricultural Research Council – Plant Protection Research Institute)

New

- **1120** Cost-effective methods for monitoring pesticide pollution in water systems: Technologies and procedures for field use in rural areas (University of Cape Town – Department of Community Health)
- **1121** Integrated approach to biomonitoring of wastewater for the presence of biologically active agents (Highveld Biological Association)
- **1147** Design and development of an implementation plan for a national eutrophication monitoring programme for South Africas water resources (CSIR – Division of Water, Environment and Forestry Technology)

9 Groundwater

At the beginning of 2000 the Co-ordinating Committee for Geohydrological Research (CCGR) was reconstituted. This was necessary to secure added expertise and new experience. The role of the CCGR is to assist in closing the knowledge gap which affects the sustainable use of groundwater resources; to guide the transfer of information and technology; to develop young (and new) researchers; to promote capacity-building initiatives, and to advocate trans-discipline (and programme) interaction.



Pure potassium nitrate (saltpetre) occurring naturally near Marydale in the Northern Cape, resulting in possible high concentrations of nitrate in groundwater. (Photograph courtesy of Gideon Tredoux, CSIR, Stellenbosch).

The first task of the CCGR was to assist in the development of a new 5-year strategic plan. The plan was based on the premise that, in order to find solutions to real-world problems, a collaborative framework is required. This means breaking down traditional disciplinary boundaries, designing research to support both integrated management and policy-making, and communicating research output in an appropriate manner. This will require scientists and other professionals from different disciplines to work together towards a common goal. After acknowledging these challenges, a vision for groundwater research was established:

"The realisation, through excellence in research, of the full potential of groundwater in contributing to equitable and sustainable development in Southern Africa"

New goals for the groundwater research field were developed, based on identified driving forces, such as alleviation of poverty and promotion of quality of life. The following goals (problem areas) for groundwater research, to be implemented over a 5-year time frame, were to:

- Refocus groundwater characterisation towards integrated water resource management in line with national needs and priorities.
- Manage groundwater quality with emphasis on the prevention of contamination/pollution.
- Support research that develops appropriate professional, institutional and management practices in order to achieve integrated water resource management.
- Encourage innovative and imaginative research (lateral thinking) with the potential to contribute to meeting the identified vision of groundwater research.

During the course of 2000, two international experts were invited to review research programmes in the groundwater research field. Dr T Hatton of the CSIRO in Australia reviewed the research programme on the **"Comprehensive Determination of the Groundwater Component of the Reserve"**. This programme supports the National Water Act of 1998. Dr M J Hendry from the University of Saskatchewan in Canada was invited to review the research programme on **"Groundwater Quality and Protection"**. The purpose of such interaction was to assess the research programmes and intended outputs; give an international perspective; provide guidance and input in terms of future research areas requiring focus; and establish links among researchers in various countries.

A number of workshops were held during the year. These included sessions designed to integrate the component projects of the groundwater reserve programme and to facilitate the implementation of recommendations made by Dr T Hatton. A workshop to identify research needs and priorities in order to protect groundwater from pollution was held in Cape Town.

Completed projects

Relationship between the geotechnical and hydrogeological properties of residual soils and rocks in the vadose zone

(No 701) University of Pretoria – Department of Earth Sciences

Residual soils and rocks, which, in most cases, constitute a major portion of the unsaturated zone overlying an aquifer, form the first line of natural defence against pollutants arising from, for example,

on-site sanitation systems and the application of agricultural chemicals to the surface of the earth. A wealth of data on the physical properties of residual soils and rocks has been generated through geotechnical investigations and engineering geological mapping. Correlation of these data with hydrogeological properties that affect aquifer contamination and recharge will add considerable value to existing land type and geological databases. These will, in turn, facilitate the preparation of groundwater vulnerability maps to aid the sustainable development of our groundwater resources.

Five extensive field experiments were conducted in order to determine the characteristics of residual soils. These studies, combined with literature studies, enabled the description of water flow through soil. During the course of the research, four aspects regarding flow through the vadose zone have been identified as being important factors to be considered in groundwater recharge and vulnerability studies. These are:

- Identification and quantification of unsaturated flow through the soil matrix.
- Identification and quantification of preferential flow occurring in the vadose zone and contributing to groundwater recharge.
- The character and spatial distribution of hydrogeological units within a specific area.
- Methods in delineation and quantification of the variability of soil properties of each unique hydrogeological unit.

Identification of different flow regions in the soil profile and hydrogeological properties is important in understanding recharge mechanisms, contaminant routes and attenuation mechanisms. The project also identified sources of information which are crucial sources of data for practitioners.

Cost: *R220 000*
Term: *1995-1999*

Chlorofluorocarbons (CFCs) and groundwater age-dating in South Africa's fractured-rock aquifers

(No 731) CSIR – Division of Water, Environment and Forestry Technology

The chlorofluorocarbon gases CFC-11, CFC-12 and CFC-13 were developed during the 1930s. The known growth rates of atmospheric CFCs, the rapid mixing world-wide, their solubility in water and their good chemical stability have enabled CFCs to become a useful tool for hydrologists to trace water movement in the oceans, in surface water and in groundwater. The method was considered to hold great promise as a valuable tool for the hydrogeologist, in using dissolved CFC gases as groundwater age-dating tools for groundwater younger than 50 years of age.

Three case-study sites were used to test the CFC method of age dating in the South African fractured-rock environment. The Agter-Witzenberg and Klein Karoo Rural Water Supply Schemes both located in the Table Mountain Group quartzites, and the Dewetsdorp aquifer which is located in Karoo sandstones were the test sites. The use of CFCs has been demonstrated successfully in the environments investigated. By using CFCs, the mixing of young and old waters could be shown, including information on groundwater flow patterns. Because of the mixing of groundwater of various ages, the CFC results produced recharge dates of 1960/70, but carbon-14 isotope analysis recorded ages of 1 000 years and older. Thus, the application of this method in fractured-rock environments requires further investigation. In the South African context, the method was tested, but still needs to be proven.

The quick response of CFC in young and rapid-flowing recharge water was seen in the TMG quartzites at Agter-Witzenberg. The CFC recharge dates were consistent within the ranges given by likely modelling parameters and other isotopes. Much more episodic recharge was indicated in the Dewetsdorp Karoo sandstone where CFC data indicated recharge during a few single high rainfall years and delays within the aquifer. However, to translate CFC concentrations into ages based on simple calculations is not feasible. Age determination requires an understanding of the mixing ratios of older and younger waters.

Cost: *R200 000*
Term: *1996-1997*

Critical evaluation of groundwater monitoring in water resource evaluation and management

(No 838) Water Resources Evaluation and Management cc

A major component of the study has been the validation of the integrity of groundwater level observations and the extension of limited data series by means of rainfall records, employing the cumulative rainfall departure (CRD) method. This is because the cumulative departures of rainfall from the average rainfall have been shown to match groundwater level fluctuations fairly well and to mimic the hydrogeological balance of an aquifer based on the rainfall occurring in an area. The CRD method represents a useful hydrologic model of the groundwater balance and the response of water levels to recharge. Consequently, the impact of abstraction can be determined.

The study has provided further insights and perspectives concerning groundwater monitoring activities and the value of reliable long-term measurements. The CRD and moving average (MA) rainfall methods were used to determine the response of water levels in mostly dolomitic aquifers in order to determine aquifer characteristics. Most monitoring records either cover a short period, are intermittent or could contain unreliable data. It is, therefore, important to be able to fill gaps in a record and to extend it back and forth in time. Because the technique facilitates extrapolation of time-series data, it provides for a "check" on monitoring data. Thus, it allows for an assessment of the reliability of data gathered during monitoring programmes. Aquifer parameters were obtained using the CRD and MA series and the groundwater level series. However, the estimation of reliable storativity values remains difficult and requires a process of iteration.

Cost: *R194 000*
Term: *1997-1999*

New projects

Guidelines for aquifer parameter estimation with computer models

(No 1114) University of the Free State – Institute for Groundwater Studies

The estimation of aquifer parameters in fractured rock domains is problematic because 3-dimensional groundwater flow needs to be considered. Conventional analytical solutions to estimate aquifer parameters such as the Theis or Jacob-Cooper methods are not suitable for use in fractured-rock environments. This is because the drawdown due to pumping is affected by several hydrogeological parameters, including:

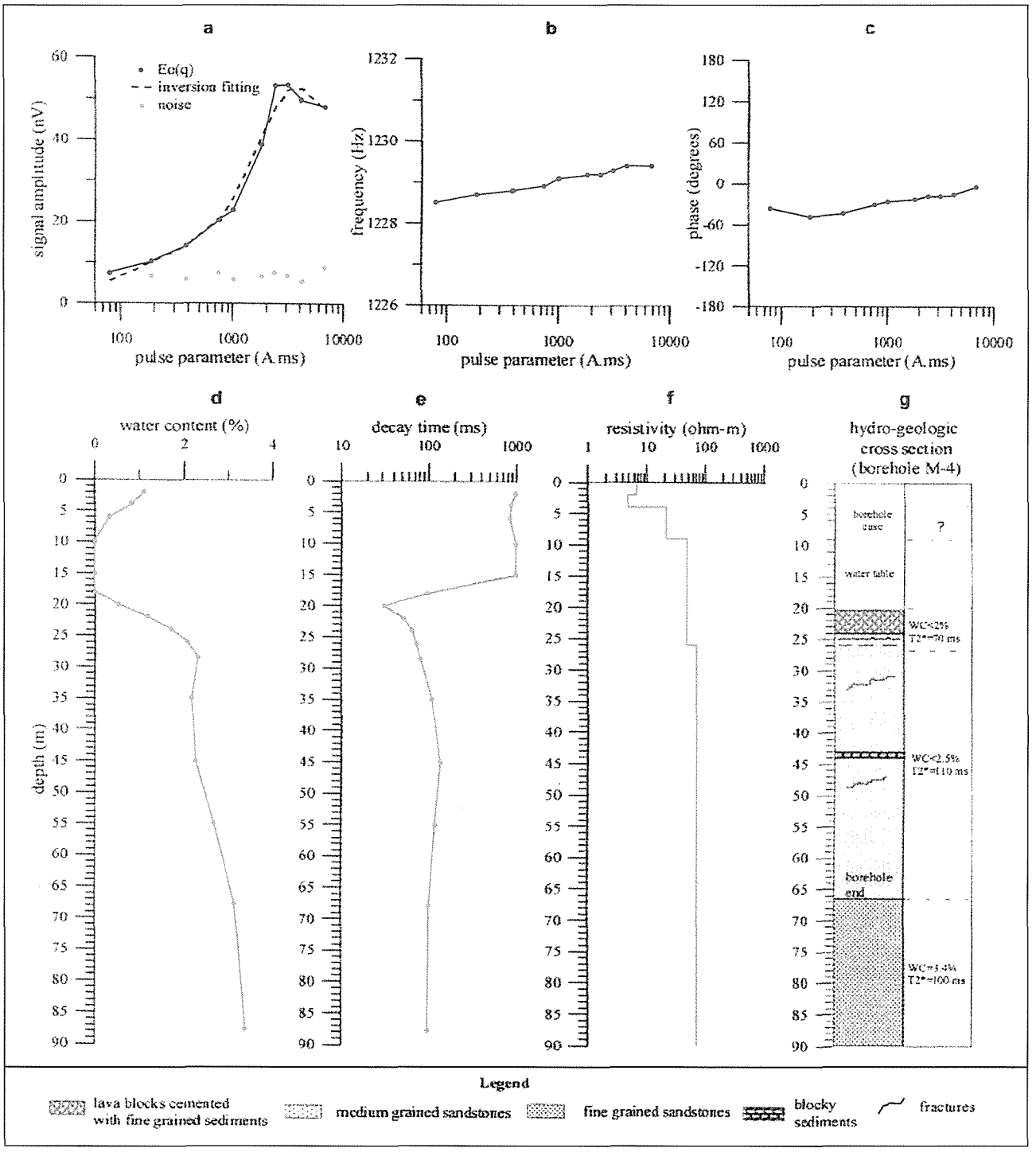
1. The horizontal hydraulic conductivity of the matrix.
2. The vertical hydraulic conductivity of the matrix.
3. The specific storage coefficient of the matrix.
4. The horizontal hydraulic conductivity of the fracture.
5. The vertical hydraulic conductivity of the fracture.
6. The specific storage coefficient of the fracture.

The conventional methods can only provide an estimate of the transmissivity (a mixture of points 1, 2, 4 and 5) and storage coefficient (a mixture of points 3, 6 and aquifer thickness). Thus, to estimate these parameters separately will require a more sophisticated method. The estimation of these separate parameters is vital in using groundwater models to address practical issues such as contaminant transport to and within aquifers.

This project proposes to use numerical groundwater models and inverse modelling techniques to solve the problem of aquifer parameter estimation. This is necessary because a good estimation of the aquifer parameters is the basis for successful groundwater management.

The research proposed here aims to:

- Provide guidelines for estimating aquifer parameters, which are essential for:
  - Determining the degree and potential of groundwater contamination
  - Sustainable use and management of groundwater resources



An interpreted magnetic resonance sounding curve measured near Settlers, Northern Province, on a fractured basal/sandstone aquifer. It is the first time that this technique has been used in South Africa and, when fully developed, promises to provide important information for aquifer evaluation purposes in future.

- Provide pre-built groundwater models for different scenarios to facilitate the use of the parameter-estimation guidelines.
- Provide a better understanding of aquifer parameters, especially of the Karoo aquifers.

Estimated cost: *R200 000*
Expected term: *2000*

Impact of groundwater abstraction on ecosystems in the Kammanassie Nature Reserve and environs

(No 1115) Technikon of South Africa – Department of Applied Natural Sciences

The Vermaaks River well-field established in the Kammanassie Mountain range to the east of Oudtshoorn supplies water to the Klein Karoo Rural Water Supply Scheme. The scheme provides the largest groundwater supply from a fractured-rock aquifer source in South Africa.

A current study which aims to model the groundwater flow in the Vermaaks River well-field is contributing to our understanding of the hydrogeological conditions at the study site. However, a cause for concern is the effects that high abstraction rates may have on the ecology of the area. This project will advance our current understanding of the interaction between groundwater and the environment, which means that the project can also contribute significantly to establishing methodologies to determine the "Reserve", as required by the National Water Act. The experience gained here can be extrapolated to areas with similar vegetation and environment, where groundwater is either abstracted, or where abstraction is planned.

The Vermaaks River well-field represents an ideal site for an investigation of this nature, because it is the priority augmentation option for water supply to the Klein Karoo Rural Water Supply Scheme. This provides an opportunity to measure environmental impacts under controlled but increased abstraction conditions from the well-field. The involvement of Cape Nature Conservation, DWAF, Technikon RSA and the University of Pretoria provides an excellent project complement, consisting of conservation practitioners, groundwater resource planners/managers and academics.

This project aims to determine the impact of groundwater abstraction on:

- Riparian vegetation
- Terrestrial vegetation
- Springs
- Aquatic ecosystems
- Cape mountain zebra and other fauna.

The case study will have immediate application in the management of groundwater resources in the region, which supports a groundwater-dependent human community and ecosystem.

Estimated cost: *R200 000*
Expected term: *2000-2001*

Manual on pumping test analysis in fractured-rock aquifers

(No 1116) University of the Free State – Institute for Groundwater Studies

The flow characteristic (FC) method has been developed for the analysis of pumping tests in fractured-rock aquifers. This was because experience in SA had shown that the fractured-flow behaviour observed during pumping tests could not be satisfactorily simulated with standard methods, which use porous flow equations.

The methodology includes the following important features:

- Use of constant-rate pumping test data to estimate risk-based "sustainable" abstraction rates for a borehole by using drawdown derivatives, boundary information and error propagation.
- Characterisation of flow regimes in fractured-rock aquifers (i.e. well-bore storage, linear, bi-linear and radial flow).

Usually the duration of a constant-rate test is between 1 and 3 days. To be cost-effective, an optimal abstraction rate must be found to permit the use of a shorter duration, higher pumping-rate test which would yield the same results as a lower pumping-rate test. The FC-method makes it possible to determine an optimal pumping rate and duration, thereby resulting in considerable cost savings.

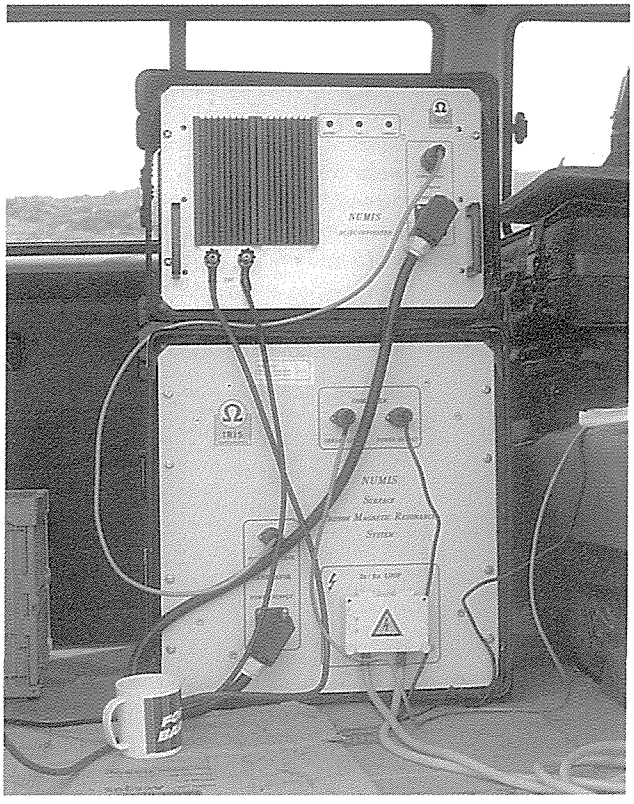
There is a critical need for a step-by-step manual on how to perform and analyse pumping tests in the fractured SA aquifers, preferably using a suitably modified FC method. The basic FC program needs to be enhanced to:

- Include step drawdown and multi-rate analyses into the program.
- Delineate borehole protection zones from early pumping test data.
- Make the current FC-workbook menu-driven.

The development of a manual and software in user-friendly format will contribute to cost-effective groundwater development, and thereby also to sustainable rural livelihoods. Therefore, the project aims to:

- Produce a step-by-step manual on how to conduct and evaluate pumping tests in fractured-rock aquifers.
- Enable optimal choice of the length of a constant-rate test.
- Enable the use of pumping test data to delineate borehole protection zones.
- Enhance the current FC-EXCEL program.

Estimated cost: *R195 000*
Expected term: *2000*



Part of the equipment used to obtain a magnetic resonance sounding.

Importance of groundwater in the hydrological cycle and the relationship to surface water bodies

(No 1168) University of Zululand – Department of Hydrology

By understanding the concept of groundwater, one realises that surface water interactions are becoming increasingly more important for protecting the integrity of groundwater – surface water related ecosystems. In some situations, aquifers are fed from surface water bodies (influent), while in other locations groundwater feeds streams, rivers and lakes (effluent).

The National Water Act (Act 36 of 1998) requires that a "Reserve" be set for basic human needs and to protect aquatic ecosystems in order to secure sustainable development and use of the relevant water resource. To sustain functionality of an aquatic ecosystem, instream flow requirements (IFRs) must be set. The IFRs, described in terms of maintenance, drought flow and floods, are transformed into time-series, which can be compared with natural historic flow series. The important role of groundwater in sustaining the functions of wetlands has also been recognised.

Various scales of groundwater flow have been identified, i.e. continental/regional flow, intermediate flow and local flow. In local flow pathways, groundwater flows nearer the surface and resides within the flow path for a shorter duration of time, relative to the other flow paths. This pathway is most susceptible to land-use changes and is most likely to be impacted by human activities. In some situations, river seepage (losses to the aquifer) may be affected by groundwater pumping and natural variations in aquifer water level. Conversely, events that cause the aquifer water level to rise (recharge events) will result in a decrease in river seepage. When aquifer water levels rise above the level of the river, a previously losing river reach will now become a reach gaining water from the aquifer. It is apparent that the groundwater-surface water interface provides a number of ecologically important services such as chemical buffering/cleaning capacity, reduction of potential for floods (bank storage), formation and maintenance of habitat and maintenance of low flow (base flow).

It is imperative that our understanding of the interaction between groundwater and surface water bodies be developed further. The aims of the project are therefore to:

- Develop conceptual models of typical conditions (or scenarios) for groundwater-surface water processes in South Africa.
- Establish compatible methods of estimating time series of surface and groundwater flow rates for comparative analyses.
- Establish methodologies to quantify the surface water – groundwater interaction between riverine and aquifer systems.
- Develop monitoring systems to contribute to the measurement and interpretation of the groundwater – surface water interface.

Estimated cost: *R770 000*
Expected term: *2000-2002*

Research projects

Completed

- **701** Relationship between the geotechnical and hydrogeological properties of residual soils and rocks in the vadose zone (University of Pretoria – Department of Earth Sciences)
- **731** Chlorofluorocarbons (CFCs) and groundwater age-dating in South Africa's fractured-rock aquifers (CSIR – Division of Water, Environment and Forestry Technology)
- **838** Critical evaluation of groundwater monitoring in water resource evaluation and management (Water Resources Evaluation and Management cc)

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)
- **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)
- **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 Geohydrology and the Council for Geoscience)
- **676** Preparation of a monograph on South Africa's groundwater resources (JR Vegter)
- **702** Development of a Windows-based interpretation system for hydrogeologists (WISH) – (University of the Free State – Institute for Groundwater Studies and 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 (SRK (CE) Inc.)
- **732** Cost-effective development of groundwater in problematic terrain and low-potential areas: An 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 Free State – Institute for Groundwater Studies)
- **841** Assessment of ambient groundwater quality on a national scale in the Republic of South Africa (Hydromedia Solutions and DWAF)
- **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)
- **935** Evaluation of nuclear magnetic resonance (NMR) as a new geophysical technique for groundwater exploration in fractured rocks (CSIR – Division of Water, Environmentek and Forestry Technology)
- **936** Flow and transport characteristics of groundwater in Karoo formations – (University of the Free State – Institute for Groundwater Studies)
- **937** Influence of dolerite ring structures on the occurrence of groundwater in Karoo fractured aquifers: A morpho-techtonic approach (The Council for Geoscience)
- **966** Groundwater development for rural water supply in complex and problematic terrain: An assessment of geological controls, geophysical exploration methods and the quantification of exploitation potential (The Council for Geoscience)
- **967** Pilot artificial recharge schemes: Testing sustainable water resource development in secondary aquifers (CSIR – Water Quality Programme)
- **968** Amalgamation of munibase and WISH software into a user-friendly software package to be used by South African geohydrologists (University of the Free State – Institute for Groundwater Studies)
- **969** Decision tool for establishing a strategy for protecting groundwater resources: Data requirements, assessment and pollution risk (University of the Free State – Institute for Groundwater Studies)
- **1006** Enhancement of the WISH software package to meet current requirements of geohydrologists (University of the Free State – Institute for Groundwater Studies)
- **1007** Development of a Windows based interactive 3D visualisation computer program for geohydrological data (University of the Free State – Institute for Groundwater Studies)
- **1008** Protocols for assessing groundwater pollution impacts – formulation of a research strategy (CSIR – Division of Water, Environment and Forestry Technology)
- **1009** Evaluation of groundwater resources in fractured-rock aquifers at a catchment scale using evidence of mixing of groundwater from CFC and isotope data (CSIR – Division of Water, Environment and Forestry Technology)
- **1037** Hydrogeochemical evaluation of groundwater in fractured rock aquifers using trace elements and stable isotopes at Loxton Central Karoo (University of Stellenbosch – Department of Geology)
- **1058** Nitrate and associated groundwater hazard quantification and strategies for protecting rural water supplies (CSIR – Division of Water, Environment and Forestry Technology)
- **1090** Modelling decision-support system for the groundwater reserve (a component project of the research programme on the determination of the groundwater reserve) (University of the Free State – Institute for Groundwater Studies)
- **1091** Groundwater reserve: Delineation, reference conditions and classification (a component project of the research programme on the determination of the groundwater reserve) (CSIR – Division of Water, Environment and Forestry Technology)
- **1092** Classification of critical groundwater-dependant terrestrial ecosystems (a component project of the research programme on the determination of the groundwater reserve) (CSIR – Division of Water, Environment and Forestry Technology)
- **1093** Groundwater recharge to basement aquifers (A component project of the research programme on sustainable groundwater management and utilisation in the Northern Cape) (University of the Western Cape – Department of Earth Sciences)
- **1094** Fluoride in drinking water and its effects on human health and nutrition (A component project of the research programme on sustainable groundwater management and utilisation in the Northern Cape) (University of the Western Cape – Faculty of Dentistry)

New

- **1114** Guidelines for aquifer parameter estimation with computer models (University of the Free State – Institute for Groundwater Studies)
- **1115** Impact of groundwater abstraction on ecosystems in the Kammanassie Nature Reserve and environs (Technikon of South Africa – Department of Applied Natural Sciences)
- **1116** Manual on pumping test analysis in fractured-rock aquifers (University of the Free State – Institute for Groundwater Studies)
- **1168** Importance of groundwater in the hydrological cycle and the relationship to surface water bodies (University of Zululand – Department of Hydrology)

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10 Agricultural water management

It is widely accepted that poverty, hunger and malnutrition amongst rural people are major problems in South Africa. This is exacerbated by the spread of Aids. The urgency of a programme of action is emphasised by the current situation where at least 53% of rural households are living below the breadline.

The daunting challenge which must be faced becomes clear when it is realised that approximately 13 million individuals in rural areas are poor. At the same time, the members of rural communities are considered to be disadvantaged or marginalised for various social and political reasons.

Even with the most ambitious assumptions, simple analysis of the ratio of irrigation land to people shows that development prospects for subsistence irrigation farming calls for realism. It can only make a partial and largely subordinate contribution to poverty alleviation or reduction. What is required is a wide-ranging programme to develop agriculture, i.e. rangeland livestock, rainfed and irrigated cropping, and improving skills to earn non-farming income, through integrated rural and urban development.

Nonetheless, efficient use of water resources through rainfed or irrigated production of food crops can contribute to improved living standards. The challenge for experts who are currently active in research on agricultural water management is to work together with farmers to find acceptable solutions under real-life conditions. This involves addressing immediate needs, but also initiating an on-going process which creates an awareness for viable alternatives.

Accordingly, in 1998, the WRC initiated a research programme on **Sustainable Water-Based Agricultural Activities in Rural Communities** with the following objectives:

Firstly, enhancing the management capacity of resource-poor farmers.

Secondly, improving living conditions by moving out of a situation of survival to achieving food security and, eventually, producing surplus food.

Thirdly, promoting social change by the empowerment of rural people through:

- Training in literacy and numeracy
- Obtaining knowledge of farming
- Improving skills for different management practices (i.e. biological, technical and financial)
- Gaining access to water, land, finance and markets
- Alleviating or reducing poverty levels
- Improving individual leadership capabilities for local organisation and management of e.g. irrigation schemes.

These objectives directly support the recently-announced **Presidential Imperative Programme on Rural Development**. The goal of the Programme is to promote sustainable development and to improve the quality of life of marginalised groups and communities. The objectives are to alleviate poverty through enhanced production, productivity, creation of employment opportunities and a more equitable distribution of resources. Outputs which are envisaged include agricultural production systems and sustainable utilisation and management of natural resources and the environment.

Through participatory action research, the emphasis in the WRC-funded projects is a combination of three principal activities: research, education and action. This requires the involvement of people in the systematic assessment of specific problems; analysis and learning about the causes and possible solutions by a multi-disciplinary team of researchers together with participants; and implementing the findings practically. Planning and implementation of research projects of this nature are probably the most difficult of all, but progress is slowly being made. This is shown by the results of the completed research projects which are reported on this year and the aims of a number of new research projects.

Completed projects

Effect of exchangeable sodium percentage and clay mineralogy on the infiltration capacity of soils already sealed due to cyclic irrigation

(No 499) University of Potchefstroom for CHE – Department of Plant and Soil Science

The presence of seals or crusts at the soil surface often plays a dominant role in determining the volume of water which infiltrates into a soil before runoff starts to take place during irrigation applications. Earlier local and international investigations determined which factors control crust formation on recently cultivated (i.e. unsealed) soils. Little was, however, known about the effect that cyclic irrigation had on soils which have already been sealed by previous irrigations – as is evident in practice. This study found that the cumulative infiltration after a given period generally decreased from one irrigation phase to the next, and thus over an irrigation season. This decrease became more pronounced as the exchangeable sodium percentage (ESP) in soils increased, or the salinity of irrigation water decreased. Illitic soils were also more affected than kaolinitic soils. Because of their tendency to crack upon drying, the cumulative

infiltration of smectitic soils was least affected at low ESPs. However, at higher ESPs, the reduction in infiltration was more pronounced because of stronger dispersion. Regression equations were derived to relate the various effects to cumulative infiltration prior to runoff, and guidelines were proposed for irrigators to deal with the problem.

Cost: *R95 800*
Term: *1992-1995*

Evaluation of irrigation techniques used by subsistence and emergent farmers

(No 578) MBB (CE) Inc.

Small-scale irrigation farmers in South Africa can be categorised in terms of their water supply as farmers on irrigation schemes, vegetable gardeners (served by communal water supply infrastructures); and independent farmers, each with a "private" water supply. There are examples of very successful independent farmers and community garden operations despite the problems that must be overcome. Access to appropriate equipment and technical support is a major problem.

The initial objective of this project was essentially technical and the intention was to evaluate existing irrigation techniques and equipment used by small-scale farmers with a view to establishing design methods and norms that would facilitate the future planning and development of small-scale farmer irrigation projects.

When both designer and farmer have the same understanding of crop/irrigation relationships, significant improvements and savings can be achieved through design. There are ways of designing in order to promote simpler and more efficient irrigation management for the farmer. This is particularly important when small-scale farmer projects are being planned. These farmers face constraints that make non-standard irrigation management procedures more the rule than the exception and these should be addressed from the outset.

Short-furrow flood irrigation has been practised in South Africa for many years, but there has been a complete lack of theory to support rational design. The research done included field evaluations and computer simulations of the efficiency of distribution in the short furrows and losses in the earth-supply furrows. Guidelines for on-scheme water distribution design, including the layout of plots and secondary canals, have been compiled.

Analysis has shown that sprinkler irrigation can be surprisingly flexible, but that design for the specific circumstances encountered in small-scale farmer irrigation requires refinement and the application of basic principles. In time, a new set of "standards" may emerge, but designers need to be made aware of how to approach the present situation.

Field visits paid to small-farmer irrigation schemes and farms across South Africa afforded the project team an invaluable opportunity for observation and discussion. Evaluations of irrigation systems were carried out in the field during normal operation and the research team came to realise that the purely technical evaluation of irrigation systems as a basis for design norms is inadequate. It is essential to adopt a participatory "bottom up" approach to irrigation planning. However, technical aspects remain important. The successful development of small-scale farmer irrigation requires exceptionally high technical and organisational proficiency on the part of planners, designers and implementing agencies.

Cost: *R850 000*
Term: *1993-1995*

Emergent farmers using short-furrow irrigation for tomato production.

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

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

Two problem species of filamentous algae were identified. *Oedogonium capillare* occurred in the lower pH water in the canals of the Breede River System, and *Cladophora glomerata* occurred in alkaline waters elsewhere in the country.

A satisfactory method of monitoring the time and rate of algal invasion was developed during the project. This involved fastening plastic petri dishes to a board suspended in the canals in such a way that they could be detached for laboratory examination.

There were a number of cases of illegal control with copper sulphate, possibly by the farmers themselves, which made the recording of the growth of algae related to environmental conditions frustratingly difficult for the project team. However, it was established that *Cladophora* recruitment can occur throughout the year. During the project *Oedogonium* blooms were confined to only one part of the Breede River system. Control with copper sulphate is easier in this system as the water is naturally slightly acid to neutral, and does not need the pH to be lowered before treatment.

Laboratory culture of *Cladophora* is difficult, but a technique was developed which gave acceptable results. This allowed some laboratory work on basic growth requirements, as well as determining the relationship between copper uptake and environmental variables. This, in turn, enabled specific recommendations to be made regarding the use of copper sulphate in the control of the algae.

Cost: *R554 000*
Term: *1994-1998*

Start of the *Cladophora* growing season below Kalkfontein Dam in the south-west Free State.

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

(No 624) MBB (CE) Inc.

There has long been a need among irrigation planners and designers for an updated guide to the estimation of irrigation requirements of crops in South Africa. This project set out to complete and refine a computerised guide, the development of which had commenced in an earlier WRC-funded project with the intention of replacing the outdated existing guide which had been available in hard copy only.

The resulting computer program, SAPWAT, is a planning tool which enables irrigation planners and designers to obtain realistic estimates of irrigation requirements for a wide variety of crops in a wide range of production areas of South Africa. For the first time, practitioners are also able to rapidly explore the effects of various irrigation management practices on the irrigation requirements of crops. It is possible, for instance, to simulate the effects of crop type, wide-bed planting, inter-cropping, different irrigation methods and various soil management options such as deficit irrigation.

SAPWAT incorporates an extensive South African crop and climate database, while maintaining the flexibility of being able to accept "customised" input data whenever more appropriate data than those in the databases are available. Compatibility with FAO procedures such as those used in CROPWAT has been successfully maintained, while considerably extending the facilities offered by CROPWAT.

SAPWAT has been designed in a manner which will encourage discussion and interaction among users, namely irrigators and advisors. A comprehensive user-manual is built-in by means of the provision of "what-to-do" functions at every stage in the use of the program.

Cost: *R632 000*
Term: *1994-1995*

Irrigation water requirements for small-plot vegetable farmers

(No 689) Agricultural Research Council – Institute for Soil, Climate and Water

There are many irrigation schemes in the former homeland areas where the farmers have been allocated rather small plots. The Farming Systems Research and Extension (FSRE) approach was used in this project to address the need for improved technology transfer to these farmers.

Many lessons were learned from these "on-farm" trials. One of them focuses on the difficulty encountered in the selection of farmers to participate in the on-farm trials. Several different methods of selection were used in different seasons. One of the principles that must be upheld is that of participation of the relevant community; in this case the farmers themselves. At all times a team must include farmers as well as extension and research personnel.

The on-station experiment was designed to generate yield-water production functions for vegetable production under alternative agronomic practices. It was found that, despite the fact that the irrigation applied ranged from half to double, only small changes in yield were measured. The yield of the various treatments did not differ significantly from each other. The crops receiving sparse irrigation also extracted the water available in the soil at the beginning of the season, giving similar seasonal water-rise values. This type of deficit irrigation gave a saving of 16% to 26% of total water use over the season to produce a crop of similar yield.

This project has successfully implemented a typical FSRE approach, where the farmer is considered to be the centre of the viable agricul-

tural production system. The various aspects of participatory methods for needs assessment, and both the "on-station" and "on-farm" trials have contributed to its success. The process was one of learning by doing as the theoretical principles were applied in practice by the team, which involved members from the farming community, the extension staff and researchers.

Cost: *R450 000*
Term: *1995-1998*

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

(No 740) University of the Free State – Departments of Soil Science and of Agronomy

It is foreseen that increasing water demand and salinisation in the Vaal River system could negatively affect irrigators in the Lower Vaal River in that they will increasingly have to contend with a water supply that is less assured and of lower quality. This exploratory investigation found the trend for water quality to deteriorate, to be much less pronounced than anticipated and to be dominated by annual and multi-year wet and dry cycles. Only isolated river stretches were exposed to relatively serious water quality problems. A comparison of a limited sample of virgin and irrigated soil profiles from irrigated areas showed that the salt content of soils was reduced under irrigation when they contained more than 4 t salt/ha.m in the virgin state, and increased under irrigation, when the virgin state salinity was lower. No decrease in crop yield was calculated with the present crop mix and the best observed water quality in various river segments, while crop yield was calculated to be reduced under the worst water quality conditions in most river stretches. Long-term model predictions indicated that all undrained soils could become unsuitable for crop production over the next 50 years as a result of excessive salt accumulation.

Cost: *R581 00*
Term: *1997-1999*

Evaluation of the appropriateness and management requirements of micro-irrigation systems in small-scale farming

(No 768) MBB (CE) Inc.

The objective of this project was to assess how small-scale farmers experience the concept of micro-irrigation systems and how they cope with problems. The aim was to identify those aspects that eventually determine the success or failure of small-scale crop production, utilising these systems.

During the course of the project it became apparent that external factors, generic to any small-scale farming system and seemingly unrelated to micro-irrigation, had a significant influence, and that it would, therefore, be almost impossible to evaluate the former without taking the latter into account.

As a result, the project not only provided an opportunity to identify aspects related directly to micro-irrigation, but also an opportunity to demonstrate the impact of external factors on emergent farmers. During the course of the project about 30 sites were monitored or visited where small-scale farmers use micro-irrigation. Of the 23 sites discussed in detail in the report, 11 were newly established for purposes of the project. A further 11 had already been established in South Africa, and the remaining site in Israel was visited by a member of the project team.

Observations made during the monitoring of the trial plots, and a survey of existing systems, together with information obtained through literature studies and discussions with other parties involved with small-scale irrigation, were used to identify six aspects which were considered to be of major importance when evaluating small-scale micro-irrigation farming. These were:

- The farmer and his circumstances
- Water supply
- The irrigation system
- General management
- Infrastructural, institutional, extension and social factors
- Economic and financial factors.

The investigation provided extensive information on small-scale irrigation. Most of the relevant issues and problems that were encountered were generic problems of small-scale irrigation, of which few are related directly to micro-irrigation. This information formed the basis of a set of guidelines aimed at project planners and managers for small-scale farmers' use of micro-irrigation.

It is important to realise that micro-irrigation is not the answer to all small-scale irrigation farmers' problems and that there are situations where its implementation may cause farmers to be worse off than before. However, it is the responsibility of the engineer or designer to identify a potentially hazardous situation before a resource-poor farmer invests his resources without realizing good returns.

Micro-irrigation can be implemented successfully in small-scale farming, provided that a number of support services are in place. Small-scale farmers experience very few problems with the operation of the system as long as the design and materials are of a good quality and he follows operational guidelines reasonably well. However, when something fails in the system, especially if it is related to the water upply, a project can come to a sudden standstill with serious consequences for the farmer.

Practical guidelines were developed for the implementation of micro-irrigation in small-scale farming. These guidelines are based on the results of this project, are practical, and can serve as a checklist for planners, designers and extension officers. Currently the guidelines are being refined and will be published as a separate document by the WRC. The aim of the guideline report is to help prevent mistakes of the past and, hopefully, it will contribute to policy-making on a small scale regarding the utilisation of micro-irrigation. Thus, the successful use of the systems is ensured.

Cost: *R989 600*
Term: *1996-2000*

Development of guidelines for appropriate training levels and content in support of sustainable small-scale irrigation development

(No 774) MBB (CE) Inc.

The study which resulted in these guidelines was undertaken as a result of the frustration which is expressed repeatedly by developers, extension officers, operators and farmers involved in smallholder irrigation in South Africa, with their own lack of knowledge and practical understanding and how this hampers their performance in their respective roles. The consequences for small-scale farmer irrigation development are found in inappropriate designs and poor irrigation practices, operation and maintenance. This leads to poor water-use efficiency, under-utilisation of infrastructure and hardship.

Appropriate training courses cannot be designed without first-hand knowledge and understanding of the circumstances within which the training will be applied. This implies a thorough understanding of the agricultural resources, irrigation and other infrastruc-

Effect of the introduction of agroforestry species on the soil moisture regime of traditional cropping systems in rural areas.

ture; the nature, availability and reliability of agricultural inputs and support systems; and, most importantly, the farmers' desires, aspirations and constraints.

The focus of these guidelines is the development of the marginalised rural poor. The trainer and developer must become aware of the fears that have emerged among the rural poor, owing to a lack of contact with and knowledge of the outside world. It is of fundamental importance to understand something of the difficulties involved in escaping from the trap of poverty and the 'resistance to change' which is inherent in survival strategies.

Attempts to stimulate development will be fruitless unless people's fears are addressed first. The training process can be used to overcome resistance to change and to stimulate "bottom-up" development. The trainer should establish principles such as voluntary participation, open discussions and long-term involvement for the trainer and the training group in the beginning and reinforce them as often as necessary.

These guidelines have identified a wide range of role-players in smallholder irrigation development and information that is typically overlooked in the implementation of a development initiative. The checklists which are provided can be broadened and further refined through feedback on field experience with the practical application of the guidelines.

Cost: *R126 300*
Term: *1996-1997*

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

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

The project concentrated on improving crop production in an area with a low production potential. The reason for the low production potential is marginal and erratic rainfall, which is exacerbated by high runoff and evaporation losses. The hypothesis was that a production technique combining the water conservation benefits of water harvesting, no-till, basin tillage, mulching and long fallow would make sustainable crop production possible at a reasonable level for selected crops.

The results of the project showed that the water harvesting and basin tillage (WHB) part of the hypothesis is correct. Indications are that in the long term, average yield increases of around 50%, compared to conventional tillage, can be expected from maize and sunflower using the technique on the ecotopes tested. Although long fallow has proved its value for very dry seasons, long-term yield predictions indicate that this strategy will be uneconomical. Mulch in the basins has been shown to be beneficial under certain circumstances. Additional research is needed for clarification in this connection.

The critical end-products of the project are the measured yields for the different treatments and the cumulative probability function graphs of predicted long-term yields of maize and sunflower. The latter embody the current understanding of the critical water balance processes, and the ability to express these quantitatively and model them in a simple empirical way. Because of its simplicity in focusing on the dominating factor and the ease of adaptation to the complex spatial non-homogeneity of the WHB technique, the empirical sunflower stress model has made a valuable contribution to this study. With the introduction of more advanced modelling procedures it may be possible to adapt the DSSAT V3 maize model (Decision Support System of Agrotechnology Transfer: Version 3) to perform well even for very low yields.

The overall result is confidence in the conclusion that the WHB technique is significantly better than conventional tillage on these

ecotopes for maize and sunflower, and probably also for sorghum. Sunflower and the new short-season maize cultivars have the advantage that they can be planted early in January, which ensures flowering in March. This ensures that it experiences the most favourable rainfall: evaporation ratio of the summer months, and also the highest and most reliable rainfall. Sorghum and wheat, however, are not well-suited to these ecotopes. The main reasons for the success of the WHB technique are its ability to reduce runoff to zero and to reduce Es (evaporation from the soil surface) significantly.

Because the WHB technique has been shown in these experiments to generally reduce the overall runoff from the land to zero, soil loss from the land as a whole will also be minimal. This is an important advantage over conventional tillage. Measurements of soil losses on the long-term experiments at Pretoria and Glen have shown that mean annual soil losses from conventionally-tilled lands range from 8 to 22 $t \cdot ha^{-1}$, compared to 0.3 to 0.7 $t \cdot ha^{-1}$ from veld. Use of the WHB technique will, therefore, make a contribution to sustainable productivity.

Cost: *R458 300*
Term: *1997-1999*

Guidelines for rehabilitation of small-scale farmer irrigation schemes in South Africa

(No 891) Prof Emeritus TJ Bembridge, Private Consultant

Despite huge investments, with a few exceptions, the performance of most small-scale farmer irrigation schemes in South Africa falls far short of the expectations of engineers, politicians, development agencies and the participants themselves. Due to financial constraints over the past few years, provincial governments have withdrawn their support from a number of schemes. This has resulted in considerably reduced efficiency and, in some cases, almost complete collapse of certain schemes.

The aim of the study was to contribute to the knowledge of the constraints facing small-scale irrigation schemes in the Eastern Cape, KwaZulu-Natal and Northern Provinces through an overview of 184 schemes in the three provinces, followed by four case studies of "top down" bureaucratically-managed schemes. The aim of the research was to devise general guidelines and strategies for rehabilitating small-scale farmer irrigation schemes in South Africa.

Problems and constraints tended to centre around poor maintenance of infrastructure and equipment, lack of institutional support in terms of land tenure, credit, marketing, draught power, extension, research and, in some cases, high energy costs. There were also problems of marginal soils and water quality and quantity.

One of four households was headed by a female, a high proportion of people were illiterate in the upper age groups, and they had limited resources. Approximately three in five households were living in varying degrees of poverty.

In many cases, modernisation and rehabilitation are only justified on the grounds of food security and poverty relief, provided that interest and redemption of rehabilitation costs are completely subsidised.

A checklist and discussion of general basic elements which need to be considered in rehabilitating selected irrigation schemes includes the need for a participative approach in establishing human potential and environmental constraints, topography and soils, land use and related factors and infrastructure and water supplies, all aimed at assessing scheme viability.

The success of scheme operation and maintenance, depends on farmer participation, formation of WUAs, upgrading infrastructure, operational and maintenance guidelines, as well as institutional support, including credit, marketing, inputs, mechanisation, extension, research and training.

Cost: *R194 500*
Term: *1998-1999*

Factors which influence the acceptance of irrigation scheduling with specific reference to scheduling models

(No 893) University of Pretoria – Department of Agricultural Economics, Extension and Rural Development

This pilot research project was undertaken at three different sites, namely the Rust de Winter, Riet River and Loskop Irrigation Schemes. Since Rust de Winter differs from the other sites in terms of its socio-economic circumstances, different research methodologies were employed at the sites. Rust de Winter required a range of typical participatory rural appraisal (PRA) techniques, while at Riet River and Loskop, questionnaire-based semi-formal interviews were used.

At Rust de Winter it was found that the general agricultural knowledge of irrigation farmers was poor and they conceded this by complaining that they did not have access to effective extension advice or services. Their working knowledge of specific crops was acceptable. Irrigation scheduling did not feature in the needs analysis.

Respondents on the Riet River Irrigation Scheme were very positive about irrigation scheduling. They mentioned variety in soil types, water-table problems and lack of infrastructure as factors that hampered scheduling. Yet, they did not respond very positively to the attributes of computer-based irrigation scheduling models. It seemed that many (42.9%) were satisfied with the current (low) levels of sophistication of irrigation scheduling that they were applying. Respondents seemed to be divided regarding computer-based irrigation scheduling, with 28.1% perceiving it as being very difficult. More than 70% agreed that scheduling could save water and money.

The results of the Loskop Irrigation Scheme showed that 73% of the respondents applied irrigation scheduling. There is a relationship between the practice of scheduling and knowledge thereof. Six respondents had an intimate knowledge of scheduling, yet only four of them applied it. Respondents perceived scheduling as being important, and linked scheduling with sustainable water use, saving money and securing crop yields. Only 22.6% of respondents claimed that scheduling was "not easy" to apply. There was a relationship between the respondents' perception of the importance of scheduling and applying it. Respondents were aware of the need to save water in future and indicated that scheduling could play a big role in this regard.

The implications of these findings are that irrigation scheduling technology is available, irrigation farmers' knowledge seems to be deficient and extension can play a role in alleviating this problem

Cost: *R100 000*
Term: *1998-1999*

WRC archiving system for research projects on crop water-use systems

(No 912) NB Systems cc

The WRC is funding many projects that produce valuable data on crop water use. There is a tendency for these data to be inaccessible and scattered.

A centralised database located at either the WRC or the CCWR

that is accessible to all researchers was seen as a solution. In order to investigate the feasibility of such an approach, a pilot project, initially focusing on bringing together all data sets resulting from research into crop water-use systems, including forestry, was undertaken and NB Systems cc was commissioned to develop a Data Administration System (DAS) which could assist in alleviating the problem. DAS was designed to be simple and user-friendly. It uses the Interbase Software – it will be possible, subject to certain conditions, to access an Interbase database directly through the Internet. At this stage it is possible for a researcher to export data from DAS to files that can be compressed and the database application can be used by WRC researchers to archive their research results on crop water-use systems at the end of each project. The database has the following capabilities:

- It runs on the Windows 95 or higher operating system
- It runs on a single PC
- It runs in a client/server environment
- It handles large amounts of data
- The uploading and downloading of data/results have been made as easy as possible
- Extensive querying facilities for selective data retrieval are provided.

The WRC intends, through the CCWR, to maintain a master database where each project that has produced useful data, can download its data for future reference.

The Interbase 6.0 software is available on the Internet free of charge. A detailed user guide is available. Any organisation wanting to use the DAS system can obtain it from the WRC, free of charge.

Cost: *R142 000*
Term: *1998-1999*

New projects

Contribution of root-accessible water tables towards the irrigation requirements of crops

(No 1089) University of the Free State – Department of Soil Science

The motivation for this project was provided by the fact that 260 000 ha irrigated land and 500 000 ha dryland experience the problem of shallow water tables. Prolonged waterlogging leads to harmful salt accumulation in the soil, which, in turn, causes structure degradation and results in severe crop losses. Waterlogging of soils can be controlled by artificial drainage or by planned deficit irrigation; in the latter case, stimulating the crop to withdraw part of its water requirement from the water table.

Under field conditions, quantification of the contribution of water uptake from shallow water tables is problematic. Current technologies are inadequate in measuring lateral underground water fluxes resulting from non-uniform irrigation and/or drainage-restricting soil layers. Consequently, it is virtually impossible to distinguish between contributions of water uptake from a shallow water table and water provided through irrigation when measuring the evapotranspiration of a crop under field conditions. Application of deficit irrigation under these conditions should also result in the utilisation of any water originating from leaking distribution and storage systems, excessive rainfall and unintentional over-irrigation.

Water uptake subroutines of the irrigation scheduling models currently utilised by irrigation farmers do not adequately account for the contribution of root-accessible water tables to the water requirements of crops. This contribution needs to be quantified more accurately under controlled two-dimensional conditions of zero or controlled horizontal influx.

These results will be used to improve available irrigation scheduling models in order to provide for well-managed deficit irrigation under high yielding conditions where root-accessible water tables are present. In addition to adapted irrigation schedules, thus promoting water conservation, this project should also provide guidelines of value to dryland farming practices under these conditions.

Estimated cost: *R498 000*
Expected term: *2000-2002*

Cheap and simple irrigation scheduling using wetting front detectors

(No 1135) University of Pretoria – Department of Plant Production and Soil Science and Department of Agricultural Economics, Extension and Rural Development

Currently, a wide range of methods and devices are available for irrigation scheduling. These include either physical measurement of the soil water content by means of e.g. tensiometers and time-domain reflectometry, or simulation models using data from automatic weather stations and crop-growth parameters. However, in practice, it is found that irrigation scheduling is not widely applied, mainly because methods are not always user-friendly, farmers have insufficient knowledge and incorrect water charging approaches are followed. These problems occur in both commercial and subsistence farming, but are particularly of concern in small-scale subsistence and emergent farming because of, amongst others, a lack of training.

Irrigation farmers face the challenge of increasing food production, while competition for the water which is currently apportioned to irrigated agriculture, is also increasing. Therefore, scheduling tools will have to be utilised to maximise crop income in relation to water input costs. According to the discussion document on an Agricultural Policy for South Africa, one of the priorities is that "key constraints facing small-scale producers must be identified, and adaptive research done in order to overcome these problems." In this regard, the wetting front detector developed by the CSIRO in Australia has vast potential. It gives a visual, audible or electronic signal when the wetting front reaches the required soil depth. The device is simple to manufacture, easy to use and needs no calibration for soil types. A version of the wetting front detector containing no electronic components, has been developed for resource-poor farmers.

In the proposed research project, participatory action research involves:

- Application of the tool
- Training of farmers
- Field evaluation of findings.

The aims of the research are to:

- Introduce farmers to the wetting front detector method and to install detectors on selected farms.
- Develop appropriate guidelines for the use of wetting front detectors for different crops, soils and irrigation systems.
- Evaluate factors affecting the perceived acceptability of this irrigation scheduling technology by small-scale and commercial farmers.
- Determine from users their perception of whether the wetting front detectors saved water and/or increased yield.
- Research the best method for emergent and commercial farmers to use the wetting front detector.

Estimated cost: *R961 000*
Expected term: *2000-2002*

Optimisation of irrigation management in subtropical fruit trees by determination of water and carbon demands to improve water-use efficiency and fruit quality

(No 1136) University of Pretoria – Department of Plant Production and Soil Science

It is estimated that approximately 90% of the national production of citrus and subtropical fruit, which is under irrigation, is exported. Owing to increasing competition on international markets, efforts must be made to improve the quality of fruit delivered to overseas consumers. Through better water management of orchards, the correct balance between vegetative growth, yield and fruit quality can be achieved.

The emphasis in this research project is on the plant physiology of water use, in particular those processes that determine fruit quality. This interaction between water use and fruit quality can be influenced by regulated deficit irrigation. It requires knowledge about the growth stage, during which time the trees can be stressed in order to enhance fruit quality. Overseas research, which has led to the development of a model for peach trees, will be verified for subtropical crops and tested on mango trees. After the model has been validated for mangos it can, with minor adjustments, be applied to other subtropical trees with similar physiological processes regarding fruit formation.

Mangos have been selected because Merensky Technological Services (MTS), who are prepared to assist, have made mango orchards available for the research. MTS will also commit R1 250 000 or approximately 56% of the total budget, to the project by means of facilities, equipment and staff.

The aims of the research are to:

- Determine vegetative and reproductive growth patterns which are essential for the application of regulated deficit irrigation treatments.
- Develop a model for reproductive and vegetative growth of subtropical fruit trees.
- Manage fruit tree irrigation for minimum water and nutrient losses and, at the same time, to improve fruit quality, in particular, fruit of export quality, by manipulating the water supply to trees.

Estimated cost: *R984 000*
Expected term: *2000-2002*

Investigation of the range and distribution of irrigation scheduling models in South Africa in general, with specific reference to the application of selected models

(No 1137) University of Pretoria – Department of Agricultural Economics, Extension and Rural Development

According to the recently published draft Water Conservation and Demand Management Strategy of DWAF, the endeavour is to improve the efficient use of water by all consumers in South Africa. In addition to efficient, equitable and sustainable use of water, cornerstone principles of the strategy framework have become the responsibility of water users. With reference to irrigated agriculture, it is clear that water distribution and irrigation methods, soil preparation, crop selection and irrigation scheduling have a significant impact on efficient water use. Irrigation scheduling based on appropriate methods can make a major contribution towards exercising responsible decisions regarding the timing and quantity of the application of irrigation water.

In the past, much research has been done on the physical principles underlying irrigation scheduling and a range of techniques and methods has been developed. Nonetheless, available evidence shows that these tools are not widely applied in practice. A pilot project on farmer perceptions, acceptability and adoption of computerised scheduling models is nearing completion. Provisional results indicate that a number of factors such as the design of the tool itself, availability of expert advice, awareness, interest and knowledge of the farmer, and the level and method of charging for water use, have an influence. The important need which has been highlighted is that the emphasis in research must shift from the technological hardware to the human and managerial factors which play a pivotal role in the application of irrigation scheduling technology.

Therefore, for strategic reasons, a need exists for information on the variety of and continued or discontinued irrigation scheduling methods in South Africa. Apart from an audit of irrigation scheduling, it is important to determine under which circumstances and how effectively irrigation scheduling has been adopted and applied.

The aims of this research project are to:

- Investigate and describe the variety, range and scope of irrigation scheduling models in South Africa.
- Investigate, analyse and describe the levels of application by a cross-section of small-scale disadvantaged farmers and commercial farmers, organisations and advisors of a selection of irrigation scheduling models.
- Investigate, analyse and describe the reasons from a cross-section of small-scale disadvantaged and commercial farmers, organisations and advisors for using the different irrigation scheduling models.
- Investigate, analyse and describe why irrigators discontinue the application of irrigation scheduling models.

Evaluation of a model for water use in deciduous fruit orchards and scheduling of irrigation with the aid of meteorological data.

- Make recommendations concerning the propagation and institutionalisation of the proper continued application of irrigation scheduling models.

Estimated cost: *R586 000*
Expected term: *2000-2002*

Investigation into the potential of sustainable irrigation in black developing communities of two subcatchments of the Pongola and Thukela Rivers

(No 1138) Sineke Developments (Pty) Ltd.

It is generally recognised that in order to improve equitable and sustainable irrigation water management, opportunities must be created for resource-poor and small-scale farmers that will increase efficiency, food security and competitiveness. Furthermore, it is known that water is a more limiting resource than land. Projections show that there is limited potential for expansion of the area under irrigation, while there is scope for upgrading under-utilised land and water on existing irrigation schemes. Consequently, in the discussion document on an Agricultural Policy for South Africa it is stated under the heading of small-scale farming that "in general, most black farmers, whether small scale or not, have limited access to land and capital, and have received inadequate or inappropriate research and extension support. This has resulted in chronically low standards of living and reliance to a greater or lesser extent on subsistence production. To achieve the Government's objectives of black empowerment and poverty alleviation, policy must address problems faced by black farmers in general and resource-poor farmers in particular". Under research priorities for irrigation farming it is also highlighted that "many of the irrigation systems in the former homelands are unproductive compared to commercial schemes. Research to understand the constraints facing irrigation farmers, including tenure issues and institutional arrangements, could significantly improve the productivity of these systems".

Therefore, emphasis must be placed on the enhancement of management capabilities of black farmers and rehabilitation of small-scale farmer irrigation schemes. The proposed research methodology will lead to a better understanding of the requirements for community participation, appropriate institutions and indigenous farming systems that will promote upliftment of the poor in rural areas. In particular, it is necessary to analyse the social organisation according to which conflicts regarding the access to resources are resolved in black developing communities.

Through this project an important contribution will be made to capacity-building by involving a new group of black researchers in this field, who will be collaborating with staff and students at the University of Zululand.

The main aim of the research is to define the socio-economic context of importance for developing sustainable water-driven systems in black rural and peri-urban communities to improve productivity and standards of living.

Estimated cost: *R995 000*
Expected term: *2000-2002*

Application of risk assessment modelling in groundwater for humans and livestock in rural, communal systems

(No 1175) NCE cc

The proposed project is the fourth in a programme dealing with water quality requirements for animal production. The first project (completed in 1993) dealt with the identification of those chemical constituents which are unacceptable from an animal production point of view. In order to facilitate the classification of water regarding its suitability for animal production, the second project (completed in 1996) attended to the development of an index for water classification and computerisation thereof. The third project (completed in 1999) concentrated on expanding the scope of the index to also provide for livestock production under intensive, semi-intensive and peri-urban production systems, as well as for game under game farming conditions.

An important observation during the current project was that the water source was usually shared by humans and livestock. At the same time, the results of another WRC project (No 839 entitled **Correlation of high uranium, arsenic and other chemical element values in groundwater with abnormal haematological values**, involving the University of Stellenbosch – Department of Community Health) were brought to the attention of the animal water quality requirements research team.

The above-mentioned developments led to the identification of an ethical concern and a modelling consideration.

The ethical concern is that solutions cannot be recommended for use in communal areas, even if these solutions alleviate the adverse effects of hazardous constituents on livestock, whilst knowledge exists that the water is also utilised by humans. Very often, the solutions recommended for livestock purposes, will render the water unfit for human consumption. In most cases, the water is already unfit for human consumption, and the quality will worsen for human use should the alleviatory chemicals be administered at their current dosage levels.

The modelling consideration is that risk assessment and solution formulation need to focus on both livestock and human models, allowing the output to be fit for both user groups.

The project will, therefore, concern itself with quantifying the risk assessment to humans in communal areas, and investigating means of applying solutions that will benefit both user groups. It will address the formulation of alleviatory treatments of a lower dosage and different chemical composition that will still serve to significantly mitigate adverse effects on livestock production, whilst making the water suitable for human consumption.

Estimated cost: *R1 500 000*
Expected term: *2000-2002*

Water conservation techniques on small plots in semi-arid areas to enhance rainfall-use efficiency, food security, and sustainable crop production

(No 1176) Agricultural Research Council – Institute for Soil Science, Climate and Water

Food production is fundamentally a product of the atmosphere-plant-soil system with water being the main factor limiting productivity, especially in semi-arid regions. To promote sustainable crop production, rainfall use efficiency, therefore, needs to be optimised. In a previous project (Project No 878), entitled **Optimising rainfall use efficiency for developing farmers with limited access to irrigation water**, an in-depth study was made of all the relevant production techniques and identification of the most appropriate techniques for long-term implementation. The stage has now been reached where the latter techniques (consisting mainly of specific cultivation practices, water harvesting by means of runoff manipulation techniques and certain water conservation practices) need to be demonstrated and evaluated under actual farming conditions on specific benchmark ecotopes.

Against the above background, the project's aims are as follows:

- Further evaluation of the recommended water conservation crop

production techniques that will result in enhanced rainfall use efficiency.
- For the specific ecotopes, determine the area of land needed to provide food security for an average-sized rural family, and the manpower needs for this production when employing the recommended techniques.
- Effective technology transfer by means of judiciously placed demonstration plots to departmental officials, small-scale farmers and those with access to communal land.

Estimated cost: *R1 000 000*
Expected term: *2000-2002*

Subsurface drip irrigation

(No 1189) Agricultural Research Council – Institute for Agricultural Engineering

Drip irrigation was first researched in the early 1960s. As a result of the advantages associated with this irrigation technique, it was well-received in South Africa; so much so that in 1991 South Africa was the fourth largest user of this irrigation technique in the world.

Subsurface drip irrigation (SDI), first reported on in 1970, has become an established technique in the USA and is currently being actively marketed in the RSA. SDI provides *inter alia* the following advantages:
- Improved water use efficiency since the dry soil surface results in reduced evaporation losses
- The dry soil surface also results in improved weed control (no germination of shallow seeds), and disease control (reduced humidity between the plant canopy and the soil)
- Mechanical cultivation practices not interfered with by irrigation equipment, and less soil compaction by implement traffic.

On the other hand, a number of disadvantages are also experienced, e.g.:
- Inoperative emitters not easily noticed
- Root intrusion, and soil particles entering emitters due to negative pressures when systems are not in operation
- Difficulties with seed germination and irrigation of transplants.

In view of the expected increase in the utilisation of these systems, the need has been identified to have their performance systematically and effectively evaluated. Only then will it be possible to provide irrigation practice in South Africa with directives on selection of emitters, their installation, management and maintenance, thus contributing to the realisation of the potential benefits of this system.

Estimated cost: *R343 000*
Expected term: *2000-2002*

Research projects

Completed

- **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 Science)
- **578** Evaluation of irrigation techniques used by subsistence and emergent farmers (MBB (CE) Inc.)
- **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.)
- **689** Irrigation water requirements of small-plot vegetable farmers (Agricultural Research Council – Institute for Soil, Climate and Water)
- **740** Effect of water quality on irrigation farming along the lower Vaal River: The influence on soils and crops (University of the Free State – Department of 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.)
- **878** Optimising rainfall-use efficiency for developing farmers with limited access to irrigation water (Agricultural Research Council – Institute for Soil, Climate and Water)
- **891** Guidelines for rehabilitation of small-scale farmer irrigation schemes in South Africa (Prof Emeritus TJ Bembridge, Private Consultant)
- **893** Factors which influence the acceptance of irrigation scheduling with specific reference to scheduling models (University of Pretoria – Department of Agricultural Economics, Extension and Rural Development)
- **912** WRC archiving system for research projects on crop water-use systems (NB Systems cc)

Current

- **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)
- **573** Water-use efficiency of cultivated subtropical forage and pasture crops (University of Pretoria – Department of Plant and Soil Sciences)
- **581** Computerised weather-based irrigation water management system (University of the Free State – Department of Agrometeorology)
- **645** Optimal management of uncertain water availability at farm and regional level with due allowance for risk and the environment (University of the Free State – Department of Soil Science)
- **646** Maximisation of economic water-use efficiency of processing tomatoes (University of Pretoria – Department of Plant Production)
- **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)
- **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)

- **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)
- **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 as a biological control measure for excessive water weed growth in irrigation systems (Rand Afrikaans University – Department of Zoology)
- **857** Extension to and further refinement of a water quality guidelines 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)
- **892** Evaluation of a model for water use in deciduous fruit orchards and scheduling of irrigation with the aid of meteorological data (Agricultural Research Council – Infruitec)
- **894** Implementation of the FARMS (firm-level agricultural risk management simulator) system for management decision-making in irrigated farming (University of the Free State – Department of Agricultural Economics)
- **918** Investigation into the use of pathogenic organisms for the biological control of the troublesome alga *Cladophora glomerata* (Agricultural Research Council – Plant Protection Research Institute)
- **944** Selection of drought tolerance in the germplasm of *Vigna unguiculata* (cowpea), *Vigna subterranea* (bambara groundnut) and *Amaranthus spp.* (marog) (Agricultural Research Council – Vegetable and Ornamental Plant Institute)
- **945** Two-dimensional water balance and energy interception model for fruit trees (University of Pretoria – Department of Plant Production and Soil Science)
- **946** Development of an integrated information system using the WAS, SWB and FARMS computer models (NB Systems)
- **947** Economic impact of changing water quality on irrigation farming in the Lower Vaal River (University of the Free State – Department of Agricultural Economics)
- **974** Economic efficiency of irrigation systems for large- and small-scale farming enterprises (University of the Free State – Department of Agricultural Economics)
- **1036** Performance of drip irrigation systems under field conditions (Agricultural Research Council – Institute for Agricultural Engineering
- **1046** Quantification of the water use of four tree crops in the Lowveld of Mpumalanga (Agricultural Research Council – Institute for Tropical and Subtropical Crops)
- **1047** Water-use efficiency of multicrop agroforestry systems, with particular reference to small-scale farmers in semi-arid areas (University of Pretoria – Department of Plant Production and Soil Science)
- **1048** An analysis of the social, economic and environmental direct and indirect costs and benefits of water use in the irrigated agriculture and forestry sectors (CSIR – Division of Water, Environment and Forestry Technology)
- **1049** Application of rainfall intensity – runoff relationships to water harvesting from micro-catchments to stabilise food production in rural and peri-urban settlements (University of the Free State – Department of Agrometeorology)
- **1050** Sustainable local management of smallholder irrigation (University of the North – Faculty of Agriculture)

New

- **1089** Contribution of root-accessible water tables towards the irrigation requirements of crops (University of the Free State – Department of Soil Science)
- **1135** Cheap and simple irrigation scheduling using wetting front detectors (University of Pretoria – Department of Plant Production and Soil Science and Department of Agricultural Economics, Extension and Rural Development)
- **1136** Optimisation of irrigation management in subtropical fruit trees by determination of water and carbon demands to improve water-use efficiency and fruit quality (University of Pretoria – Department of Plant Production and Soil Science)
- **1137** Investigation of the range and distribution of irrigation scheduling models in South Africa in general, with specific reference to the application of selected models (University of Pretoria – Department of Agricultural Economics, Extension and Rural Development)
- **1138** Investigation into the potential of sustainable irrigation in black developing communities of two subcatchments of the Pongola and Thukela Rivers (Sineke Developments (Pty) Ltd.)
- **1175** Application of risk assessment modelling in groundwater for humans and livestock in rural, communal systems (NCE cc)
- **1176** Water conservation techniques on small plots in semi-arid areas to enhance rainfall-use efficiency, food security, and sustainable crop production (Agricultural Research Council – Institute for Soil, Climate and Water)
- **1189** Subsurface drip irrigation (Agricultural Research Council – Institute for Agricultural Engineering)

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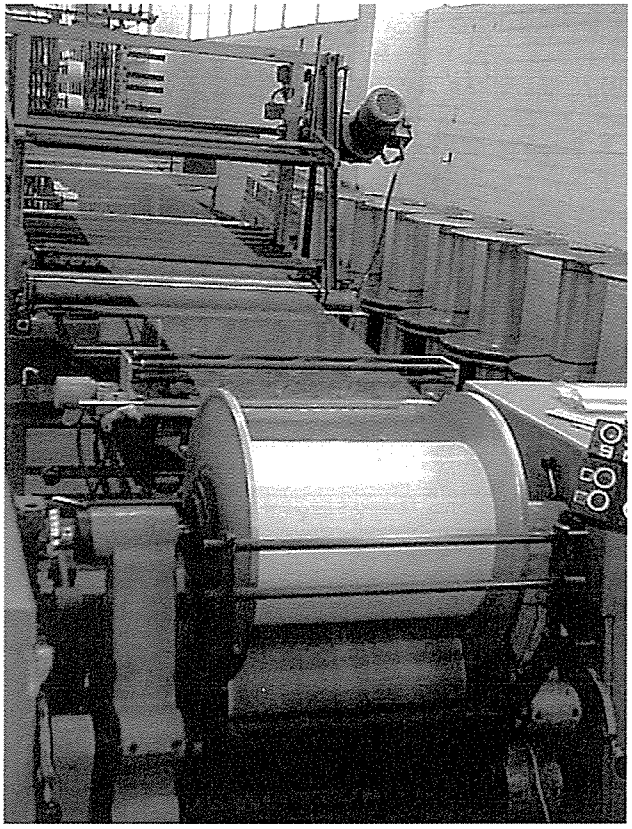
11 Industrial water management

"Sustainable industrial development in the RSA is the corner-stone of government policy for the upliftment of previously-disadvantaged sectors of the population. Progressive implementation of water conservation, waste minimisation and cleaner production are key aspects in achieving local growth and global competitiveness of our nationally-important industries"



In all aspects of current government policy in the RSA, industrial development is the corner-stone of future wealth creation and quality-of-life for the whole population. Increasingly, as world globalisation facilitates supply and demand of processed products, international competitiveness has developed from bottom-line price considerations to a generally more progressive evaluation of the true life-cycle environmental costs associated with the exploitation of limited raw material resources, processing impacts and the final disposal of the products.

In the water-scarce RSA situation, the provision of suitable-quality water for processing purposes, and the environmentally-acceptable disposal of the aqueous effluents generated, are crucial aspects in the sustainable development of industry. This is particularly relevant to "wet" processing industries, but, nominally "dry" industries, which consume electrical power, also impose an environmental burden in terms of acid mine drainage and air pollution, often remote from the area of the industrial operation.

Current and new research in the industrial water portfolio is aimed at reducing water demand at source per unit of production, reducing the corresponding pollutant loads in aqueous effluents and solid wastes, developing appropriate treatment technologies for the residual wastes generated, and, most importantly, integrating all these aspects into progressive management tools in which wastes are minimised at source, cleaner production and clean technology practices are developed and implemented, and opportunities for the conversion of "waste" materials into higher-value products are researched and developed.

The success of a pilot study (WRC Project No 973 **Waste minimisation clubs – Phase 1**) in which two waste minimisation (wastemin) clubs were established, namely a sectoral club in the metal-finishing industry and a regional club involving, *inter alia*, textile factories and a poultry abattoir, both of which recorded very significant reductions in water use and effluent generation. This led to a further study (WRC Project No 1171 **Establishment of a methodology for initiating and managing waste minimisation clubs**) which was aimed at establishing a methodology for initiating (proliferating) and managing wastemin clubs nationally. The objective is to create more wastemin clubs countrywide, while maintaining quality control standards which will ensure sustainability.

Biotechnological research has been intensified with regard to biological sulphate removal from high-sulphate effluents arising from acid mine drainage and industrial sources. Collaborative research efforts between Rhodes University (Department of Biochemistry and Microbiology) and the University of Cape Town (Departments of Chemical Engineering and Civil Engineering) are aimed at developing fundamental kinetic data and an overall dynamic simulation model for such processes within the next few years. As indicated in **Chapter 7**, the research outcomes will also be applicable to the rapid digestion of sewage sludges in the presence of sulphate-reducing bacterial systems.

Holistically, it is believed that life-cycle assessment (LCA) considerations will provide the basis for assessing the environmental rationale of many industrial operations and their consequent economic implications for competitiveness and sustainability in local and world markets. Research in this area is continuing, and is aimed at developing a customised RSA protocol for environmental impacts including salination. A particular study (WRC Project No 1077 **The use of life cycle assessments in the selection of water treatment processes: Chapter 7**) is an LCA comparison of alternative water treatment processes (membranes vs. conventional physico-chemical).

Completed projects

Recovery of water and chemicals from ion-exchange regeneration effluents

(No 308) University of Natal – Pollution Research Group

Ion-exchange systems were studied in order to determine the operating conditions, regenerant make-up requirements, plant modifications required and the economic cost-benefits if recovery and recycling of regeneration chemicals were to be practised and the volume of the regeneration effluents were to be reduced.

The first case study (sodium chloride recovery from anionic exchange regeneration at a sugar refinery) targeted a significant environmental problem (disposal of the spent brine), but the recovered sodium chloride had a low value. The technical feasibility of implementing the process is thus dependent on the economic assessment of cost factors at a particular sugar refinery.

The second case study (sodium hydroxide recovery from anionic exchange regeneration in a demineralising plant at a power station) has a more promising economic basis because of the much higher value of sodium hydroxide. The recovery of sodium hydroxide was found to be technically feasible, but the purity of the recovered chemical would probably not meet the increased stringency of Eskom's quality specification for its high-pressure boilers and, hence, for an increased purity of the regeneration chemicals used. The regenerant recovery techniques demonstrated would, however, be adequate in other industrial situations utilising ion-exchange processes to treat water for low- to medium-pressure boilers.

The technical feasibility of recovering regenerant chemicals from ion-exchange processes has thus been demonstrated, but other factors were found to constrain implementation, namely poor economics in one case study and very stringent quality requirements in the other case study. Reuse of chemicals in ion-exchange systems remains an important goal, and the results of this project contribute significantly towards environmentally cleaner ion-exchange trains.

Cost: *R388 000*
Term: *1990-1994*

Development and demonstration of effluent treatment systems appropriate to the needs of the red meat abattoir industry

(No 546) SRK (CE) Inc.)

The results obtained in surveys at four abattoirs showed a high day-to-day variability which led the project team to deduce that smoothed historical data provided a better picture for analysis of the trends, and that a "target management" approach, which incorporated processing areas for individual abattoirs, was the most effective means of realizing the potential water-use benefits indicated, by reducing above-target variability. The *pro forma* target management schedule which was produced was confirmed as being an effective tool which could be used by non-expert personnel towards achieving this aim. The data have been used to indicate achievable updated water intake and water use targets for A-grade abattoirs, significantly below those proposed in NATSURV 7 (WRC Report No TT 41/89).

The abattoirs surveyed showed "better effluent management" than the average of A-grade abattoirs reported in NATSURV 7. Accordingly, the project team proposed new (reduced) targets for "A-grade abattoirs operating above 50% of design capacity" in terms of specific effluent volume (0,77 k*l* per water-related cattle unit or wrcu, reduced from 1,10 k*l* /wrcu), specific pollution loads in terms of chemical oxygen demand (COD, now 4,0 kg COD/wrcu, reduced from 4,62 kg COD/wrcu) and suspended solids (SS, now 1,0 kg SS/wrcu, reduced from 1,4 kg SS/wrcu). The COD and SS pollution loads were broken down into the contributions from each of the major processing areas, and the "target management" approach developed for water intake and use was also recommended as a methodology for achieving managed reductions in pollution load.

Overall, the cost-effectiveness of on-site pretreatment, rather than direct discharge to sewer, was found to be heavily site-specific, depending, in particular, on the local authority's effluent discharge tariff which varies widely countrywide. With regard to particular effluent pretreatment technologies, ultrafiltration was found to offer the most widely-applicable benefits in effluent load reduction, water reuse (for restricted application) and concentrate (solids) recovery. The feasibility exercises carried out showed that the significant capital operating investment required would still only be justified under particular conditions. Export requirements regarding eco-friendly production will make such options more attractive in the future.

Cost: *R470 000*
Term: *1993-1994*

Use of algal and yeast biomass to accumulate toxic and valuable heavy metals from wastewater

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

This study was carried out in four sections. The first part of the work was aimed at defining the mechanisms of metal accumulation by yeast cells and cellular components. It was concluded that metal accumulation appears to be a function of all the cell wall components. Storage of metal ions within the cell occurred predominantly in the vacuole, and was related to ionic size. Uptake of heavy metals by viable yeasts appeared to be generally non-selective and was a function of the ratio of ambient metal concentration to biomass quantity. All three types of biomass preparations developed in the study fulfilled the necessary physical requirements.

The information from these initial studies provided a basis for the second part of the study, i.e. development of a bioremediation system. A novel method of immobilising *S. cerevisiae* as a biosorbent for the treatment of metal-laden waste effluent was developed. Immobilising the yeast cells conferred additional mechanical integrity and stability on the biomass, which could effectively remove Cu, Zn and Cd from solution at naturally-occurring pH values. The recovered metals were concentrated in small enough volumes to enable recycling or precipitation to be carried out. The yeast could be reused repeatedly.

A more detailed investigation of the kinetics of metal removal from a mine effluent by *S. cerevisiae* showed that the process was rapid, pH-dependent, and that the isotherms followed typical Michaelis-Menten binding kinetics, indicating a biosorbent suitable for treating relatively low-concentration, high-volume effluents.

The final section of the project investigated the use of algae (*Spirulina*) for the treatment of zinc-copper mine (Black Mountain) effluent. The system that was utilised was one of metal removal by both pH control induced by the algae and by bioremediation. The data indicated that metals in the effluent could be effectively removed from solution using this system, and that the process could therefore be linked to algal systems such as AIPS (algal integrated ponding system).

Cost: *R573 200*
Term: *1994-1996*

NATSURV: Water and wastewater management in the petrochemical industry

(No 759) CSIR – Division of Water, Environment and Forestry Technology

In this project the water intake, water use and pollutant loads of the crude oil refinery, synthetic fuel refinery and refining sectors of the industry were surveyed and characterised. Crude oil refineries in the RSA were found to have a relatively narrow range of specific water intake (SWI 0.51 to 0.67 m^3/t) and re-refining SWIs were found to vary widely (0.06 to 7.2 m^3/t), depending on the type of process used. Specific pollutant load (SPL) values in the three sectors display similar trends, although the specific effluent volume (SEV) during re-refining can exceed 100% of water intake due to the large volumes of wastewater taken in with the feedstock.

The results obtained present a "snapshot" of the water and wastewater characteristics of the industry in which crude oil refining (at four refineries) is around 20 million t/a, syn-fuel refining (at two refineries) is around 9 million "equivalent" t/a and oil re-refining is around 120 000 t/a. The first two sectors are highly capital-intensive operations which result in very concentrated point-source situations of water demand and effluent generation. Re-refining operations are smaller and more numerous, and present a different kind of management problem.

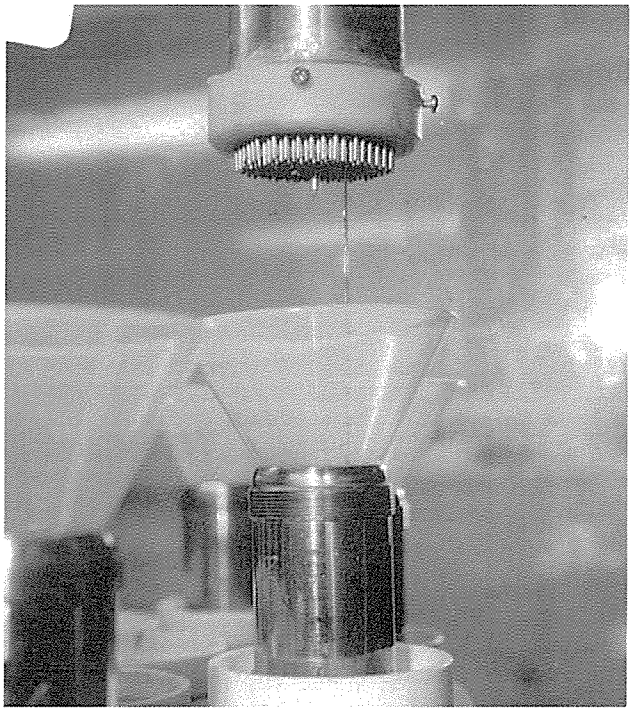
In addition to the water and effluent survey data, the Guide produced contains a number of specific recommendations for reducing water use and effluent generation in the industry. Practical water-saving measures identified include condensate recovery, air cooling, vacuum drawing by pumps rather than steam ejectors, elimination of steam leakage and upgrading of treated wastewater for use in cooling-water circuits. Measures identified for reducing pollution loads include more efficient oil recovery devices, segregation of clean and dirty surface runoff, effluent segregation, reducing pollutant loads (e.g. detergents and oils) at source and the implementation of clean technology. The improvements proposed are not, in all cases, suitable for retrofitting, but should certainly be considered for plant expansions or new facilities.

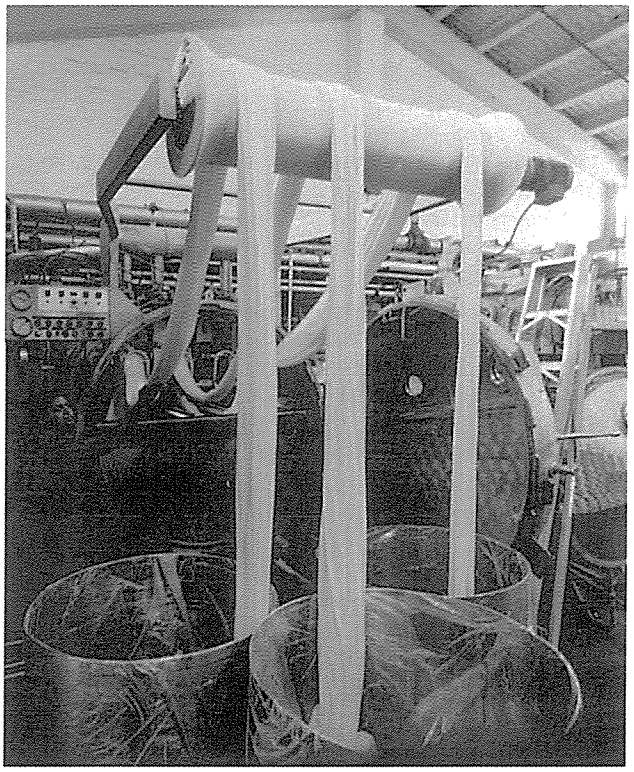
Cost: *R190 000*
Term: *1996-1998*

Waste minimisation and effluent treatment guide for the textile industry

(No 760) University of Natal – Pollution Research Group

The research product in this project is the *Waste Minimisation Guide for the Textile Industry*. In its development during the project, the Guide was drafted (in a somewhat different format compared to the final version), peer-reviewed by a range of parties actively involved with the environmental performance of the textile industry in the





Scenes from the Ninian and Lester dyehouse in Pinetown, KwaZulu-Natal: Laboratory-scale colour dispensing machine (top), yarn cones prior to knitting (left) and a jet dye machine for fabric (bottom right).

RSA, field-tested by students carrying out water and effluent surveys in the industry, and has thus undergone thorough evaluation during its development.

The Guide has been found to be a useful tool for assisting the RSA textile industry to improve its environmental performance in the following areas of application:

- The textile industry can use the Guide to self-assess and improve its implementation of waste minimisation practices and, hence, its aquatic environmental performance.
- Similarly, use of the Guide will assist factories in achieving compliance with environmental management standards e.g. 1S0 14000, and, thereby, improving their international competitiveness.
- Local regulatory authorities can use the Guide both as a training tool and as a management tool for monitoring and assessing the performance of textile manufacturers in their area of jurisdiction.

A key feature of the Guide is the comprehensive set of work-sheets, which provide a structured basis for establishing essential information regarding water use, effluent generation and process-related data such as chemicals and energy use. In achieving the final Guide format, the assistance of the Danish Technical Institute, and particularly Prof H Wenzel who voluntarily contributed many days of editorial and re-drafting input, is gratefully acknowledged. Follow-up activities stimulated by the project include the DANCED project to promote cleaner production in the RSA textile industry commencing in 2000, in which the Guide will be used for technology transfer and training.

Cost: *R345 000*
Term: *1996-1997*

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

(No 762) University of Natal – Pollution Research Group

During this project, anaerobic digesters and the evaluation of the performance efficiencies of the individual digesters in the KwaZulu-Natal region were surveyed and the performance efficiencies of individual digesters were evaluated in order to provide an indication of the wastewater treatment plants with the potential to accept greater loads, in the form of industrial effluent. This information could facilitate the rational location of new industries that produce high-strength or toxic organic effluents in KwaZulu-Natal. The survey also identified under-performing digesters. Remedial actions, which often involve simple solutions such as heating or mixing the digester contents to improve the degradation process, were suggested.

Industries producing high-strength or toxic organic effluents were identified. Nearby wastewater treatment works were evaluated in order to assess the potential for treatment of the effluents in the available anaerobic digester capacity. The majority of the high-strength effluents were found to be discharged to sea. Thus, the implementation of anaerobic treatment would safeguard the marine environment.

A laboratory-scale protocol was developed for the assessment of the anaerobic degradability of an effluent and its components. This research concentrated on the treatment of high-strength organic effluents. However, the protocol could also be applied to toxic organic effluents containing toxic components, such as the high-strength textile size effluent for which acclimation techniques were investigated.

During the course of the project, two landfill sites in the greater Durban area were closed due to subsidence problems. Implementation of these research outcomes would provide a safe treatment option for those industries producing high-strength or toxic organic effluents, thereby providing a solution to the co-disposal problem, preventing dilution of the effluents with valuable freshwater and protecting the marine environment by reducing pollution at sea outfalls.

Cost: *R243 000*
Term: *1996-1998*

Utilisation of earthworms and associated systems for treatment of effluent from red meat abattoirs

(No 766) Abakor Ltd. – Multilog Division

This "alternative" vermiculture technology has yielded interesting results. Preliminary indications suggest that the technology could potentially be used at small abattoirs as "appropriate" technology for reducing the strength of some of the concentrated wastes such as paunch contents and blood, either as a stand-alone treatment or as a pretreatment. Other benefits offered are:

- Good deodorising of the wastes treated in this way (odour, and corresponding public nuisance problems, are particular considerations in the abattoir industry).
- A useful, i.e. saleable, by-product is produced in the form of vermicompost.

In order for the indicative potential of this technology to be realised, matured and (hopefully) transferred into the industry for application, it will be necessary to determine the essential kinetic and stoichiometric parameters, in particular, the bio-conversion of organic material to eathworm mass and other components. This will establish the indicative scale and costs of particular design applications, which will, in turn, be a measure of the attractiveness or otherwise of such systems for implementation by the abattoir industry.

The other strategic requirement is to determine the physico-chemical-microbiological quality of the vermicompost in order to determine whether an additional pasteurising or sterilising step is needed before it can be used in general application. These considerations will significantly affect the cost of producing usable vermicompost, and, therefore, the viability of the whole process. It should be noted that the management approach required for successful and sustainable operation of vermiculture technology is ecological control rather than direct process control. This difference in approach will need to be taken into account in any further development and implementation of this technology.

Cost: *R520 000*
Term: *1996-1998*

Solid stabilisation of soluble wastes from the ferro-alloys industry

(No 942) Mineralogy and Process Chemistry, Council for Mineral Technology

The research team has combined its expertise in mineral phase chemistry and technology with practical experience from the local ferrochrome industry and building material manufacturers to extend the technological options available, and cost-effectiveness thereof, for the environmentally-safe disposal of bag filter dust (BFD) from the ferrochrome industry. The quantity of BFD produced by this industry is estimated to be around 100 000 t/a, with high indicative pollutant components of hexavalent chromium (Cr(VI)) and salts. These wastes are often dumped in slimes dams and incur great costs in the process.

Major results of the study have revealed that:

- Treatment of BFD slurries with ferrous ions in sulphate or chloride form, as practised by the industry, reduces the bulk of the chrome from the hexavalent (Cr(VI)) to the less toxic trivalent (Cr(III)) state. This treatment method is, however, not complete in terms of Cr(VI) conversion to Cr(III), and not permanent in that slow leaching of the chrome continues from the precipitates that are formed.
- Incorporation of Cr(VI)-containing wastes, comprising ferrochrome slag, electric-arc furnace slag and BFD (up to15% m/m) into cement blocks made with water or brine and cured for varying periods, showed that up to 50% of the salts and > 99% of the chrome was effectively immobilised. Leaching tests carried out on the cement blocks in accordance with DWAF guidelines showed that whole blocks were below the acceptable risk level for Cr(VI), but crushed blocks exceeded the stipulated levels.
- Incorporation of BFD (up to 50% m/m) in slag bricks fired at 1200 °C for 6 h gave a further improvement in the degree of Cr(VI) immobilisation as measured by the same leaching test procedures. The significantly greater proportion of BFD that can be incorporated in clay-fired (50% m/m) compared to cement-block (15% m/m) building materials, reduces the specific cost of treatment of BFD from estimated values of R235/t (cement-block route) to R190/t (fixed clay-brick route).
- Where it is possible to recycle BFD back to the furnaces, this is the most cost-effective option using in-house technology available in the industry, specifically where electric-arc furnace capacity is available. This finding is consistent with a generic situation in industry where it is usually preferable to minimise/recycle at source rather than to recover/beneficiate materials from waste streams. If the recycling of BFD is a successful option for utilising and disposing of BFD in the local ferrochrome industry, then it is only necessary to monitor the groundwater in the vicinity of these operations to ensure that there is no evidence of further Cr(VI) contamination.

Cost: *R205 000*
Term: *1998-1999*

Use of AQUASIM to model the performance of a bacterial sulphate reduction pilot plant treating acid mine drainage

(No K8/312) University of Cape Town – Department of Chemical Engineering

In the work carried out and reported on by the University of Cape Town (Department of Chemical Engineering) research team in this consultancy project, the AQUASIM simulation package has been successfully applied to literature data to develop a preliminary kinetic model for the multi-stage biological sulphate reduction ("BioSURE") process that was developed and operated by Rhodes University (Department of Biochemistry and Microbiology) in the remediation of acid mine drainage. Experimental data from pilot-scale trials at Grootvlei Mine were incorporated into the model to verify the kinetic parameters (although in a different temperature range than the literature values). An improved version of the model that was obtained was first used to optimise the pilot-plant studies and is currently being applied on a full-scale basis by **ERWAT** (WRC Project No 1169; *see* **Chapter 7**).

Further work remains to be done to improve certain aspects of the model, in particular: temperature effects; the (possible) acceleration of sludge hydrolysis in the presence of sulphur bio-systems; the effect of pH variations on the model behaviour; kinetic and equilibrium aspects relating to liquid-vapour mass transfer; and the mechanism and kinetics of sulphide inhibition. These aspects are being dealt with in follow-up research being carried out by the University of Cape Town by the Departments of Chemical Engineering and Civil Engineering.

Cost: *R85 000*
Term: *1998-1999*

New projects

Survey of pesticide wastes in the RSA and a preliminary study of their biodegradation

(No 1128) University of Natal – Pollution Research Group

The increasing use of chemical pesticides (including herbicides, fungicides, nematocides, etc) poses an ever-growing threat to the aquatic environment. This threat arises during production, distribution, storage, use and runoff of the toxic compounds concerned. The DWAF/DEAT National Waste Management Strategy (NWMS) has identified pesticides as an unquantified but significant environmental hazard, for which no national database exists in terms of mass pollutant discharges to the environment, potential (e.g. stockpiled) quantities, aquatic impacts (present and future, including also toxic breakdown products), diffuse and cumulative discharges from agricultural use, etc. Destructive disposal methods such as incineration of point-source discharges are strenuously opposed by environmental lobbies because of "transferring the problem" from a solid/liquid context to the atmospheric environment. Diffuse discharges of pesticides are not quantified, and the fate/efficiency of their breakdown in engineered treatment processes or natural ecosystems is not understood in terms of their life-cycle impacts.

In the project, the research outcomes would be a national schedule of pesticide production, distribution, storage and use, as well as a comprehensive survey of existing technologies providing treatment options for pesticides and associated waste products.

The aims of the project are to:

- Provide a comprehensive survey of existing technologies for the degradation of pesticides.
- Provide a comprehensive schedule of pesticide use, waste production and treatment options in the Southern African region.

Estimated cost: *R125 000*
Expected term: *2000-2002*

Further application and development of pinch analysis for water and effluent management

(No 1158) University of Natal – Pollution Research Group

Pinch analysis is an innovative technique developed to analyse all water and effluent streams in a factory, or even a group of factories, and to methodically find and manage the most "pinched" (i.e. constrained in terms of quality and quantity) water streams in order of priority in order to limit freshwater intake, effluent discharge and production costs. Initial results from the existing WRC water pinch analysis project (No 851) indicate that the three-year investment in the project will have been recovered by South African industry in a short period of time, even though only a few factories have been investigated to date.

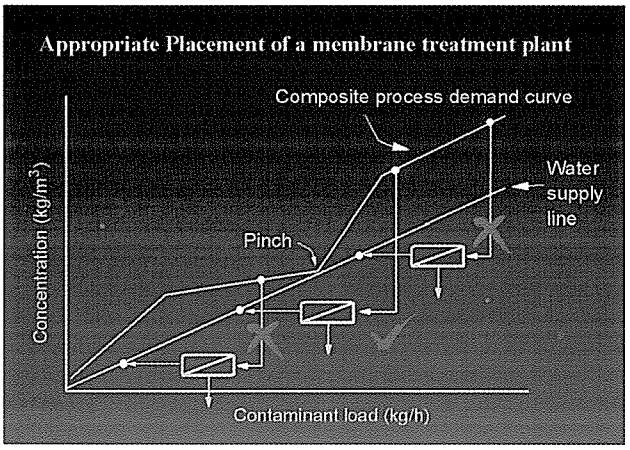
An example of an immediate large-scale application is that the City of Durban has proposed a scheme for the provision of reclaimed wastewater to Durban South industrial areas. However, pollutants from certain factories in the area may prejudice the reuse of water by other participating factories. Pinch analysis of the water use of the entire industrial community could provide a valuable tool to make such a scheme workable and beneficial to the whole community

by identifying the optimal technical decisions and targets. In this context, where co-regulation is a potential regulatory strategy being debated for the environmental control of industry, pinch analysis is a neutral tool that can be used by industry to set targets and to indicate their environmental performance to the public and the authorities.

The project aims to:

- Promote the widespread application of pinch analysis for the management of water and effluents.
- Develop the technique for specific problems associated with the South African industry.
- Promote better water management by undertaking pinch analysis studies at selected sites.
- Enhance the capacity within South Africa to undertake pinch analysis studies and to promote the wider understanding of this technique within educational institutions, industry and government by training people in the technique.

Estimated cost: *R1 603 000*
Expected term: *2000-2002*



An illustration of a hypothetical case of a plant where it was proposed to include a membrane plant to allow for recycling of water. Theory states that this will only be beneficial if it takes water from above the pinch and purifies it to a quality below the pinch.

Establishment of a methodology for initiating and managing waste minimisation clubs

(No 1171) University of Natal – Pollution Research Group

Current WRC Project No 973 (1998 to 2000) being carried out by the UND-PRG has been very successful in establishing the feasibility of "waste minimisation (wastemin) clubs" as a model for achieving significant improvements in local environmental performance by industry. In this multi-stakeholder approach, the interests of industry, regulatory authorities and affected communities are constructively combined. Two pilot wastemin clubs have been established in the Durban metropolitan region (one in the metal-finishing sector and one cross-sectoral in a major industrial area). The preliminary successes achieved have led to interest in establishing a third wastemin club in the Cape Town metropolitan area (by others). The approach has been endorsed in the DWAF/DEAT National Waste Management Strategy and in two DANCED-funded cleaner production projects aimed at the national metal-finishing industry and the textile industry in the RSA.

The main aim of the project is to develop a sustainable method of promoting and managing wastemin clubs, by producing, *inter alia*, a guide for effectively establishing and managing wastemin clubs, specific sectoral self-assessment guides, and training material for wastemin consultants in a quality-controlled operation.

Estimated cost: *R882 000*
Expected term: *2000-2002*

Effective design of woven fabric microfiltration and tubular filter press technologies for different process applications in South Africa

(No 1172) Umgeni Water

A number of WRC-funded projects have supported the development of woven fibre/cross-flow microfiltration technology for a variety of solids clarification and dewatering applications. In this proposal, long-term performance and operating/maintenance considerations are addressed in critical comparative assessment studies to be carried out by Umgeni Water and ML Sultan Technikon according to agreed task activities. The programme is aimed at optimising the tubular filter press (TFP) process and providing least-cost data from pilot-scale studies on an existing TFP plant which was re-installed at a suitable Umgeni Water waterworks to dewater waterworks sludges, and to compare the results to other full-scale dewatering technolo-

Polifin chlor-alkali plant in Durban. Development of pinch analysis for water and effluent management.

gies. Other applications of the TFP process (on textile and mining effluents) would be investigated on laboratory- and pilot-scale to assess the optimised viability of the process. The results obtained will provide a guide to the potential commercialisation of the TFP process, via an under-discussion multiparty joint venture technology company using a licence to a patent held by the WRC.

Estimated cost: *R587 000*
Expected term: *2000-2002*

Purification of wastewater with crown ethers and other macrocycles bound to water-soluble and/or elastomeric polymers

(No 1173) University of the Free State – Department of Chemistry

Current technological options for the treatment of industrial effluents containing inorganic pollutants mostly fractionate the effluent into dilute (clean) and concentrated portions. The dilute-treated effluents are difficult to polish further in a cost-effective manner because of their high-volume/low-concentration nature. Treatment and disposal of the resultant concentrated brines are problematic and expensive.

The technology to be investigated involves the development of a ligand system which can be tailored to selectively trap the contaminant ions in both high-concentration/low-volume as well as low-concentration/high-volume effluents. The ligand system will consist of macrocyclic crown ethers, anchored on a mobile polymer support which will allow the contaminants and the ligands to be brought into contact for trapping and then releasing of contaminants (regeneration of the ligands) for subsequent recovery, sale or recycling.

The specific technical aims of the project are to:

- Modify crown ethers and other macrocycles to ultimately allow for polymer anchoring.
- Develop a suitable polymeric (elastomeric or rubber-like) carrier to which the crown ethers can be anchored.
- Evaluate the polymer-bound macrocycles as sodium, calcium, chloride and phosphate scavengers of wastewater contaminants from both high-concentration/low-volume and low-concentration/high-volume contaminated wastewater systems.
- Develop techniques that will allow the release of these contaminants from the ligand/polymer matrix to allow its recovery for recycling purposes.

Estimated cost: *R780 000*
Expected term: *2000-2002*

Research projects

Completed

- **308** Recovery of water and chemicals from ion-exchange regeneration effluents (University of Natal – School of Chemical Engineering, Pollution Research Group)
- **546** Development and demonstration of effluent treatment systems appropriate to the needs of the red meat abattoir industry (SRK (CE) Inc.)
- **616** Use of algal and yeast biomass to accumulate toxic and valuable heavy metals from wastewater (Rhodes University – Department of Biochemistry and Microbiology)
- **759** NATSURV: Water and wastewater 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 – School of Chemical Engineering, Pollution Research Group)
- **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 – School of Chemical Engineering, Pollution Research Group)
- **766** Utilisation of earthworms and associated systems for treatment of effluent from red meat abattoirs (Multilog Division, Abakor Ltd.)
- **942** Solid stabilisation of soluble wastes from the ferro-alloys industry (Council for Mineral Technology, Mineralogy and Process Chemistry)
- **K8/312** The use of AQUASIM to model the performance of a bacterial sulphate reduction pilot plant treating acid mine drainage (University of Cape Town, Department of Chemical Engineering)

Current

- **331** Improved oxygen transfer for high biosludge concentrations (University of Pretoria – Department of Chemical Engineering)
- **455** Anaerobic digestion of dairy factory effluents (Agricultural Research Council – Irene Animal Production Institute)
- **457** Monitoring and optimisation study of high-rate biofiltration, aerobic biological treatment processes for tannery and fellmongery wastewater (Rhodes University – LIRI Technologies)
- **495** Biotechnological approach to the removal of organics from saline effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **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 wastewater (University of Stellenbosch – Department of Chemistry)
- **652** Purification of abattoir effluents by means of the protein reclamation process (Abakor Ltd.)

- **657** Course development for the education and training of industrial wastewater 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)
- **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)
- **763** Biotechnological approach to the management of effluents from the pulp and paper industry (University of the Free State – Department of Microbiology and Biochemistry)
- **778** Total recycling of effluent from the protein recovery process appropriate to the red meat and poultry abattoir industries (Abakor Ltd. – Multilog Division)
- **826** Operation and monitoring of the WRC/LIRI wastewater treatment pilot plant for industrial effluent research and training of wastewater treatment personnel (Rhodes University – LIRI Technologies)
- **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)
- **939** Development of bioreactor systems for the conversion of organic compounds in industrial effluents to useful products (Rhodes University – Department of Biochemistry and Microbiology)
- **940** Electrochemical treatment removal of phosphates and sulphates from sewage and acid mine drainage respectively (Anglo Operations Ltd. – Anglo Coal)
- **941** Research and development of electronic distance-learning methodology for the education and training of industrial wastewater treatment personnel (Rhodes University – LIRI Technologies)
- **972** Process development and system optimisation of the integrated algal trench reactor process for sulphate biodesalination and heavy metal precipitation in mining and industrial effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **973** Waste minimisation and effluent treatment clubs – Phase 1: Initial assessment and pilot study (University of Natal – Pollution Research Group)
- **1022** Mass culturing of granules for use in upflow anaerobic sludge blanket bioreactors (UASB) by process induction and microbial stimulation (University of Stellenbosch – Department of Food Science)
- **1033** Caustic management and reuse in the beverage bottling industry (ML Sultan Technikon – Department of Chemical Engineering)
- **1081** Optimisation of protein recovery in treatment of organic effluents : Feeding trials on biomass from pilot plant (DB Thermal (Pty) Ltd.)
- **1082** Further development of a biotechnological approach to the management of effluents from the pulp and paper industry (University of the Free State – SAPPI Biotechnology Laboratory)
- **1083** Assessment and application of the latest technology available for the bioremediation of heavy metal effluents (Technikon Natal – Centre for Water and Wastewater Research)
- **1084** Development of biological treatment technology for the remediation of edible oil effluent (Technikon Natal – Centre for Water and Wastewater Research)
- **1085** Upgrading of WRC/LIRI wastewater treatment pilot plant for industrial effluent treatment and training of wastewater treatment personnel (LIRI Technologies)

New

- **1128** Survey of pesticide wastes in the RSA and a preliminary study of their biodegradation (University of Natal – School of Chemical Engineering, Pollution Research Group)
- **1158** Further application and development of pinch analysis for water and effluent management (University of Natal – School of Chemical Engineering, Pollution Research Group)
- **1171** Establishment of a methodology for initiating and managing waste minimisation clubs (University of Natal – School of Chemical Engineering, Pollution Research Group)
- **1172** Effective design of woven fabric microfiltration and tubular filter press technologies for different process applications in South Africa (Umgeni Water)
- **1173** Purification of wastewater with crown ethers and other macrocycles bound to water-soluble and/or elastomeric polymers (University of the Free State – Department of Chemistry)

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12 Membrane technology

Membranes have emerged as effective unit processes which may be used in a wide range of water-related 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.

Brown water, typical of waters found along the South African South Coast. Treating this water to drinking standards without oxidative processes and the addition of chemicals is part of the membrane research effort of researchers at the University of Stellenbosch (Institute for Polymer Science, Department of Biochemistry) and ML Sultan Technikon (Water and Wastewater Technology Development Group). The innovative research is outcome based, fully South African, and will be applicable for use on other surface waters as well.

Membrane separation processes are not only relevant to first-world conditions, but also have a great potential for water supply to rural and peri-urban communities. Membrane-based systems have been developed and are being further evaluated for the supply of potable water to small communities in South Africa. The plight of small communities in the dry regions of South Africa, where only sea water or brackish groundwater is available, is also being addressed. A project for the development of a small solar-powered membrane system has recently been completed and the cost-effective supply of water from brackish sources using solar stills is being researched and evaluated at a small community in the Karoo. Fundamental aspects such as computational fluid dynamics, engineering, and microbiological and social aspects are being investigated in these initiatives. The locally-developed tubular filter press is being further evaluated and improved for the dewatering of sludges from drinking water and wastewater plants. Development is continuing on the prevention and control of membrane fouling. Noteworthy results in fouling control are being obtained with electromagnetic, physical, membrane surface modification, *in situ* enzymatic, and defouling-on-demand enzymatic methods. Research is being conducted on a promising new affinity separation membrane for the highly selective removal of wanted and valuable chemicals from water and wastewaters. Exciting new developments in affordable electro-conducting and catalytic membrane technology are being followed up and evaluated for both water and industrial effluent treatment. This research includes the development of novel proton-conducting membranes and the generation of ozone, using membrane technology. Work is continuing on the employment of bioreactors in the production of algal toxins for experimentation, the remediation of industrial effluents and the use of environmentally-friendly chitosan-based membranes for the adsorptive removal of heavy metals. A project has further been initiated for the treatment of South African high-strength leachates using reverse osmosis and electrodialysis.

The strengthening of the manpower base involved in research and development in the membrane field continued over the past year. Joint research and general co-operation among the Universities of Stellenbosch, Rhodes, Western Cape, South Africa, Potchefstroom, and the ML Sultan, Cape, Peninsula, Northern Gauteng and Vaal Technikons have not only resulted in exciting technical developments, but have also created a core of knowledgeable scientists and technologists in this field. Co-operation with private membrane manufacturing and supply organisations has resulted in increased local and foreign application of local membrane research and development.

During the year a national Co-ordinating Committee for Research on Water-Related Membrane Technology (CCMT) was established to assist the WRC in its role of co-ordination of water-related membrane research in the country. The inaugural meeting of this committee was held on 3 October 2000. (See also **Chapter 1**).

Completed projects

Design criteria for cross-flow microfiltration

(No 238) University of Natal – Pollution Research Group

Cross-flow microfiltration (CFMF) and associated technology has been demonstrated on particular effluent and sludge feeds in order to be able to produce high quality water and to be suitable for dewatering slurries. In this project the development of semi-fixed membranes, optimum pre-coat methods, cloth systems to cope with oily effluents, hydraulic flow conditions to initiate cleaning and improved manifold design to prevent tube blockages were investigated. The fundamental processes which are occurring in woven fibre cross-flow microfiltration were modelled. Dead-end microfiltration (DEMF) was also compared with the normal CFMF. A simple model was developed which compares the DEMF against a hypothetical best-performance CFMF. Using this model, it was found that operation in the DEMF was more favourable than the CFMF, both in

terms of area and power, for low concentrations. A final report has not been published on this research since all of the work performed under the project has been incorporated into, and has been surpassed by, the research performed in the following follow-up projects: No. 386 – **The development of a crossflow microfilter for rural water supply**; No 560 – **The development of a cross-flow microfilter to improve the performance of anaerobic digestors at wastewater treatment works** and No 568 – **The development of an EXXPRESS unit for the dewatering of waterworks sludges and the production of potable water**.

Cost: *R1 301 600*
Term: *1988-1994*

Polymeric and ceramic-based membranes for use in electromembrane reactors

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

The fouling of ion-exchange membranes by large organic anions together with their low chemical, mechanical and thermal stability, impose serious limitations on electromembrane separation processes. Chemical and electrochemical pretreatment techniques are promising means by which to reduce these problems.

A novel procedure for the coating of standard (Ionics) polymeric-electrodialysis membranes was developed by the project team in conjunction with Eskom. This coating renders the membranes more resistant to fouling by organic material. The modified membranes will be very useful in applications where organic material is present together with inorganic salts, such as the situation that exists in many industrial water and effluents from Sasol, Eskom and others. As another product from the project, a significant step was taken toward the development of ceramic membranes possessing conductive and catalytic properties for the oxidation of unwanted organic material. These properties of ceramic membranes, together with their high stability in aggressive media, allow their potential use for plating-effluent treatment, extraction of non-ferrous metals by electrodialysis, treatment of mine waters, electrochemical synthesis of acids and alkalis, and for the preparation of sodium hypochlorite disinfectant.

Cost: *R192 000*
Term: *1997-1998*

Development of a solar-powered reverse osmosis plant for the treatment of borehole water

(No 1042) Envig (Pty) Ltd – now Weir Envig (Pty) Ltd.

The main aim of the project was to design and construct a reliable reverse osmosis (RO) unit, powered by solar energy which was capable of producing potable water from brackish borehole feed for rural households or small communities. The concept is relevant to areas where small communities are spread over large areas, where the high cost of erecting large desalination plants and reticulation of desalinated water, or, alternatively, the piping of freshwater from other sources, is neither practically nor economically viable.

The unit was evaluated at a few relevant sites over an extended period. It proved to be easy to operate, very durable, and required little maintenance. Additional operator input did, however, prove to increase production, although stand-alone operation rendered acceptable production figures. The test work, completed mainly during the winter months, indicated that the unit produced potable water at 750 *l*/d with little input from an operator. This is sufficient to supply a full water service to five rural units or to meet the drinking water requirements of up to 40 people in a rural setting. Basic and practical guidelines are provided for the sizing and choice of a reverse osmosis unit and a solar cell combination, which will be useful to all consultants and decision-makers responsible for the planning and implementation of water supply from saline groundwater sources.

Cost: *R85 000*
Term: *1999*

Ion-exchange and reverse-osmosis technology for water defluoridation, water denitrification and water desalination

(K8/220) CSIR – Division of Water, Environment and Forestry Technology

This project concentrated on demonstrating the feasibility of using advanced adsorption, ion-exchange and membrane technologies to remove fluorides, nitrates and dissolved suspended solids from groundwater in order to produce potable water for rural communities which are remote from first-world infrastructure. In many areas in the country, such as North West, Northern and Northern Cape Provinces and the Karoo areas, groundwater contains high levels of fluorides, nitrates and other dissolved salts, preventing the use of this water for potable consumption.

Activated alumina, ion-exchange and reverse-osmosis systems were evaluated at a number of rural sites in terms of both technical and social acceptance factors. The results achieved in these demonstration studies show that activated alumina and ion-exchange processes and advanced water treatment processes such as membrane filtration can be employed successfully for the purification of adverse-quality groundwater to potable standards in the rural areas. An advantage of membrane desalination is that the reject water may still be used for stock watering or gardening under most circumstances. Guidelines on the removal of dissolved solids, fluorides and nitrates from groundwater, under the conditions investigated, were compiled. Even when using membrane treatment, total water purification costs (i.e., including running costs and capital redemption) of equal to or below R4/m^3 were realised.

Cost: *R 60 000*
Term: *1996-1997*

New projects

Development of a novel membrane photo-bioreactor for the production of algal toxins

(No 1103) Rhodes University – Department of Biochemistry and Microbiology

The phenomenon of algal toxins in surface waters is regarded as a serious problem to human health. This research group at Rhodes University had previously developed and patented the idea of a "gradostat" reactor, which ensures a nutrient gradient across a layer of fungal micro-organisms, thereby pressurising the organisms from the nutrient-deficient region into the production of enzymes as a method of survival. It is intended to employ the same principle in this research. However, in this instance, algae will be put under nutrient and light gradient stress to force them into the production of scarce and expensive algal toxins. An abundance of inexpensive algal toxins will greatly stimulate research on the effects and prevention of algal toxicity. The potential of this system for nutrient removal from contaminated surface or groundwater will also be evaluated.

Estimated cost: *R81 000*
Expected term: *2000*

Development of a membrane bioreactor system using the white-rot fungus *Trametes versicolor* for bioremediation of industrial wastewater

(No 1129) Rhodes University – Department of Biochemistry and Microbiology

In a previous project funded by the WRC (No 687 – **Membrane-based biotechnological systems for treatment of organic pollutants**) this research group performed laboratory investigations on the organics removal capabilities of a number of fungi from the white-rot group using single-fibre membrane reactors. One fungus, *Trametes versicolor*, showed excellent potential for the removal of aromatic hydrocarbons, and especially for the recalcitrant chlorinated aromatics. At the end of the project it was recommended to take this laboratory-scale work to pilot scale, in order to further develop the technology and to take advantage of the large specific surface area and the separation capabilities of membranes as bioreactors. The project aims to develop a practicable bioremediation process for using the enzymes of *Trametes versicolor* to degrade chorinated aromatics and polyphenolics produced by the local pulp-and-paper and petrochemical industries.

Estimated cost: *R533 000*
Expected term: *2000-2002*

Effluent harvesting and detection of steroidogenic agents by affinity separation

(No 1165) University of Stellenbosch – Institute for Polymer Science

The project is based on a technology developed under a recently completed WRC project, (No 769 – **Development, fabrication and production protocol for capillary and hollow-fibre membranes and special modules for the low-cost treatment of contaminated water**). This innovation entails the non-chemical binding of the "foot" of a long-chain substance to the surface of the membrane. The two "arms" of this molecule are hydrophylic and swing freely in the water phase. A carefully-selected ligand is then attached to the active end of each of these "arms". This ligand is chosen so that it is able to "catch" certain wanted substances from the effluent which is being filtered through the membrane. At the same time, the hydrophylic long-chained molecule prevents fouling of the membrane. The concept has been proven in the laboratory by selectively removing high-value bovine serum albumin while clarifying abattoir effluent.

The implication of this innovation is that various high-value products could be harvested while treating either industrial or municipal effluents, thereby off-setting the relatively expensive membrane costs, or even effecting a profit. A further application of the technology suggested in this proposal is the analysis of low-concentration steroidogenic components, such as oestrogen or the oestrogen-mimicking compounds in surface or drinking water.

Estimated cost: *R1 560 000*
Expected term: *2000-2002*

Visualising the effects of electromagnetic and turbulence defouling techniques in membrane modules

(No 1166) University of Stellenbosch – Institute for Polymer Science

The overall aim of this project is to apply visualisation tools to monitor and control the fouling on membrane surfaces. The study intends to "visualise" what happens right on the surface of a membrane by using non-interfering fouling layer measurement techniques. The biggest stumbling block to the free and inexpensive application of membranes in water and wastewater treatment is the fouling phenomenon taking place on the surface of the membrane material. Various techniques to clean a fouled membrane or to prevent the membrane from fouling are being investigated. However, most of these techniques suffer from the current inability to measure or "see" the resulting effects in real time and not only after a period of months. Using the envisaged visualisation technique, the effects of changes made when investigating any of the membrane defouling methods will be noticed immediately without interfering with the membrane module or its operation in any way. Should this project be successful, it will enhance research on membrane fouling and greatly facilitate the use of membranes in future.

Estimated cost: *R992 000*
Expected term: *2000-2002*

Development of electrodialysis and reverse osmosis process technology for the treatment of hazardous municipal leachates

(No 1167) CSIR – Division of Water, Environment and Forestry Technology

Municipal leachates are regarded as one of the most pressing pollution problems in South Africa, and one of the most difficult problems to solve. Current oxidation technologies, such as ozone, ultraviolet light and hydrogen peroxide are not adequately effective for the detoxification of leachates, or for the removal of high concentrations of salts – which are integral to most leachates. Therefore, membrane processes have been offered as an alternative internationally as a possible and feasible solution to the leachate problem. Membrane treatment can remove both the organic and inorganic pollutants and the small volumes of concentrates may then be dried and pelletised, or immobilised in power station ash or in cement. The main aim of this project is to develop a combined electrodialysis and reverse osmosis process technology for the treatment of typical South African hazardous municipal leachates – which contain mainly high total dissolved solids (TDS) and high organic concentrations. The secondary aim of the project is to also evaluate reverse osmosis technology on hazardous municipal leachates with low TDS and low organic concentrations.

Estimated cost: *R630 000*
Expected term: *2000-2001*

Research projects

Completed

- **238** Design criteria for cross-flow microfiltration (University of Natal – Pollution Research Group)
- **844** Polymeric and ceramic-based membranes for use in electromembrane reactors (University of the Western Cape – Department of Applied Chemistry)
- **1042** Development of a solar-powered reverse osmosis plant for the treatment of borehole water (Envig (Pty) Ltd. – now Weir Envig (Pty) Ltd.)
- **K8/220** Ion exchange and reverse osmosis technology for water defluoridation, water denitrification and water desalination (CSIR – Division of Water, Environment and Forestry Technology)

Current

- **201** Treatment of inorganic brines and concentrates (University of Natal – Pollution Research Group)
- **723** Designed functionalised polymers by anionic macro-molecular engineering for membrane development (Vista University, Port Elizabeth Campus – Department of Chemistry)
- **769** Development of the 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)
- **846** Development of a continuous-flow membrane bioreactor (University of the Western Cape – Department of Microbiology)
- **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)
- **930** Water desalination and clarification by electronically enhanced membrane defouling (Mineral Water Development (Pty) Ltd.)
- **931** Transverse-flow module fabrication technology development (University of Stellenbosch – Institute for Polymer Science)
- **932** Development of a "defouling on demand" strategy for the operation of bio-active membranes (Rhodes University – Department of Biochemistry)
- **964** Electromembrane reactors for desalination and disinfection of aqueous solutions (University of the Western Cape – Department of Chemistry)
- **965** Capillary ultrafiltration membrane process systems R and D (University of Stellenbosch – Institute for Polymer Science)
- **1034** Microbiological assessment of membrane technology in water treatment (ML Sultan Technikon – Biological Sciences)
- **1035** Implementation of membrane cleaning and pretreatment techniques for membranes fouled during the filtering of pulp-and-paper effluent (University of Stellenbosch – Department of Biochemistry)
- **1071** Electrochemical generation of high-concentration ozone in compact integrated membrane systems (Dinax Technologies cc and University of Stellenbosch – Department of Chemistry)
- **1072** Development of environmentally friendly bio-polymeric heavy metal adsorbing membrane materials for industrial wastewater treatment (Potchefstroom University for CHE – Department of Chemical and Mineral Engineering)

New

- **1103** Development of a novel membrane photobioreactor for the production of algal toxins (Rhodes University – Department of Biochemistry and Microbiology)
- **1129** Development of a membrane bioreactor system using the white-rot fungus *Trametes versicolor* for bioremediation of industrial wastewater (Rhodes University – Department of Biochemistry and Microbiology)
- **1165** Effluent harvesting and detection of steroidogenic agents by affinity separation (University of Stellenbosch – Institute for Polymer Science)
- **1166** Visualising the effects of electromagnetic and turbulence defouling techniques in membrane modules (University of Stellenbosch – Institute for Polymer Science)
- **1167** Development of electrodialysis and reverse osmosis process technology for the treatment of hazardous municipal leachates (CSIR – Division of Water, Environment and Forestry Technology)

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13 Hydroclimatology

Hydroclimatology is viewed by the WRC as being an area which encompasses atmosphere-related science and technology in the water industry and the community of water users in South Africa.

The strategic plan for hydroclimatological research makes provision for research in six areas, namely:

- Precipitation monitoring systems and networks for water resource assessment, development and management.
- The generation and beneficial use of weather and climate predictions in support of water resource management.
- The impacts of atmospheric change and atmospheric variability on the water resources of South Africa.
- Impacts of aerosols of natural and anthropogenic origin on the hydroclimatology of South Africa.
- Methods of monitoring evaporation from land surfaces (transpiration included) and water bodies.
- Harvesting of cloud water.

In addition to a number of stand-alone projects, a formal research programme, **Real-time mapping of daily rainfall over South Africa for water resource applications**, has been structured to address the first of the above-mentioned research areas. In this programme, networked weather radars, used in conjunction with satellites and rain gauges in a complementary and integrated fashion, form the basis of a monitoring system which is being designed to provide countrywide rainfall data in near-real time at high spatial and temporal resolution. The programme, being undertaken in close collaboration with the South African Weather Bureau, currently contains three projects: One deals with the development and refinement of the infrastructure which is needed to achieve the goals; the second focuses on improving radar and satellite products needed for quantitative rainfall measurement; the third seeks to overcome difficulties in merging rainfall data of different types and from different sources in order to arrive at the best possible product in terms of accuracy, spatial coverage and resolution. Further projects which are envisaged within this programme are pilot applications of real-time spatial rainfall data which would evaluate and quantify benefits in terms of improved water resource management.

Understanding and predicting climatic and hydrological variability, in order to better predict and manage climatic impacts on South Africa's water resources, are supported by a range of current research projects. The key role of the oceans in this quest to understand and predict climate variability is acknowledged by the inclusion of projects which investigate sea-air relationships, model them numerically and examine the ability of coupled ocean-atmosphere models to simulate known atmospheric behaviour in a satisfactory manner. The projects also encompass a wide range of time scales, recognising the potentially-devastating impacts of short-term extreme events (floods) and the long-term effects of global climatic change.

The 3-year field observational phase of the Aerosol Recirculation and Rainfall Experiment (ARREX) project which examines the transport of aerosols, mainly of anthropogenic origin, and investigates their influence on cloud processes and rainfall characteristics, is nearing completion. Preliminary data analyses have revealed much promise and further scope for more detailed analyses to be undertaken over the next two years. This project helped to spawn, and benefited from, the larger, much publicised, SAFARI 2000 experiment which was jointly undertaken by the USA's National Aeronautics and Space Administration (NASA) and a number of Southern African scientific teams and funding agencies. SAFARI 2000's goal was to understand links between emissions from both anthropogenic and natural land-based sources, the transport of emissions over the subcontinent and the impacts of deposition of atmospheric constituents on the environment.

The two hydroclimatology research thrust areas which are currently receiving minimal attention are those concerned with methodologies for monitoring evaporation and harvesting of cloud water. With regard to the latter, a small project (listed under **Chapter 2 – Rural Water Supply and Sanitation**) has been resoundingly successful in demonstrating the feasibility of fog harvesting for the provision of potable water to a small rural community.

Completed projects

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

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

This project was a sequel to project No 843 (**The development of a real-time, non-conventional rainfall mapping system**) which had been relatively successful in producing algorithms for deducing rainfall data for large-scale continental convective rainfall systems from Meteosat data. The purpose of this follow-on study was to investigate the feasibility of extending the satellite rainfall-estimation approach to coastal zone cloud systems. Results were negative in the sense that little potential for the successful use of satellite data for rainfall measurement in coastal situations was revealed. However, the project did provide useful information on the current capacity of weather radar installations at coastal sites in order to provide rainfall data of acceptable accuracy.

Cost: *R121 000*
Term: *1994-1996*

Weather radar measurement of rainfall as well as hydrological applications of weather radar

(No 693) University of Pretoria – Department of Civil Engineering

This project was initiated soon after the installation, near Bethlehem, of an MRL-5, Russian-built dual-band (S, X) weather radar. The purpose was to investigate the acquisition of quantitative rainfall data by the radar at temporal and spatial scales (and resolution) suitable for hydrological applications. To facilitate this, a high-density network of 20 recording rain gauges, covering an area of approximately 20 km^2, was established about 60 km east of the MRL-5 radar. Measurements permitted radar- and gauge-derived rainfall estimates to be compared on an areal and on a pixel-by-pixel basis. Comparisons revealed that radar had good potential of providing accurate rainfall information, both at wide-ranging spatial (down to pixel, i.e. 1 km^2 resolution) and temporal (season down to event) scales. Studies on a large number of individual rainfall events supported the use of the conventional Marshall-Palmer Z-R relationship for converting the radar reflectivity factor (Z) to rain rate (R). There were, however, indications that event- and/or storm-based classification might be useful for assigning reliability ratings to radar-derived rainfall for different classes of events.

Cost: *R759 985*
Term: *1995-1999*

Dynamic modelling to investigate the regional climate response to global change forcing

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

In order to address, more effectively, potentially serious consequences of global climate change for South Africa, this project sought to:

- Develop a viable base for regional climate change studies through process-based modelling.
- Adapt and evaluate nested modelling procedures.
- Develop skills and expertise in regional climate modelling among local scientists and students.
- Formulate process-based regional climate-change scenarios to complement those generated using empirical techniques.

Capacity-building, which is reflected strongly in the above objectives, was achieved through the establishment of a computational system which was capable of supporting climate change modelling activities and the installation, validation and use of suitable global and regional climate models. Furthermore, a core group of scientists and students, having key expertise in running the models and understanding the related operational difficulties and model capacities, has been established. In experiments with global models, simulated climate dynamics were found to fall within the observed variability of the climate system and, when doubled CO_2 was assumed, modelled responses corresponded with physical principles. In experiments with regional models, the Laingsburg flood event of 1987 was well-simulated and, when driven by coarse-resolution global simulation data, the regional model effectively captured regional detail over the subcontinent, including the complexities of topographic forcing.

Cost: *R474 559*
Term: *1997-1999*

New projects

Spatial interpolation and mapping of rainfall: Maintenance and upgrading of radar and rain gauge infrastructure

(No 1151) SA Weather Bureau – Meteorological and Technology Systems

This project is a component project of a WRC-sponsored research programme entitled: **Real-time mapping of daily rainfall over South Africa for water resource applications**. The umbrella programme provides the framework for research and development which is needed to put in place, for the entire country, a rainfall monitoring system which is capable of providing rainfall data in near-real time at the highest possible spatial resolution permitted by available hardware, whether this includes rain gauges, radars or satellite-borne instrumentation or any combination of these. There is a crucial need for such information for both water resource and disaster management, especially given that the number of rain-gauge stations reporting daily for the benefit of South Africa has dwindled to a mere 600.

This project aims to provide the foundation for optimal utilisation of the country's rain-gauge and radar infrastructure in satisfying the national needs for rainfall monitoring. It will extend a current pilot project being undertaken in the Vaal Dam catchment to include mountainous and coastal regions. The current project has produced enhanced radar hardware, software and signal-processing systems, applied to S-band and C-band radars sited near Bethlehem and Irene, respectively, in order to make them reliable instruments for rainfall measurement. Data formatting, transmission, mapping and the display of real-time maps on the Internet have also been preliminarily mastered. The project seeks necessary refinements, and the development of guidelines for the maintenance and operation of larger radar networks intended for routine, precision rainfall measurement. It also seeks to provide the infrastructure for overcoming specific problems associated with radar measurements in mountainous and coastal areas and in specific atmospheric conditions, frequently encountered in such areas. Furthermore, it seeks to set up dense temporary rain-gauge networks for calibration and verification purposes in new geographical settings. These are necessary steps in the quest to assist the Weather Bureau, the custodian of available radar installations, to use such installations to their full potential as part of the national rainfall monitoring system.

Estimated cost: *R1 647 000*
Expected term: *2000-2002*

Spatial interpolation and mapping of rainfall: Radar and satellite products

(No 1152) SA Weather Bureau – Meteorological and Technology Systems

This project is a component project of a national research programme entitled **Real-time mapping of daily rainfall over South Africa for water resource applications**.

The project aims to refine and extend procedures whereby radar and satellite data are converted into the best possible rainfall measurements for areas of data coverage in Southern Africa. The emphasis will be on ensuring reliability of data from radar and satellite sources, through the removal of spatial bias, filtering of effects of potential sources of error such as melting layer bright-band effects, anomalous propagation, ground clutter, etc., and ensuring the reliability of all algorithms developed and employed. In this regard the potential of the USA's NASA TRMM satellite for instantaneous wide area inter-calibration of data sources will be utilised wherever possible. Finally, using techniques developed in the sister project **Optimal integration of rain gauge, radar and satellite-derived rainfall data** (No 1153), merged, high-resolution, digital maps of daily rainfall for South Africa will be produced on a trial basis with a view to operational production. Such maps and their underlying digital data are not only sought for water resource applications, but also for agricultural applications and disaster management.

Estimated cost: *R318 000*
Expected term: *2000-2002*

Spatial interpolation and mapping of rainfall: Optimal integration of rain-gauge, radar and satellite-derived data in the production of daily rainfall maps

(No 1153) University of Natal – Department of Civil Engineering

This project is a component project of a national research programme entitled **Real-time mapping of daily rainfall over South Africa for water resource applications**.

The project aims to optimise the process of merging different rainfall data sources available over a designated time interval and area in order to obtain the best (most reliable) estimates for that time/space interval. Rain gauges will remain an important source of data, but they differ from radar and satellite sources in that the former provides point data and the latter two provide spatially-distributed data. Thus, part of the merging process will be to infer, with the assistance of space-time rainfall modelling and interpolation procedures addressed in previous and ongoing WRC projects, what the most likely spatial distribution of daily rainfall recorded by rain gauges would have been. The merging procedures will have to take into account that there will be instances where either one, two, or three of the possible rain-gauge, satellite and radar data sources are available, and utilise these sources preferentially according to potential reliability and spatial and temporal resolution.

The final product of this research, produced in conjunction with the sister project **Radar and satellite products**, will be merged, higher-resolution, digital maps of daily rainfall for South Africa, produced on a trial basis with a view to immediate operational production.

Estimated cost: *R270 000*
Expected term: *2000-2002*

Dynamic modelling of present and future climate system variability at inter-annual and inter-decadal time scales

(No 1154) University of Cape Town – Department of Environmental and Geographical Sciences

Recent years have seen considerable progress being made in the conceptual understanding and numerical modelling of atmospheric dynamics over the Southern African region. Nevertheless, it is recognised that much of the current understanding is still based on hypotheses which need to be substantiated or improved in order to be able to use models optimally to predict the variability of the present and future climate system at annual and decadal time scales. This is becoming especially important in the light of the increasingly convincing evidence that significant climate change is occurring in response to both anthropogenic and other factors. Such change is bound to have an impact both on the availability and the demand for water in South Africa.

The research aims to maintain and extend South Africa's research capacity in climate modelling and to provide South Africa's water resource planners and managers with increasingly realistic and reliable future climate scenarios at the seasonal, annual, and decadal time scales. The specific objectives of the research are to:

- Continue capacity-building and developing in dynamic modelling of the physical climate system as it impacts on Southern Africa.
- Identify and interpret dynamic process controls of past and present variability in the Southern African climate system relating to vulnerability of water resources and agriculture.
- Investigate the dynamics of extreme events through case study modelling.
- Interpret the future dynamics of the processes controlling climate. variability and refine climate change scenarios with the objective of better projecting climatic impacts on society and natural resources, and providing information for the development of policy and management options.

Estimated cost: *R1 616 000*
Expected term: *2000-2003*

Development of an improved gridded database of annual, monthly and daily rainfall

(No 1156) University of Natal – School of Bioresources Engineering and Environmental Hydrology

A previous WRC project (K5/109) completed in 1987 produced a gridded (1`x1`) database of mean annual precipitation (MAP) and associated monthly rainfall series over Southern Africa. This data set has proved to be one of the most used and valuable data sets in the water management field. Since its inception, there has been a shift in demand towards more detailed data both in terms of time (daily) and space (finer grid).

Since this previous project was started, about 20 years of additional rainfall data and more detailed data on physiography and topography have become available. Results of pilot studies with updated, fixed period and quality-controlled data sets along the North Coast of KwaZulu-Natal show marked differences compared with results using the 1987 values. Moreover, computing techniques and the emergence of GIS and spatial analysis software have created a great opportunity for improved data analysis and synthesis on a national scale. It is estimated that this proposed work will considerably improve the information for more than 60% of the present data set.

All the research will be undertaken in the School of Bioresources Engineering and Environmental Hydrology in co-operation with the

Computing Centre for Water Research, the Weather Bureau and the Institute for Soil, Climate and Water of the Agricultural Research Council.

The specific aims of this research are therefore to:

- Develop revised maps of annual, monthly and daily precipitation and related rainfall statistics on a refined roster base.
- Develop and use new regionalised infilling/data extension techniques and updatable regionalised regression functions.
- Automate input into hydrological simulation models using GIS.

Estimated cost: *R2 277 600*
Expected term: *2000-2002*

Research projects

Completed

- **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)
- **806** Dynamic modelling to investigate the regional climate response to global change forcing (University of Cape Town – Department of Environmental and Geographical Science)

Current

- **804** Acquisition of off-shore marine sediment samples for palaeoclimatic and hydrological record reconstruction (University of the Witwatersrand – Climatology Research Group)
- **868** Modelling variability in the Agulhas Current system and its influence on South Africa's climate (University of Cape Town – Department of Oceanography)
- **903** Development of optimum statistical long-range forecast models of summer climate and hydrological resources over Southern Africa (University of Zululand – Department of Geography)
- **904** Seasonal climate predictions with a coupled atmosphere/ocean general circulation model: A contribution to water resource management over Southern Africa (University of Pretoria – Department of Civil Engineering)
- **938** Aerosols, recirculation and rainfall experiment (ARREX) (University of the Witwatersrand – Climatology Research Group)
- **953** The ocean's role in South Africa's rainfall (University of Cape Town – Department of Oceanography)
- **954** Integrated radar-based precipitation observing system for the Vaal Dam catchment to facilitate water resource operations and research (Weather Bureau – Department of Environmental Affairs and Tourism)
- **1005** A real-time flood forecasting model using radar and satellite data (University of Natal – Department of Civil Engineering)
- **1010** Space-time modelling of rainfall using the string-of-beads model: Integration of radar and rain-gauge data (University of Natal – Department of Civil Engineering)
- **1011** Short-term weather forecasting techniques dedicated to flood management systems (University of Pretoria – Chair of Meteorology)
- **1012** Climatology of water vapour sources, sinks and transport in Southern Africa (University of Cape Town – Department of Environmental and Geographical Sciences)
- **1013** Reconstruction of long-term, high-resolution records of summer rainfall and its variability on South Africa from cave speleothems (University of Cape Town – Department of Archaeology)

New

- **1151** Spatial interpolation and mapping of rainfall: Maintenance and upgrading of radar and rain-gauge infrastructure (SA Weather Bureau – Meteorological and Technology Systems)
- **1152** Spatial interpolation and mapping of rainfall: Radar and satellite products (SA Weather Bureau – Meteorological and Technology Systems)
- **1153** Spatial interpolation and mapping of rainfall: Optimal integration of rain-gauge, radar and satellite-derived data in the production of daily rainfall maps (University of Natal – Department of Civil Engineering)
- **1154** Dynamic modelling of present and future climate system variability at inter-annual and inter-decadal time scales (University of Cape Town – Department of Environmental and Geographical Sciences)
- **1156** Development of an improved gridded database of annual, monthly and daily rainfall (University of Natal – School of Bioresources Engineering and Environmental Hydrology)

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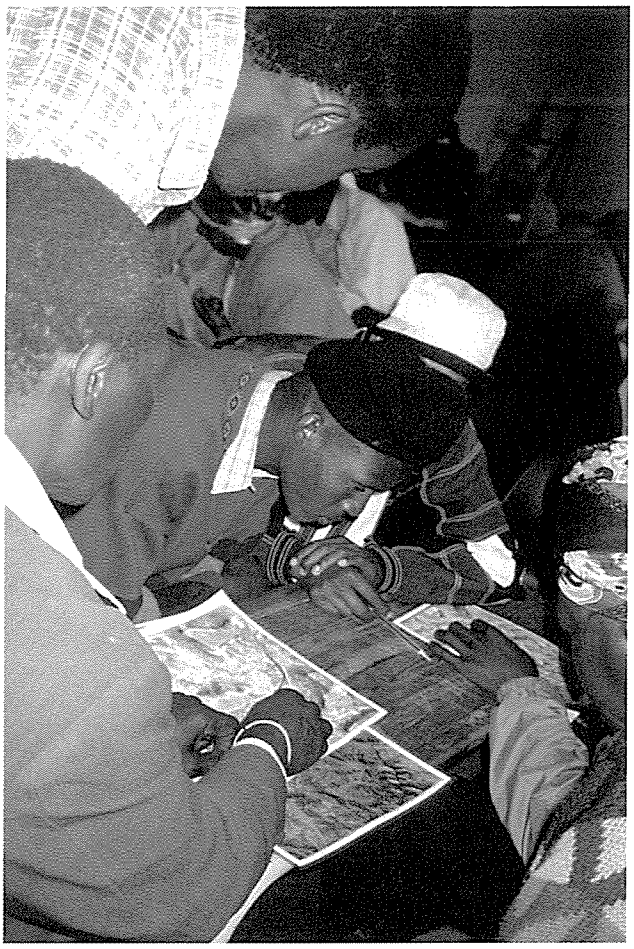
14 Integrated water resource management

In February 2000 a milestone was reached when the WISA Division on River Basin Management, Division of Management and Institutional Affairs, DWAF and the WRC organised a well-attended workshop. The title of the workshop was: Catchment Management in South Africa: Turning Policy into Practice.



One of the outstanding conclusions of the workshop was that the management objective for integrated water resource management is *what people do with water*. It, therefore, became clear that we need a focus on people, their behaviour and the way in which they organise themselves. We need a shift from a technocratic approach to a social behaviour approach. With the imminent establishment of catchment management agencies, there is an overwhelming amount of activity in the country and it is becoming increasingly important that experiences are shared. Public participation needs to evolve through a continuous process of deepening our democratic society, based on empowerment of communities, where we build on existing local experience, taking into account our cultural diversity and the realities of our bio-physical landscapes.

There is presently a strong groundswell of interest in catchment management. We need to develop key performance indicators and tools for evaluating progress and successes or failures. There is a growing need for information at various levels of detail. At various levels in society, people are becoming involved in different aspects of integrated water resource management. All this human activity should become a research programme in action: Action, learning and reflection...

Completed projects

Technology transfer of computer programs and other tools for management of flood plains within catchment areas

(No 358) University of the Free State – Department of Agricultural Economics

In previous WRC-funded projects, research was done on loss functions to estimate in advance flood damage for floods with different probabilities of occurrence. During the first phase, models were developed and loss functions were compiled. During the second phase, models were refined and tested for application on a wider range of flood plains. The third and final phase, which is due to be completed in 1999, involves user-friendly adaptations of models. With the aid of these models, flood damage control planning can be undertaken and the associated major financial benefits, due to reduced flood risks, can be quantified in urban and irrigation areas. The flood damage simulation models, called FLODSIM and TEWA, are ready for operational application and need to be transferred to prospective users.

The White Paper on Disaster Management requires proactive action, which is only possible if appropriate decision-support systems are available. This support can now be provided with the aid of the flood damage simulation models. It will enable local, provincial and national authorities to formulate sustainable flood management plans, which form an integral part of disaster management. In this way a contribution will be made to the implementation of the policy on disaster management. Support for such action has, therefore, been expressed by the Department of Provincial Affairs and Constitutional Development and DWAF.

New concepts and approaches are being introduced for the management of flood plains in catchment areas. Training of officials or agents of local, provincial and national authorities, who are responsible for flood management is, therefore, essential. The need for such training and assistance with disaster management has already been expressed by local and provincial governments in the Gauteng, Free State and North-West Provinces. Requests in this regard have been directed at the Department of Agricultural Economics, University of the Free State (UFS), who have the staff, expertise and skills to present workshops and other training sessions.

The main aim of this project is to transfer decision-support systems for flood management to local, provincial and national authorities and to promote pro-active disaster management.

Cost: *R300 000*
Term: *2000*

Multi-level decision support for the control of alien invasive plants in South Africa

(No 807) CSIR – Division of Water, Environment and Forestry Technology

The structure and development of an Internet-based Gateway to Knowledge on alien invading plant management in South Africa is described. The Internet serves as the medium for a strategic, co-operative approach by permitting input from diverse sources and facilitating communication. The Gateway takes the form of a web-site linked to relevant databases, spatial information, and related websites.

The structure of the Gateway reflects a national collaborative strategy for alien plant management in South Africa by addressing the entire invasion process (from pre-introduction screening to long-term management and rehabilitation of damaged ecosystems) at multiple levels (global, continental, national, provincial, biome, catchment, local authority and on-site) in a holistic manner; treating plant invasions as one of many contributors to environmental degradation and considering multiple objectives (e.g. agricultural productivity, conservation of biodiversity, water use and socio-economic cost-benefit). The fynbos biome is covered in-depth and sets a precedent for the other biomes (broadly Savanna, Nama-Karoo, Grassland, Forest and Aquatic/riparian).

This report summarises the structure of the Gateway and suggests a way forward, based on the insights and experience gained during collaborative development.

Databases need to be accessed via the Internet:
http//aliens.csir.co.za/plants

Cost: *R352 945*
Term: *1997-1998*

Socio-economic impact of the Komati River basin development with special reference to irrigated agriculture

(No 888) Conningarth Consultants

Since the formal start of the Komati River Basin Development Project (KRBDP) in 1990, questions were raised as to whether the objectives of the project can be realised effectively. In particular, more certainty was required with regard to the prospective benefits to the communities that were initially targeted for development purposes. The main aim of this research was to make use of the social accounting matrix (SAM) as an analytical tool to quantify the impact of the irrigation projects on the social and economic aggregates that form part of the economy of both the Kingdom of Swaziland and the Republic of South Africa. The SAM is well-known for displaying a wide range of social, institutional, demographic, financial and economic aggregates as well as their fundamental economic inter-relationships.

According to the SAM-analysis, the major growth has occurred in especially the agricultural sector and to agricultural processing industries after the KRBDP came into operation. For example, the economy of the study area (in real terms) has expanded by R408 million (1996 prices) which is an increase of 15%. As could be expected, the agricultural sector together with the agricultural processing developments in both regions experience ever larger expansions. In the case of the Swaziland region, a near doubling (± 79%) of agricultural activities occurs. From a socio-economic point of view, the substantial increase in the number of small enterprises in agriculture will do much to promote a sustained process of development affecting a wide range of interest groups such as informal/formal trade, businesses and traditional financial and business services. Owing to the fact that most of the emergent irrigation farmers were previously engaged in subsistence farming and other informal activities, their increased cash income will inflate the market for locally-produced food and other basic needs.

Due to the low base as well as the limited industrialised structure of the two economies, the upsurge in agricultural and related production does not really filter through to other sectors and commodities. The only exceptions are the electricity and water sectors, but this also occurs from low bases. The conclusion can, therefore, be drawn that despite the size of the project, it does not lead to the diversification of the economies in question as would have been preferred.

Cost: *R405 620*
Term: *1998-1999*

Feasibility of using a risk-based approach to setting integrated environmental objectives for protection of water resources

(No 914) Rhodes University – Geography Department

The report produced comprises 3 sections. The first section assesses the feasibility of using a risk-based approach for setting integrated environmental objectives for the protection of water resources. The second and third parts are the proceedings of workshops. **Part 2** deals specifically with the use of risk-based objectives (RBO) in water resource management, and **Part 3** covers the findings of a workshop where RBOs were used to set flow requirements for rivers.

In **Part 1**, against a background of resource quality objectives (RQOs), the concept of risk, and the feasibility of using RBO for the management of RQO is examined. This necessitates the integration of risk objectives and risk criteria with ecological and management objectives.

The proceedings of the workshop on RBOs in water resource management highlighted the need for information on stressor-response relationships. The experimental work is normally done on a single species using a single stressor (e.g. toxin, etc.). The result is then extrapolated to ecosystem scale, often involving other species. Without the knowledge of the stressor-response relationship, it is difficult to know how much confidence to place on the results.

In **Part 3**, the proceedings of the workshop using RBO to set flow requirements tested 2 methods of setting the quantity component of the ecological reserve. These were:

- The *less frequency/assurance* method
- The *less depth* method.

The former generates different assurances of maintenance flows for different ecological management classes (EMC), i.e. maintain the depth, velocity, etc., but alter the assurance. The latter gives a way of motivating for higher or lower flows for different EMCs.

These were used on a range of rivers for which data were available, and there was no generic preference for one or the other as they offer different products.

Finally, two papers (by Hughes and O'Keeffe respectively) make a first attempt at developing a framework for defining the different levels of flow-related stress for instream fauna.

Cost: *R52 290*
Term: *1998-1999*

New projects

Estimation of the value of water in the commercial forestry sector for selected areas in SA

(No 1133) University of Natal – Department of Economics

Water requirements for afforestation are estimated at 16 x 10^6 m^3/a or 8% of the total requirements. According to the National Water Act, "the use of land for afforestation which has been or is being established for commercial purposes" has been synonymous with a streamflow reduction activity. This means that both the volume and efficiency of water use in commercial forestry is under scrutiny. So far, the main focus of water research in forestry has been on the input side by modelling water use of trees. Very little research has been done on the output side and, specifically, on modelling the value of water for forestry. With increasing competition between forestry and alternative uses, attention will have to be given to the value of water so that resources can be allocated and used where they yield the maximum benefits for society.

Information on the value of water is essential for private investment and production decisions, e.g. forestry companies. It is a factor which will influence decisions on whether to expand or reduce the area under forestry plantations. Similarly, government authorities on a national level need to weigh up different social, economic and environmental values in order to determine the "optimum use" of water. This must be done before approval is given for requests for apportionment or re-allocation of water resources to the forestry sector. Better information on water values will, therefore, provide a sound basis for application of demand management.

The economic modelling which is to be undertaken in this project, will rely on available data and forestry growth models. Co-operation for this purpose has been obtained from Mondi, the CSIR and the Forestry Growers Association.

The major aim of the project is to estimate the value of water use for commercial forestry.

Estimated cost: *R276 000*
Expected term: *2001-2001*

Effective local management of water resources with reference to the Middle and Lower Orange River

(No 1134) University of the Free State – Department of Agricultural Economics

In terms of the new water policy, emphasis is placed on the involvement of water users in resource management on a local level. With the implementation of this policy, water organisations such as water user associations (WUAs) and catchment management agencies (CMAs) are being established in accordance with the National Water Act. Consequently, the structure of water organisations and decision support systems has been highlighted as a priority area for research in the *1998 Technical Report* of the WRC.

A computer-based decision-support model is available, based on the institutional arrangement of capacity-sharing, which is applied for off-stream and in-stream water use management under conditions of uncertainty. It is of particular relevance to assisting users in the management of water releases from storage dams, transfer between competing users and to ensure that in-streamflow requirements are met in order to maintain the ecological balance of river systems. The model has been developed and tested by researchers at the University of New England in Australia over the last 20 years. The usefulness of this innovative approach needs to be evaluated under South African circumstances. This must be done within the context of the National Water Act, information requirements on the quantity and quality of water available, levying of water charges and tariffs in relation to water values for different uses and regulations for the performance of functions by the to-be-established WUAs. Based on the Australian experience, it is envisaged that the model will provide appropriate tools for water management by irrigation farmers and other water users.

The Orange River has been selected as a study area because information is required on the efficient and equitable use and allocation of water. Water is provided to irrigation areas which form the basis for socio-economic development of semi-arid rural areas in the Free State and the Northern Cape Provinces. At the same time, competition is experienced by irrigation users from alternative higher valued industrial and domestic uses. Water transfer schemes to adjacent river basins are already in operation and water resources are shared with the neighbouring states of Lesotho and Namibia.

The main research objective is to evaluate institutions and organisations for effective local management of water.

Sub-objectives are:

- Assessing the applicability of the approach of capacity-sharing.
- Providing appropriate information (e.g. prices and tariffs) about water for the effective management of water.
- Analysing structural arrangements for WUAs to manage water resources effectively.

Estimated cost: *R949 000*
Expected term: *2001-2002*

Design and testing of an installed hydrological modelling system

(No 1155) University of Natal – School of Bioresources Engineering and Environmental Hydrology

Future water management will often be characterised by a rapidly changing environment. Many conflicts are arising from inter-sectoral (e.g. agriculture vs. environment vs. industry) and intra-sectoral (e.g. forestry vs. sugarcane) competition for water resources. The National Water Act binds DWAF to establish a system of integrated water resource management on a catchment basis. Water resource management will be formulated according to an inter-related, two-tier strategy, namely:

- A national water resource strategy
- A number of catchment management strategies in declared catchment management areas with responsible CMAs.

These CMAs will require a wide range of technical tools, including computer-based simulation models for generating information and for assistance in decision-making. One type of model will be a rainfall-runoff model with relatively fine resolution and sensitivity to land-use changes. It is believed that each CMA or their expert advisors will need answers continuously from such a modelling system which would provide an up-to-date numerical simulation of the CMA.

Estimated cost: *R2 104 000*
Expected term: *2000-2002*

Towards integrated catchment management in the Mlazi River: A model for participation in the South African context

(No 1157) University of Natal – Farmer Support Group

With the implementation of the new Water Act, the constitution of CMAs is planned for some time in the next 3 to 5 years. Although the proposed catchment management areas initially cover primary catchments, the process does foresee activity at the subcatchment level.

In a previous WRC-funded project, Dr Auerbach and the Farmer Support Group have, over the past 5 years, achieved considerable success in working together with a large number of stakeholders in the middle and upper Mlazi River catchment. The main objective of this previous research was the development of a framework for community participation in integrated water management.

Some examples of community involvement brought about by the previous project are the following:

- Mondi Forest has cleared trees from wetlands to enable community groups to use reeds for basket making.
- The Hammarsdale industries are cleaning up their pollution in consultation with the community.
- The Mlazi Irrigation Board is being transformed into a WUA and has appointed an ecologist to assist communities in cleaning up rivers.
- The number of community gardens has grown from 2 to 28.

The project team is developing useful indicators that will enable the monitoring of progress and the level of success achieved with regard to community involvement. The sustainability of this active involvement of Mlazi catchment communities in integrated catchment management after the withdrawal of WRC funding is cause for concern. This is an issue which will receive serious attention in the new project. The next two years will also see the completion of the "framework for community participation" that can be used in other regions.

Estimated cost: *R1 000 000*
Expected term: *2000-2001*

Decision support of stakeholder involvement in reserve determination and other catchment management agency responsibilities

(No 1186) University of Cape Town – Department of Statistical Sciences

For a number of years now, the decision sciences group of the Department of Statistical Sciences at UCT has been engaged in developing decision-support principles and tools to facilitate group decision making in the presence of conflicting goals and interests. In a sense, the requirements of the new Water Act were correctly anticipated. However, because of a lack of statutory requirements, the research was stifled somewhat by a lack of real-life situations such as case studies. Nevertheless, the multicriteria decision aid (MCDA) and scenario-based policy planning (SBPP) have been applied to a number of South African test cases (Sabie-Sand, NE Cape Forestry), clearly demonstrating the viability and value of the approach. Several water resource management issues such as the determination of the class of the water resource, the resource quality objectives and the determination of the "Reserve" all have a prominent impact on water allocation. As such, multistakeholder involvement is needed.

The present research proposal will aim at empowering incipient CMAs or their precursors to fully involve relevant stakeholders using realistic case studies as a focal point.

One of the key paradigms in integrated water management is that it involves managing people's behaviour and this kind of research will assist strongly in coming to grips with this paradigm.

Estimated cost: *R578 000*
Expected term: *2001-2001*

Integrated socio-economic and cultural values as additional components of the criteria for estimating and managing the reserve

(No 1195) Institute for Natural Resources

The National Water Act of 1998 aims to achieve the sustainable use of water for the benefit of all users. It also guarantees the protection of aquatic ecosystems. Historically, the evaluation of the importance of river systems has been based on ecological importance, while ignoring social and cultural aspects. Most studies which are undertaken to determine the reserve are focusing on the requirements of aquatic ecosystems without taking cognisance of the socio-economic and cultural values of rural communities.

The proposed study will establish the importance of integrated ecological, socio-economic and cultural values in the estimation and management of the reserve. It will also provide information on the dependency of rural households on river system resources.

Estimated cost: *R300 000*
Expected term: *2000-2001*

Research projects

Completed

- **358** Technology transfer of computer programs and other tools for management of flood plains within catchment areas (University of the Free State – Department of Agricultural Economics)
- **807** Multi-level decision support for the control of alien invasive plants in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **888** Socio-economic impact of the Komati River basin development with special reference to irrigation agriculture (Conningarth Consultants)
- **914** Feasibility of using a risk-based approach to setting integrated environmental objectives for protection of water resources (Rhodes University – Geography Department)

Current

- **642** Development of a water information management database system for data capture and processing at local authority level (University of the Free State – Institute for Groundwater Studies and DWAF)
- **749** Modelling benefits of integrated catchment management (University of Natal – Department of Agricultural Engineering)
- **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 (Pty) Ltd.)
- **866** Community-based integrated catchment management programme with special reference to sustainable resource use in the Mlazi catchment (University of Natal – Farmer Support Group)
- **889** Aids for flood damage assessment and flood damage control planning in irrigation and urban areas (University of the Free State – Department of Agricultural Economics)
- **890** Development of a hydrological economic model based on the Mvoti catchment (Umgeni Water)
- **905** Model for water demand management planning and monitoring (BKS (Pty) Ltd.)
- **906** Development of a decision support system for the Mhlatuze catchment in Zululand (University of Zululand – Department of Hydrology)
- **907** Technique for modelling scenarios for alien plant control (CSIR – Division of Water, Environment and Forestry Technology)
- **913** Framework for state of the catchment report for developing catchment management plan using as a basis the Palmiet River, Western Cape (Palmiet CMP)
- **1014** Development and co-ordination of catchment forums through empowerment of rural communities (Rhodes University – Department of Geography)
- **1016** Use of grass species for rehabilitation after wattle control (ARC)
- **1038** Water resource systems analysis: Training and transfer of technology (BKS (Pty) Ltd.)
- **1043** Development of models for economic evaluation of the integrated management of quantity and quality of irrigation water within river catchments (University of the Free State – Department of Agricultural Economics)
- **1059** Predicting the impact of farming systems on sediment yields in context of integrated catchment management (ARC – Institute for Soil, Climate and Water)
- **1062** Developing protocols for integrated catchment management (ICM) based on current initiatives and techniques (CSIR – Division of Water, Environment and Forestry Technology)

New

- **1133** Estimation of the value of water in the commercial forestry sector for selected areas in SA (University of Natal – Department of Economics)
- **1134** Effective local management of water resources with reference to the Middle and Lower Orange River (University of the Free State – Department of Agricultural Economics)
- **1155** Design and testing of an installed hydrological modelling system (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **1157** Towards integrated catchment management in the Mlazi River: A model for participation in the South African context (University of Natal – Farmer Support Group)
- **1186** Decision support of stakeholder involvement in reserve determination and other catchment management agency responsibilities (University of Cape Town – Department of Statistical Sciences)
- **1195** Integrated socio-economic and cultural values as additional components of the criteria for estimating and managing the reserve (Institute for Natural Resources)

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15 Catchment hydrology

"The primary goal of research on catchment hydrology is to provide a scientific explanation and adequate quantitative understanding of the soil water balance dynamics for any spatial and temporal scale and their relationships with the physical and chemical transport of matter in the soil zone and with ecology"

The dominant route for new knowledge and understanding of hydrological processes to be brought to bear on integrated water management is through hydrological models. Models in simple terms are more or less clever simplifications of the real world. South Africa is a big country and our hydrological landscapes show extreme variability in space. The issue of scale in hydrological modelling is gradually becoming a major focus of research.

Hydrological models are important decision tools too. Whereas in the past models were mainly used in water supply planning, they now play a vital role in the water allocation negotiation process. The issuing of licences for afforestation and the associated levying of catchment management charges are based on the outputs of hydrological models. The credibility of such models in the eyes of stakeholders now becomes an essential consideration. Negotiations about water allocations are not limited to South Africa: Internationally-shared river basins are now receiving attention as far as research is concerned. The challenge to hydrologists and hydrological modellers is, therefore, to refine and validate models to the point where they have enough credibility to allow SADC water managers to use them with confidence in reaching decisions which will benefit water management in the region.

Completed projects

Root development and water usage of commercial timber species

(No 348) University of Natal – Department of Agronomy

This project was undertaken to provide a means of augmenting relatively sparse information on the water use of commercial timber species, particularly *Eucalyptus grandis*, in relation to root development. Initially, the use of laboratory rhizotron facilities for this purpose had been anticipated. However, the perceived difficulty in extrapolating laboratory results to plantation conditions led to the rhizotron approach being abandoned in favour of a field-study approach. A thorough investigation was consequently undertaken into the stem steady state energy balance (SSS) technique for monitoring the rate of sap flow through the stems and roots of trees. With the necessary refinement, the technique proved useful in obtaining accurate sap-flow measurements in plantation trees with diameters measuring up to 120 mm. Simultaneous measurements of sap flow through the stem, lateral roots and the tap root proved feasible, illustrating how transpiration (stem flow) responds to root severing or the drying-out of certain soil layers. It was shown that the SSS technique, used in combination with Bowen ratio or eddy correlation techniques for evaporation measurement, might provide a successful means of partitioning total evapotranspiration into its soil surface and plant components.

Cost: *R350 384*
Term: *1991-1995*

Assessment of the MIKE SHE hydrological model for application in South African catchments

(No 747) Rhodes University – Institute for Water Research

The outcome of this evaluation has some positive and some negative conclusions and observations.

Positive

- Certain features of the model facilitate the establishment of a model set-up for a particular catchment. This does not necessarily mean that it will generate good results.
- The model has the potential to be a valuable tool for addressing some detailed water management problems.

Negative

- Problems are experienced with understanding and interpreting certain parts of the mathematical processing which leads to excessive time needed in order to adjust the model to ensure that it runs efficiently. In particular, the setting of the number of iterations required to solve the differential equations was an important consideration.
- A number of model components are essentially empirically-based and, under certain conditions, the physically-based modules are not valid. This situation arises especially in steep catchment situations which is rather common in South Africa.
- The model is valid for very detailed studies where the flow through porous media can be described in detail. It is impossible to provide this detail at a scale larger than 1 km^2. In the 766 km^2 catchment of the Upper Sabie River, no sensible simulations could be achieved without resorting to a completely empirical method of representing the catchment.

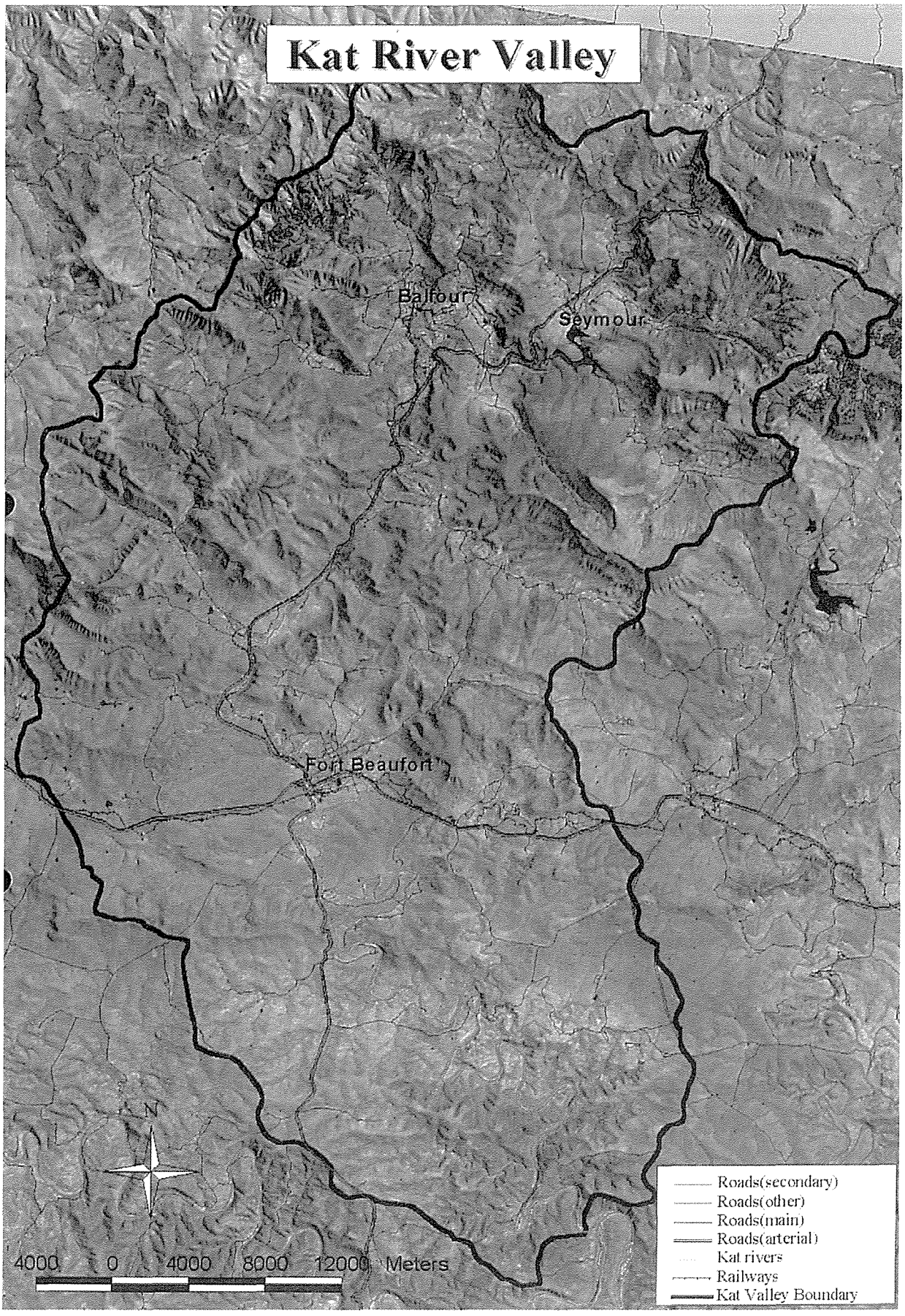
Cost: *R242 337*
Term: *1996-1997*

Long-duration design rainfall estimates for Southern Africa

(No 811) University of Natal – School of Bioresources Engineering and Environmental Hydrology

The benefits derived from this project are revised, more reliable estimates of one- to seven-day duration design rainfalls for South Africa. The revision of medium- to long-duration design rainfall depths for South Africa was based on regionalised techniques, which pool information from homogeneous regions and thus improve the reliability of the design rainfall. One-day and longer design rainfall depths are computed using rainfall data measured at 08:00 every day for the preceding 24 h period by standard, non-recording rain gauges.

Checks for erroneous data and the infilling of missing daily rainfall



The catchment constitutes the ideal management unit.

have been performed at approximately 4 000 stations in South Africa which have at least 20 years of data. This enhanced database of daily rainfall was used in this study and is available to any users of daily rainfall data in South Africa.

In this study a regionalised, index storm-based frequency analysis using L-moments was adopted for design rainfall estimation. Seventy-eight homogeneous rainfall regions in South Africa were identified using daily rainfall data from 1 789 stations which have at least 40 years of records. The general extreme value (GEV) probability distribution was found to be the most suitable distribution to estimate one-day design rainfall values in South Africa. For each of the 78 homogeneous regions and for durations of one to seven days, quantile growth curves, which relate the ratio between design rainfall depth and an index storm to return period, and error bounds for the curves, have been developed. These regionalised quantile growth curves, in conjunction with index values derived from at-site data, were then used to estimate design rainfall values for one- to seven-day durations at 3 945 rainfall stations in South Africa, which have at least 20 years of daily records. These design rainfall values, which comprise approximately 800 pages of print-out, are available for users in portable document format (PDF) via the CCWR.

Cost: *R273 424*
Term: *1997-1999*

Integration and application of daily flow analysis and simulation approaches within Southern Africa

(No 867) Rhodes University – Institute for Water Research

During the project the actual work carried out was, with the approval of the Steering Committee, modified to harmonise with some of the rather urgent requirements of DWAF in relation to the implementation of the new Water Act.

The content of the final reports reflects these changes and indicates that eventually the project consisted of three inter-linked components:

- The development and application of pragmatic methods for generating time series of daily flows led by Dr Vladimir Smakhtin. This concept focuses on the flow duration curve (FDC) as a key characteristic of streamflow variability in natural and developed catchments.

The research has resulted in a set of techniques which could be used for the provision of much-needed daily streamflow information at any catchment in South Africa, Southern Africa, or other data-poor regions.

- The development and application of integrated software to display and analyse a wide variety of hydrological and water resource time series data was led by Prof Denis Hughes.

The intention of this component of the project was to develop tools for presenting the hydrological time-series data to non-hydrological specialists in an informative, flexible and interactive manner. The software is still under development, but a prototype version has been available for some time and has been used in several IFR workshops, and is being transferred to other university departments where there are research groups working on related problems.

- The development and application of methods and tools to support the requirements of the new Water Act in terms of quantifying the ecological reserve was led by Prof Denis Hughes.

  This component specifically deals with:

  – The interface between the results being generated by the workshop participants and the water resource planning engineers who are required to incorporate the IFR into their designs.
  – The translation of the tools used for planning and design into additional tools that can be used for real-time management.

It should be noted that in all cases the emphasis has been not only on development, but also on application. Most of the methods that have been developed during the course of the project have already been applied extensively.

Cost: *R1 123 852*
Term: *1997-1999*

New projects

Development of models to quantify streamflow reductions caused by commercial afforestation in South Africa

(No 1110) CSIR – Division of Water, Environment and Forestry Technology

The new Water Act requires the formulation of water allocation plans as part of catchment management strategies, in which afforestation-related streamflow reduction quantification will play a prominent role. From the licensing perspective, the question of afforestation-related streamflow reduction will gain more importance as the competition for water resources increases. In order to establish clarity about the correct way forward, DWAF initiated a review process to deal with problems of streamflow reduction estimation. This included a workshop attended by 26 scientific and technical/administrative stakeholders. The workshop identified a range of solutions, some of which have led directly to the formulation of this project. Presently there are two assessment methods available:

- The so-called CSIR curves, derived from the results of five paired catchment experiments.
- Continuous simulation modelling using the ACRU agrohydrological modelling system based on daily soil moisture and runoff accounting.

A major shortcoming of the CSIR approach is that of climatic representativeness brought about by the fact that all experimental catchments have mean annual precipitation (MAP) greater than 1 100 mm whereas 63% of all afforestation in South Africa has an MAP of less than 900 mm. A major shortcoming of the ACRU model is that it has not been verified rigorously enough on all the available experimental data.

The main objective of the project is to verify the ACRU model on available experimental data and, thereafter, to run the model for drier areas with the goal of producing regional look-up tables that will provide site-specific streamflow reduction estimates that are acceptable to a wide group of stakeholders. DWAF funded the first phase of this project with comparable cost.

Estimated cost: *R303 000*
Expected term: *2000-2001*

Development of terms of reference for a long-term study to quantify the surface water resources of Southern Africa

(No 1112) Rhodes University – Water Research Institute

As part of the SADC/UNDP Water Round Table Programme, an SADC regional strategic action plan (RSAP) has been formulated. One of the proposed projects in this action plan is entitled: **Assessment of Water Resources**, and will be executed in three phases, preceded by a mobilisation phase.

Inadequacies in information gathering and sharing were identified as a constraint to the trans-boundary development of water

resources and serve as prime motivating factors for undertaking this project.

The purpose of the long-term RSAP project is to produce and make accessible an SADC-wide surface water resource assessment in a manner that builds capacity in participating institutions, promotes confidence in products amongst member states and which ensures that the assessment supports equity amongst stakeholders through equitable sharing of water within international river basins. The project is of strategic importance for contributing to the development in the Southern African region.

In this project, which constitutes the mobilisation phase of the larger RSAP project, consideration will be given to the following factors:

- Not all SADC countries have undertaken national assessments, notably Angola and the DRC and, therefore, a full regional assessment cannot be constructed by aggregation.
- In many countries the assessment is of residual flow due to a lack of data and estimation procedures to account for abstractions and other reductions (afforestation for example).
- Significant variations exist among the data-transfer methods adopted in national assessments. Such variations can introduce regional concerns regarding methodological rigour and consistency.
- For various reasons only very limited consistency exists between countries in methodological approaches.
- There are different methods of river flow estimation and measurement. The project will face significant challenges if it attempts to accommodate all prior work.

Estimated cost: *R300 000*
Expected term: *2000*

Limpopo River main stem hydrological model: Update of existing model and installation in the co-basin states

(No 1113) Ninham Shand (Pty) Ltd.

The Limpopo is arguably our second largest river, but we, in fact, know very little about its flow regime, greatly hampering sustainable development of this resource.

A hydrological model of the Limpopo main stem was developed during a previous project (No 746) funded by the WRC and the Water Ministries of the four co-basin states (Botswana, Mozambique, South Africa and Zimbabwe) between 1996 and 1999. The model covers the reaches between the confluence of the Crocodile and the Marico Rivers and the Chokwe downstream at the confluence of the Limpopo and Olifants Rivers.

The aims of this previous project were to:

- Develop conceptual understanding of the primary surface flow system and the inter-linked alluvial aquifer/flood-plain of the Limpopo River main stem.
- Formulate appropriate improvements to the existing hydrological monitoring systems.
- Configure a mathematical rainfall-runoff model, alluvial aquifer model and river loss model.
- Link these models to enable integrated system analysis of the Limpopo River system as far downstream as the Luvuvhu River.

The last task in this previous research was the reconstruction of a flow record near Beit Bridge, where both Zimbabwe and South Africa have been operating gauging stations, albeit some distance apart.

The Water Ministries of the four co-basin states have now expressed a need for the model to be installed in their respective offices, so that all four countries are able to view the Limpopo information in the same way. Their staff will also be trained in the use of the model.

Estimated cost: *R140 000*
Expected term: *2000*

Analysis of streamflow generation mechanisms in a wide range of catchments

(No 1193) CSIR – Division of Water, Environment and Forestry Technology

There are strong indications that the new Water Act will give considerable impetus to better land-use management as part of water resource management. The proposed licensing of streamflow reduction activities (SFRAs) and the Working for Water Programme are examples. It is generally agreed amongst natural resource managers that impacts of given land-use management practices on water resources should be site-specific. Process-based hydrological simulation models are most likely to be the best tools for managing catchment water resources.

The aims of this project are:

- To characterise streamflow generating mechanisms in a wide range of small catchments (<100 km^2) with a view to improving our understanding of streamflow generating processes.

We need to characterise the streamflow behaviour of a nationally representative range of small catchments, so that confidence can be developed in the ability of hydrological models to successfully simulate a broad scenario of different streamflow generation mechanisms. The work that the WRC funded in the Cathredral Peak catchments a few years ago (Project No 493) will form a logical part of this broad scenario, representing mainly the wetter parts of the eastern escarpment.

- To seek correlations between predominant streamflow generation mechanisms and catchment attributes from a landscape point of view.

This ability will improve our prediction of changes in streamflow regimes following land-use changes. We have a fairly good handle on predicting changes in water use by plants. However, the usually retarded impact on streamflow is less understood.

Estimated cost: *R496 000*
Expected term: *2000-2001*

Determining plantation water use and growth from integrated remote sensing, water-use models, geographic information systems (GIS) and field data

(No 1194) CSIR – Division of Water, Environment and Forestry Technology

The new Water Act makes provision for the classification of various crops and land-use practices as streamflow reduction activities (SFRAs) which are then subject to controls to ensure equity in water allocation. This is potentially a highly contentious matter, and will require objective, high-quality and credible research results to ensure acceptance of decisions by all affected parties. The influence of crops on streamflow is largely determined by the annual rate of evapotranspiration, a highly variable quantity which changes from year to year and from site to site in response to a wide range of weather, site and crop factors. Policy-makers will therefore need a rapid, simple, yet realistic means of predicting streamflow reduction effects for the major crops, and especially for forest plantations which are perceived to have high impacts on water resources.

Most of the experimental evidence on the incremental water use by plantation forest has been derived from experiments in the

relatively stress-free high rainfall areas (1 100 to 1 200 mm). It is also a known fact that a large portion of the total plantation forest area experiences moisture stress during a considerable period of its growth cycle. With the present emphasis on quantifying SFRAs and the uncertainties about the spatial variation, it appears that remote sensing is probably the only practical way to obtain useful information on actual water use and the degree of water stress over a large geographic region. Remote sensing data are becoming cheaper and the practicability of this approach for estimating water use of trees is warranted.

A recently-developed spatial forest model has been successfully used in Australia and New Zealand to assess the growth and water use of a wide range of forests based on remotely-sensed data. It is based on a process-based forest growth and water-use model (3-PG) which has already been tested in South Africa on *Eucalyptus grandis* and *Pinus patula* plantations, with favourable results.

The purpose of the proposed study would be to investigate whether the spatial version of the 3-PG model (based on an integration of remotely-sensed imagery, GIS, the 3-PG forest model, and field data) predicts the water use and growth of plantations accurately enough to serve as a useful tool for quantifying SFRAs, first with respect to forests and later with respect to other crops.

Estimated cost: *R480 000*
Expected term: *2000-2001*

Research projects

Completed

- **348** Root development and water usage of commercial timber species (University of Natal – Department of Agronomy)
- **747** Assessment of the MIKE SHE hydrological model for application in South African catchments (Rhodes University – Institute for Water Research)
- **811** Long-duration design rainfall estimates for Southern Africa (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **867** Integration and application of daily flow analysis and simulation approaches within Southern Africa (Rhodes University – Institute for Water Research)

Current

- **637** Hydrological systems modelling research programme: Hydrological process research (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **746** Development of a hydrological model of the Upper and Middle Limpopo River (University of Stellenbosch – Department of Civil Engineering)
- **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)
- **908** Flood forecasting system for Vaal Dam (DWAF)
- **909** Monthly multiple site streamflow model (BKS (Pty) Ltd.)
- **1015** Modelling the impacts of land cover and land management practices on streamflow reduction (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **1060** Regionalisation of rainfall statistics for design flood estimation (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **1061** A field study of two- and three-dimensional processes in hillslope hydrology for better management of wetlands and riparian zones (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **1086** Experimental and laboratory measurements of soil hydraulic properties for improved modelling of catchment processes (University of Natal – School of Bioresources Engineering and Environmental Hydrology)

New

- **1110** Development of models to quantify streamflow reductions caused by commercial afforestation in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **1112** Development of terms of reference for a long-term study to quantify the surface water resources of Southern Africa (Rhodes University – Water Research Institute)
- **1113** Limpopo River main stem hydrological model: Update of existing model and installation in the co-basin states (Ninham Shand (Pty) Ltd.)
- **1193** Analysis of streamflow generation mechanisms in a wide range of catchments (CSIR – Division of Water, Environment and Forestry Technology)
- **1194** Determining plantation water use and growth from integrated remote sensing, water-use models, geographic information systems (GIS) and field data (CSIR – Division of Water, Environment and Forestry Technology)

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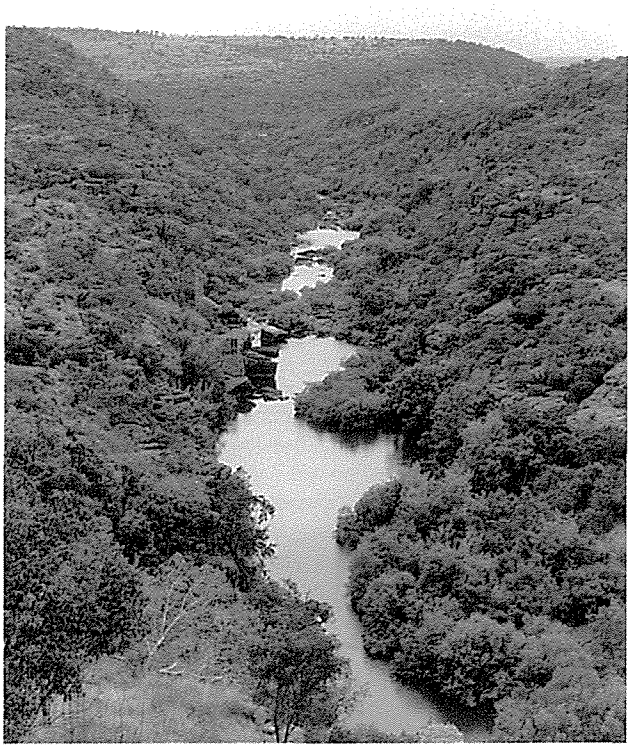
16 Conservation of water ecosystems

The use of toxicology for the monitoring of water quality has been included in the licencing requirements under the National Water Act. The WRC has supported work in this field for some time.



In various WRC-funded projects a series of tests have been conducted under local conditions and some new tests have been developed. These tests will be suitable for use in terms of the requirements. In addition, using methods developed in previous projects at the Centre for Aquatic Toxicology, Institute for Water Research, Rhodes University, it proved to be possible to develop site-specific water quality criteria for the classification of rivers as required for the Reserve determination.

A number of workshops were held under the Eastern Cape Estuaries Management Programme. One finding that consistently emerged from these workshops was that although people saw the estuary around which their community was centred as being important to the community, it was given no recognition in the Integrated Development Plan. Ongoing involvement with the Bushmans and Kariega Estuaries has led to the formation of an estuary management forum in the area which will take the initiative in managing the estuaries within the jurisdiction of both the Bushmans River Mouth and the Kenton Transitional Local Councils. The programme has been successful in other estuaries and only a few cases of conflict were reported. The Mgazana Estuary which is situated south of Port St Johns, has been selected as one example from the Pondoland Coast, partly because of its extensive mangrove swamp (one of the biggest in South Africa), and partly because there has been unplanned development on the estuary. The management plan developed for this estuary will be linked to the Pondoland SDI, in which agriculture and ecotourism have been identified as industries for the area.

Invertebrate guides

This year saw the publication of the first of a series of 10 books that will include identification keys to most of Southern Africa's fresh- and brackish-water invertebrates. The remaining 9 books in the series are scheduled for publication over the next two years. The idea was the brainchild of a group of limnologists during a meeting about a decade-and-a half ago, and the project went a long way with no formal support. Experts in the field, both South African and international, were enlisted and a number of the identification keys have been tested in undergraduate and postgraduate laboratories. The first book to be published, **Volume 2** is the first of 3 volumes on Crustacea, and includes the Notostraca (tadpole shrimps), Anostraca (fairy shrimps), Conchostraca (clam shrimps) and Cladocera (water fleas).

Publication of a *Manual on the Building Block Methodology to Determine the Flow Requirement of the Ecological Reserve*

While there are a number of methods worldwide for the estimation of instreamflow requirements, none were found to be adequate for South African conditions. Many of the existing methods rely on specific indicators. South Africa needed an approach which would give estimates with an acceptable level of confidence for data-poor systems. The Building Block Methodology has been developed over a period of years and is holistic, requiring close communication among all the experts from the different disciplines involved. The research aspects have been funded by the WRC and the management application has taken place in workshops funded by DWAF. This arrangement has enabled the process to be refined to a point where a manual on the method can be produced. The Building Block Methodology has advanced to the point where it is one of only a few methodologies worldwide which has a formal manual. This manual is necessary because the requirement for flows, sufficient to maintain the ecological integrity of rivers, has been written into the National Water Act. Currently, the need for this methodology will increase beyond the capacity of current practitioners.

Strategic research plan

A process to redevelop the strategic research plan completely has been started, and the first results should be available on the WRC home page in time for the deadline for the submission of projects at the end of April 2001.

The National Rivers Initiative

The *raison d'être* of the National Rivers Initiative (NRI) is to promote and inform the management of river systems through strategic research, knowledge management and the optimal employment of expertise.

South Africa is undergoing a period of rapid change, and the water sector is not escaping this. The demand for water both within the country and within neighbouring countries with whom we share rivers is increasing, but the resource is finite. The drivers of this change are both national and global, and arise from the social, economic and environmental sectors. The interactions between these are complex, and the solutions demanded to solve these are equally complex. These solutions can only be achieved through co-ordinated interdisciplinary research focused on specific issues. The NRI will focus on providing knowledge for integrated water resource management.

The management of the NRI process will build on the experience gained during the Kruger National Park Rivers Research Programme, but the issues addressed will go wider than this in that the NRI will be made up of a number of separate research programmes, each addressing identified strategic needs for the management of water resources. Some of the research programmes already running at the WRC, such as the research programme on the Surface Water Ecological Reserve, will be included within the NRI.

The Kruger National Park Rivers Research Programme

Phase III of the Kruger National Park Rivers Research Programme (KNPRRP) ended during 2000 with a review by an international review panel. The programme which consisted of three phases was conceptualised in early 1987 and initiated in late 1988. Work undertaken during Phase I may be broadly described as 'scientific research', and a review of this phase acknowledged the high quality of the research, but suggested that any further phases should incorporate management aspects.

Thus, Phase II (1994-1996) concentrated on the enhancement of predictive capabilities and contextualising these within the management process so that decision-making may be supported. Phase III (1997-2000) enabled the research team to complete the development of the first generation procedures and technologies which were necessary for the promotion of the strategic adaptive management (SAM) of rivers.

This commitment of informing management necessitated that the researchers understood which component of the management process their research was to address. It was, therefore, necessary to define the management process before identifying the research needs. This also required the testing of research products in the management process. This process has also enabled the research findings from Phase I to be integrated into the management process. Four fundamental principles are embodied in the process:

- Management should be directed towards achieving a desired state.
- Management decisions should be informed by predictions.
- River systems are dynamic, and it is, therefore, necessary to continuously monitor their state and to revisit the management objectives.
- River systems have characteristics of common property, so the process should be interactive with stakeholders.

Phases II and III were designed to synthesise existing knowledge to support strategic adaptive management (SAM), and much attention was given to technology transfer. Where research was needed, it was supported by discrete research projects.

The programme is seen as being innovative, cost-effective and is reputed to have delivered research of high quality. It also contributed meaningfully to policy and legislation review, the establishment of user interest groups and CMAs, and to the adoption of SAM principles and practices. These outputs will endure. It also promoted a culture of collaboration and generative learning.

The KNPRRP was reviewed by an international review panel (Dr PJ Ashton, CSIR, South Africa; Dr J Seager, Environmental Agency, United Kingdom; Dr HM MacKay, DWAF, South Africa and

Stakeholders from Sandile Village working on a presentation for the Tyolomnqa Estuary management meeting the next day, 15 August 2000.

Dr TJ Ruredzo, Commonwealth Science Council, United Kingdom) during the latter part of 1999. Very briefly, the panel concluded that:

- The objective-led approach focused the programme structure and helped integration without interfering with innovation.
- The programme raised the profile of river ecosystem science both nationally and internationally.
- The new thinking on operationalising SAM was a major success.
- The objectives-hierarchy approach focused the design of the work programme and the prioritisation of research.
- The management approaches and tools developed have potential for wider application to underpin catchment management planning.
- All the potential benefits have yet to be realised, but some of the products will benefit future CMAs.
- Perceptions of what people expected differed, owing to the lack of clearly-defined definitions.
- The programme was constrained by the early decision to limit work to within the Kruger National Park. This did focus the limited resources to within a limited area, and this decision was later recanted.
- The opportunity for corrective action was not fully developed.

Completed projects

Natural and unnatural factors regulating the structure and functioning of estuarine systems

(No 525) Institute for Natural Resources

South Africa's estuaries are under heavy pressure from a number of sources. Water use in the catchment reduces both the quality and the quantity of water reaching them. They often form nodes of development because they are scenically attractive. This development may result in further deterioration, but people still expect them to function properly and to maintain all the features which made them attractive in the first place. This project evaluated various factors regulating the structure and functioning of these systems.

The role of freshwater for other uses

Allocation of the resource for other uses left only 14.5% of MAR for estuaries in 1990, which is expected to decrease to 10.7% by 2010. The effects of this potential reduction on estuarine functioning were identified, and the links that exist among various ecosystem components were identified. One specific need which was identified was the necessity to improve co-operation between scientists, engineers and resource managers.

Biotic exchange between estuarine tidal inlets

A well-functioning estuarine mouth is cardinal to the health of an estuary. Reduction in freshwater flow alters the mouth dynamics, usually to the detriment of the fauna in the estuary. An important point noted during this project was the importance of mouth opening to certain components of the estuarine fauna.

Predictive capability

A key element of the research was the development of predictive capability for management. As a degradation of physical characteristics is reflected in changes in the biota, the prediction model was conceptualised, based on biotic responses to changes.

Ports as estuaries

Results indicate that the ports of Durban and Richards Bay, although substantially altered, still sustain a diverse and abundant estuarine fauna. Reduction in freshwater flow (and water quality) combined with a permanently open mouth, create marine-dominated systems. Environmental management plans need to be developed for each port.

Cost: *R150 000*
Term: *1992-1994*

Decision-support system for the integrated management and conservation of estuaries

(No 577) University of Natal – Institute of Natural Resources

In line with the decision of CERM (Consortium for Estuarine Research and Management) that a co-ordinated research approach to estuaries would support decision support for their conservation and management, it was decided to plan the decision support to address the requirements of the integrated environmental management (IEM) procedure of the Department of Environmental Affairs and Tourism. Five existing models for estuarine freshwater requirement were identified, none of which have either been linked or applied to the same system previously. These models facilitated the capability for both short- and long-term prediction, and a conceptual plan for inter-linkage was developed. Models giving short-term predictive capability (Mike 11, Mike 11 water quality module and Plant Estuarine Decision Support System – PEDSSys) were better developed. Substantial developments were also undertaken in longer-term capability during the project, resulting in improvements to the Estuarine Systems Model (ESM) and the Estuarine Ecosystem Evaluation Model (EEEM). Development of two other predictive models was initiated, these being a spatial dynamic biomass growth model for estuarine macrophytes and an estuarine faunal prediction model.

Case studies were done on two estuaries for which data on flow reduction were available; these being the Great Brak (temporally open/closed) and the Kromme (permanently open). The following was demonstrated:

- Mike 11 works best on permanently open estuaries with an axial salinity gradient.
- The Mike 11 water quality module worked, but more data were needed to complete calibration.
- Results from Mike 11 will provide a basis from which PEDSSys can generate predictions on changes in macrophyte growth with changes in physical conditions.
- The ESM can predict the environmental response of both permanently open and temporally closed estuaries.
- Results generated by ESM, when used in PEDSSys, allow for the prediction of the effect of mouth closure on macrophytes.
- The Dynamic Vegetation Model provides predictions which complement those of PEDSSys.
- Based on ESM the EEEM will predict the effects of mouth closure on invertebrates (specifically mud prawns) and fish recruitment.

Apart from Mike 11, the models used underwent considerable improvement during the project, as did the capability to link the various models. Linking the models has allowed effective scenario-based simulation which has, in turn, increased scientific understanding of the effects of reduced freshwater flows on the two estuaries used as case studies.

Cost: *R600 000*
Term: *1993-1995*

Freshwater requirements of plant communities in different types of estuaries

(No 601) University of Port Elizabeth – Department of Botany

During the project a system was developed by which the importance of estuaries could be rated by the plant communities occurring in them. This was designated the botanical importance rating (BIR) and was worked out for the estuaries from the Olifants River (W. Cape) to the Swartkops River (E. Cape) during this project. A number of suggestions for improvements to the BIR were made during a workshop held just before the end of the project, namely:

- Permanently and temporally open estuaries were to be separated
- The four macrophyte communities were assigned values based on their closeness of association with the estuary
- The number of impacts in the estuary to be supplemented by the impacted area, and a species richness component was included.

The first two have been incorporated in the BIR, but the latter was not included at this stage.

The coastline was divided into 4 regions (W. Cape, SW, Cape, S. Cape and SE. Cape) for the sake of the BIR and 33 estuaries were studied. The Olifants Estuary (W. Cape) received the highest score, and 2 estuaries in False Bay (Lourens and Sir Lowries' Pass) were rated the lowest.

The BIR is recognised as only one of a suite of indices for measuring estuarine importance. Other factors e.g. fish, birds and socio-economics, also need to be considered in the management of estuaries.

Estuarine microalgae (specifically diatoms) were also examined. Initial work showed that when all species were examined, the relationships were obscured by the background noise from the non-dominant species. A computerised key for estuarine diatoms was developed.

Cost: *R179 000*
Term: *1994-1996*

Assessment of the ecological impacts of inter-basin transfer schemes in dryland environments

(No 665) University of Cape Town – Department of Zoology

The output from this project consists of two documents. The first is the report on the research done during the project and the second is a worldwide synthesis of information on inter-basin transfers (IBTs) with contributions from scientists in the USA and Australia. Each of these two documents addresses specific aims of the project.

- *Project Report*: The results of the field study show that the IBT has a significant effect on the physical, chemical and biotic conditions of the recipient river. Water from Theewaterskloof Impoundment (Riviersonderend) differs chemically from that of the Berg River. The impounded water, consisting of large quantities of lentic organisms with reduced overall diversity below the discharge point, is released into the river with the discharge while the IBT is operational in summer. This results in high numbers of predatory invertebrates that prey on them. In winter, when the IBT is switched off, the fauna reverts to the same patterns as those above the discharge point.
  Guidelines and protocols for IBT operation are summarised in 2 tables which deal with the predicted and observed effects of IBTs on donor and recipient systems, with a summary of the implications of the effects.
- *Synthesis*: A global overview of IBT schemes, with an appraisal of their ecological, socio-economic and socio-political implications, and recommendations for their management.
  In this volume the theories of the river continuum concept and of the serial discontinuity concept (both aspects of river ecosystem theory) are reviewed specifically from the aspect of how they can be used for designing and operating IBTs.

A major part of the synthesis documents existing schemes worldwide, something which has not been done before. South Africa, North America and Australia are covered in detail, and these are not only the home areas of the 3 authors, but are areas where water distribution does not meet the demand.

Arising from the information presented in the synthesis, and developed more fully in the report, the authors have compiled a list of recommendations for the planning and management of IBTs.

Cost: *R250 000*
Term: *1995-1999*

Application of an artificial stream system to investigate macro-invertebrate water quality tolerances

(No 686) Rhodes University – Institute for Water Research

Salinisation of our water resources is a national problem. Water quality guidelines have been developed by DWAF for various categories of users and now, with the requirement by the ecological reserve process to classify rivers, it has become necessary to give a clearer definition of these guideline values. This project addressed part of this requirement and verified the experimental procedure.

Salinity tolerances

Salinity (measured as conductivity – mS/m) tolerance of the mayfly *Tricorythus tinctus* from the Sabie River, KNP, was tested using NaCl, Na_2SO_4, KCl, $CaSO_4$ for acute (96 h) and short-term chronic (12 d) exposure. Although toxicity was largely related to osmotic stress, SO_4^{2-} was more toxic than Cl^-, and the presence of Ca^{2+} reduced toxicity. Acute (AEV) and chronic effect values (CEV) were calculated, and these were then used to obtain a site-specific guideline for salinity in each of the reserve management classes (as specified in the process to determine the environmental reserve) as follows:

Class A: 8 to 17 mS/m
Class B: 18 to 30 mS/m
Class C: 31 to 40 mS/m
Class D: 41 to 60 mS/m

Heavy metal tolerances of riverine macro-invertebrates

The mayfly (*Adenophlebia auriculata*) and the limpet (*Burnupia stenochorias*) were exposed to copper and zinc (the speciation of both is well-understood). The limpet was more sensitive to copper than was the mayfly, and the mayfly was relatively insensitive to zinc, making the latter less suitable as an indicator for zinc pollution.

Both of the above 2 pieces of work were used to refine the water quality guidelines for the natural environment.

Scale of experimental testing

It was determined that neither the scale of experimentation, nor the water velocity influenced the results significantly. This means that the results obtained from small-scale field experiments may be considered to be representative of the organism's behaviour.

Comparison of *Daphnia* (a standard test organism) to indigenous riverine organisms

Results from this indicate that *Daphnia* and *Tricorythus* show similar tolerances to salinity, while other mayflies are considerably more tolerant.

This research has application within the National Water Act, specifically in the source-directed controls (permits and effluent standards) and the resource-directed measures (guidelines and the reserve), and are most effectively applied within the philosophy of ecological risk assessment.

Chlorinated sewage effluent was found to be toxic to mayflies at 0.004 mg/*l* free chlorine. This is well below the level specified by the general effluent standard (0.1 mg/*l*), but it shows that the guideline value for environmental values (0.001 mg/*l*) is in the appropriate range. Toad tadpoles and freshwater shrimps were tested for tolerance to NaCl and Na_2SO_4. The shrimps were shown to be twice as sensitive as the tadpoles, and the recommendation made is that shrimps would make more suitable test organisms than tadpoles for the establishment of guideline values.

Cost: *R974 000*
Term: *1995-1998*

Delegates attending an Applied Aquatic Toxicology Course at the Institute for Water Research (CAT-IWR), Rhodes University, seen with course co-ordinators and presenters.

Water quality and aquatic faunal studies in the Umzimvubu catchment, Eastern Cape, with particular emphasis on species as indicators of environmental change

(No 716) University of Transkei – Department of Zoology

This river in the former Transkei is not only practically unknown from the point of view of its fauna, but is the largest river system in the country which is unimpounded (although DWAF have plans to build a series of large impoundments on the river). Apart from this, the largest impacts are likely to come from increased farming activity.

The basic aim of this project was to assemble baseline information on the Umzimvubu River (which has not been done before) so that there is some way of assessing the magnitude of future changes.

The study showed that the Umzimvubu River is only slightly degraded, with the stressor being sediment. The water quality is good, which is reflected by the high SASS scores. Sedimentation is, however, a very serious problem. A piece of apparatus was devised, based on Australian experience, to measure the sediment load carried on the rising limb of a flood hydrograph. Only one of the samplers placed actually sampled successfully, and this indicated that the rising limb of a medium flood carried a very high sediment load. This very high sediment load is derived from a combination of agricultural practice and the high erodability of the soils in the catchment. However, it must hold implications for the fate of any future impoundments in the catchment.

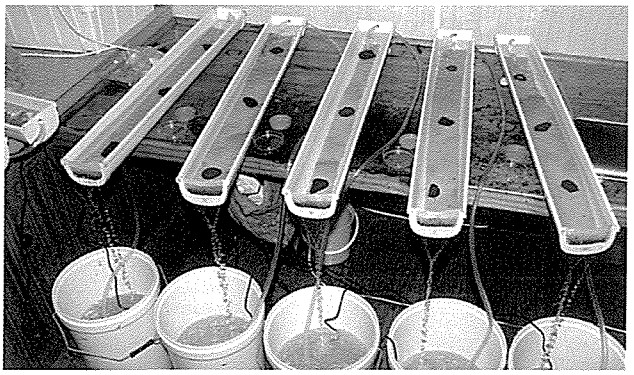
In the laboratory, the tolerance of certain invertebrates to suspended sediment was measured. Preliminary results from these experiments link the sediment tolerance of invertebrates to their distribution in the river system.

Cost: *R228 000*
Term: *1995-1999*

Effect of inter-basin transfer on the hydrochemistry, benthic invertebrates and ichthyofauna of the Mhlatuze Estuary and Lake Nsezi

(No 722) University of Zululand – Department of Zoology

Water demand in the industrialised lower Mhlatuze basin was projected to exceed current supply during the late '90s, and an IBT scheme was implemented in order to cope with this. This situation actually came about during the severe drought of the early '90s, when the scheme was brought into almost continuous service for a period. This project investigated the effect of this on both the donor and the recipient systems.



Recirculating channels used in ecotoxicological research (KNPRRP Laboratory, Skukuza KNP).

Donor system: Mhlatuze River

Water quality and hydrology The water quality in the river showed spatial variation in that the abstraction from the weir resulted in the lower reaches of the river and the estuary being marine dominated. The flow of the river in the study area was largely dependent on the water released from the Goedertrouw Dam.

Invertebrate monitoring Faunal diversity and river health declined downstream from 'fair' (upper reaches) to 'very poor' between the abstraction weir and the upper estuary. It was shown that the major factor responsible for the structure of the macro-invertebrate community was water quality in the form of TDS.

Fish fauna The weir just upstream from the head of the estuary effectively prevented estuarine fish from gaining access to the river. Thus, there was considerably greater diversity of fish below the weir, with only truly freshwater fish being found above the weir. Six SA endemics and two red data species were found during the study.

Estuary The estuary is strongly marine-dominated, due to the reduced flow below the weir, where water is abstracted for the IBT.

Recipient system: Lake Nsezi

Water quality Lake Nsezi has a high TDS which is attributed to treated wastewater being discharged into the Nseleni River upstream. Extensive water hyacinth mats give the substrate of the shallow lake a very high organic content, but the hyacinth also maintains very low levels of orthophosphate in the water column.

Fauna The benthos was dominated by Oligochaetes (80%) and Chironomids. Both of these groups are able to do well in an oxygen-poor environment. Environmental parameters accounting for variability in the benthos were, in descending order, the organic content of the sediment, the dissolved oxygen (DO) content and the sulphate content. The influence of the inflow of the IBT, apart from reducing the number of organisms in the immediate vicinity, was masked by an unmeasured (unknown) environmental variable. The fauna associated with the water hyacinth roots differed from that of the benthos because the limitations of low DO content were less pronounced.

Effects of the IBT The hydrological regime of the Mhlatuze River is highly regulated below the Goedertrouw Dam, being determined by the abstraction needs of downstream users, the major user at the lower end of the river being the IBT. Upstream of the IBT extraction weir, the water quality showed no spatial variability, but below the abstraction point flow was severely reduced and the tidal flow dominated. Low freshwater inputs into the estuary have caused the estuary to become marine dominated and depauperate.

Lake Nsezi, the recipient of the IBT, has a reduced biodiversity because it is now being maintained at a constant level. The flora and fauna need the highly variable conditions under which they evolved in order to survive, and deviation, one way or the other, will cause an alteration in the ecology.

This study has also provided baseline data against which the imminent Middeldrift IBT scheme (Thukela to Mhlatuze) can be gauged.

Cost: *R288 000*
Term: *1995-1998*

Technology transfer of the building-block methodology for instream flow assessments

(No 874) University of Cape Town – Department of Zoology

Environmental (or instream) flows are those left in or released into a river with the specific purpose of managing some aspect of its condition. Globally, river systems are deteriorating, and increasingly, the need for environmental flows is being highlighted. Although the science of determining these flows is young (<50 years), more than 100 methods exist with approximately 30 countries using them.

Recognising that international approaches did not meet South Africa's requirements adequately, the development of an approach that could be used in data-poor situations was initiated and first used on the Lephalala River in 1992. This was the first of a series of mainly DWAF-funded workshops where the expertise developed during WRC-funded research was implemented for the determination of environmental flows (known as IFR – instream flow requirement). The methodology, known as the building block methodology (BBM) has been developed to the point where it is one of only a few advanced methodologies with a formal manual in the world.

The BBM is a holistic methodology, not relying on indicator species as do other methodologies. The structure of the method requires intense communication among all disciplines involved which has greatly helped with the understanding of the needs of the various disciplines.

A number of IFR workshops have been held, with key workshops being the Luvuvhu River workshop in 1994, when the BBM "came together", the Logan River workshop in Australia (1996) and the Sabie River workshop (1996) which were attended by the Water Law review team. As a result of the team having watched the process, the requirement for environmental flows was written into legislation (National Water Act – Act 36 of 1998) as the ecological reserve.

The BBM is designed to construct a flow regime to maintain a predetermined condition. This manual describes the main activities and provides guidelines for its application.

Cost: *R95 500*
Term: *1997-1999*

Development of methodologies to promote interaction between the Kruger National Park Rivers Research Programme (KNPRRP) and catchment stakeholders

(No 986) University of the Witwatersrand – Centre for Water in the Environment

At the request of the University of the Witwatersrand, this project was terminated due to circumstances beyond their control.

Cost: *The amount paid to the University was subsequently repaid to the WRC*

Development of a programme for water quality research and technology transfer in the rivers flowing through the Kruger National Park

(No 988) University of the Witwatersrand – Centre for Water in the Environment

The Institute for Soil, Climate and Water and the Plant Protection Research Institute, both of the Agricultural Research Council, were subcontracted by the University of the Witwatersrand to execute this project.

The strategy proposed for water quality research and technology transfer comprises a multi-level stakeholder approach. This serves as a framework for technology transfer and as a platform from which

to launch current and future research and decision-support products on water quality. The needs assessment for the research facet of the strategy involves the identification, definition and prioritisation of water and land users' problems, risks and opportunities that appear susceptible to intervention.

The stakeholder needs are the products of the needs assessment process, involving not only the catchments of the KNP rivers, but also the research and technology development needs of the various stakeholders. Should the data that are required to address these needs not be available, research and development (R&D) of a basic, diagnostic, applied, adaptive or participatory nature may be necessary. This "demand-driven" approach requires for its success the development and availability of appropriate and improved technologies.

However, should the data required by the stakeholder be available, these and newly-developed data have to be integrated in decision-support (DSS) and information (INFO) systems.

Embodied in the proposed strategy is the transfer of new and appropriate technology. The integration of top-down and bottom-up actions is one of the prerequisites for technology transfer. This is needed for the empowerment of different stakeholders. By using a range of suitable mechanisms, an active and open communication environment is created which is conducive to successful technology transfer. Furthermore, in this regard, participatory research is considered to be very important since it allows stakeholders to appreciate, understand and take responsibility for the technology.

Finally, no strategy is complete without monitoring and evaluation since it provides a basis for decisions on future research, and the extent to which current research has achieved its objectives.

The report on this project, entitled: *An Action Plan for Water Quality Research and Technology Transfer in the Rivers Flowing through the Kruger National Park* (Report No 988/1/00) presents the average ratings of the water quality issues in general, and of the different catchments.

Cost: *R94 000*
Term: *1999-2000*

New projects

Benthic diatoms in the rivers and estuaries of South Africa

(No 1107) University of Port Elizabeth – Department of Botany

Phytoplankton and benthic diatoms make up a large portion of the total flora of rivers and estuaries. In many estuaries they are the most important primary producers. Research indicates, for instance, that phytoplankton alone contributed 51% of the total primary productivity of the Swartkops Estuary. However, because diatoms are small, they have been largely ignored. They are also indicators of water quality and, as such, they have an important role to play in the management of the ecology of estuaries.

This work follows from a project examining the potential to use diatoms as indicators of water quality in inland waters and a part of the project is to complete this work. The work will be extended to include the diatoms occurring in South African estuaries. The modern trend in water quality monitoring is to use the biota as a cost-effective way to assess the condition (health) of a water body. Estuarine water quality is very complex as a result of factors such as the template of varying salinity whereby all the processes occur. The understanding of the water quality requirements of individual species or communities would give insight into the health of the particular estuarine environment and would indicate where further actions are required.

This project has three sections. The objectives of each section are listed briefly below:

Section A: River diatoms

A previous WRC project (No 814), entitled: **The identification of diatoms and their use in the assessment of water quality**, was funded to examine the relationship between water quality in selected rivers and the epipelic and epilithic diatom communities. The new project aims to complete, in consultation with regional Water Boards, the database of dominant diatoms for South African rivers.

Section B: Estuary diatoms

The project aims to produce a compendium of illustrations of the dominant benthic diatom specimens collected from estuaries around the coast of South Africa. The data will relate species to water quality and habitat conditions at each site.

Section C: Manual of South African benthic river and estuary diatoms

During the project information on the dominant diatoms gathered from South African rivers and estuaries will be collated. In addition, the data produced from the previous project and those to be produced from Sections A and B will be included. Hence, the manual will be in three parts:

Part A: South African benthic diatom taxa and their sites of collection
Part B: Dominant benthic diatoms from the rivers of South Africa and the associated water quality
Part C: Dominant benthic diatoms from the estuaries of South Africa and the habitat conditions.

Estimated cost: *R415 000*
Expected term: *2000-2002*

Integration of water quality tools for the ecological reserve into a risk-based DSS

(No 1108) Rhodes University – Institute for Water Research

To date, the water quality aspects of ecological reserve determination have been less developed, and applied less frequently than methods for water quantity assessment. As the country moves towards the routine application of ecological reserve determinations, it becomes increasingly important that water quality and quantity assessments become integrated. Integration of the two components will become increasingly difficult as the methodologies for the quantity estimations of the ecological reserve develop. A standardised decision-support system (DSS)-driven approach as proposed here will drive this integration.

The objectives of this project are to:

- Record, integrate and communicate current approaches to quantifying water quality aspects of the ecological reserve.
- Develop water quality stressor-response indices, and to link these to the stressor-response indices developed in the water quantity approach, through the common development of a risk-based process (combining biotic stress/response relationships with water chemistry and flow-time series).
- Plan a process to integrate water quality tools within a DSS, based on a risk-based framework.

The achievement of the project objectives will:

- Consolidate progress in the development of methods to quantify the water quality aspects of the Ecological reserve.

- Contribute to the integration of water quantity and quality in the determination of the ecological reserve.
- Provide a process to integrate water quality aspects into the development of a risk-based DSS.

Estimated cost: *R278 000*
Expected term: *2000-2001*

Removal of marine sediment in South African estuaries with specific application to Eastern Cape estuaries

(No 1109) University of Port Elizabeth – Department of Oceanography

Excessive marine sediment accumulation is a recognised problem in many South African estuaries, but at present there has been no overall analysis of the sediment characteristics of such estuaries, or of possible remedial measures. This sedimentation is a natural process, which is caused by the flood-dominated character of most South African estuaries as a result of constricted mouths. However, long-term anthropogenic changes to the whole river/estuary systems have altered other balances by reducing the natural flow of freshwater into estuaries. This, in turn, has reduced the scouring impact of floods. In the past these floods served to scour the accumulated sediment and the whole sedimentation cycle was reset. The fact that these floods occur less frequently means that the ingress of marine sediments is occurring to a greater extent now than in the past. It also means that a much larger flood will be needed to scour the sediments, possibly with a much greater potential for flood damage due to the increased constriction caused by the sediments. This additional sediment accumulation in estuaries has a number of adverse effects on the estuarine environment and habitat, such as changing the ecology and the value for recreation.

Marine sediment accumulation in the estuaries was an overriding issue identified during the early stages of the Eastern Cape Estuaries Management Programme. Communities living beside the estuaries see this as a threat to the resource and need a way to cope with the problem. It is not the intention of this project to consider changes in the management of river catchments. This work will address mechanisms to deal with the symptom of excess sedimentation. The results will be transferrable to other parts of South Africa's coastline.

The aims of the study are to:

- Analyse the known sedimentation characteristics of South African estuaries, and review and evaluate the extent of the problems associated with the management of marine sediment accumulation in estuaries.
- Review and evaluate the methods available for managing marine sediment accumulation in estuaries. This will include a desk-top feasibility study, as well as an investigation of possible environmental constraints.
- Produce a synthesis on the management of marine sediment in South African estuaries, with specific reference to Eastern Cape estuaries.
- Produce a research programme description for marine sediment management in Eastern Cape estuaries.
- Initiate appropriate survey and monitoring procedures for the selected estuaries. This will use local TLC and NGO groups, who will be trained in these procedures.

Estimated cost: *R266 000*
Expected term: *2000*

Development of DRIFT, a second-generation methodology for instream flow assessments

(No 1159) Southern Water Research and Ecological Consulting cc

The Water Act makes provision for the ecological reserve which is there to ensure sustainability of ecosystem processes in the water resource. The reserve is assessed at three levels, the most comprehensive known as the comprehensive reserve determination. The building block methodology (BBM) is the method that is currently used to assess this. Considerable experience has been gained in the use of the BBM, and some shortcomings have been identified. Two of these are that a desired future state (DFS) has to be identified early in the process, and that only one flow regime is identified that will achieve the DFS.

During the recent past the proposer of this project has been the team leader for the instream flow assessment (IFA) of the Lesotho Highlands Water Project. The brief given to the team was considerably wider than is the case in South Africa, because in the South African situation, DWAF gave a more limited brief.

This led to the development of DRIFT (downstream response to imposed flow transformations), a demand-driven approach to IFA. This integrates the ecological needs with the economic and social requirements. It also develops a scenario-based product indicating what will happen to the system if particular components of the flow (e.g. early- or late-season floods, part of the winter base flow, etc.) are harvested. This gives managers a more powerful and more useful tool with which to work. Having the product packaged in the form of a DSS will make the decision tree much more accessible to managers.

The aims of this project are:

- The development of a second generation methodology for IFAs, after liaising with water managers, to ensure that their needs are met.
- The compilation of guidelines for applying the methodology; liaison with biophysical specialists to ensure that the correct data are collected.
- The development of a database and the creation of an expert system shell for use in IFAs where the methodology is used
- Transfer of the technology into the management milieu.

Estimated cost: *R848 000*
Expected term: *2000-2002*

Development of a computer-based decision-support system for quantifying the components of the ecological reserve

(No 1160) Rhodes University – Institute for Water Research

The incorporation of the ecological reserve in the Water Act has a far-reaching effect on the expertise required to perform the assessment. Up to now a relatively small group of experienced people have been able to perform this task. The substantial increase in the volume of work means that existing expertise will not cope with the demand. This project will provide the vehicle for the development of a computer-based DSS which will capture the reserve methodology in such a way that the intuition of the current specialists will be widely and consistently available. This will enhance the objectivity and consistency of reserve assessments. It will integrate the procedures which have been or are being developed. It will also provide a tool that can be used in training future practitioners.

The development of 'stress profiles' is a new idea which will present current knowledge in a form which lends itself to integrating the stresses imposed by the variables such as water quantity and quality in a manner that makes it clearly understood. This methodol-

ogy will be developed for inclusion into the DSS. This manner of presentation will also allow a risk-based approach to be used. This approach is favoured by DWAF. The quantity component of the ecological reserve for rivers has been chosen for the pilot application and more detailed treatment by the project team is implemented because the methodology is advanced furthest and tested.

The overall aim of the project is to develop a consistent protocol for the quantification and assessment of the ecological reserve within a risk-based framework. Within this overall aim are three objectives which aim to:

- Design and program (using Delphi) an automated DSS which will eventually accommodate all the steps and procedures required for quantifying the ecological reserve.
- Develop a risk-based process for the assessment of the water quantity aspects of the ecological reserve, by combining biotic stress/response relationships with flow-time series.
- Further understand the ecological conditions which require different flow regimes for their functioning (at present a range of flow regimes has been recommended for rivers with similar management classes and there is a need to explain this variability, so that consistent flow recommendations can be made).

Estimated cost: *R1 089 000*
Expected term: *2000-2002*

Ecological and geomorphological principles for river rehabilitation

(No 1161) University of the Western Cape – Department of Earth Sciences

Determination of the ecological reserve requires that a management class be set for each significant water resource. Policies being developed around this require that degraded water bodies be upgraded to an acceptable standard of ecosystem health. There is currently limited experience of this in South Africa, although countries in Europe and North America have been working on this for some time. More recently, great strides in river rehabilitation have also been made by the Australians.

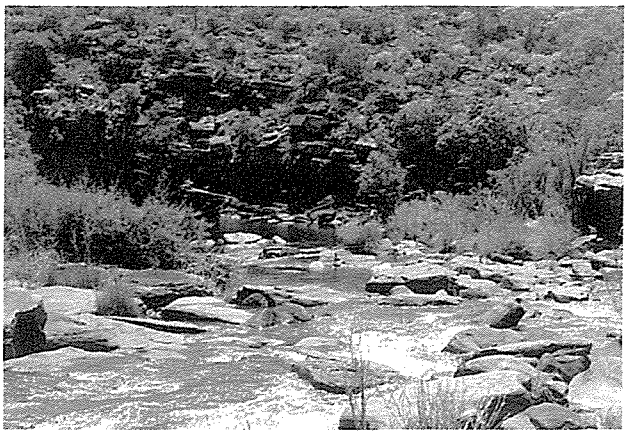
In South Africa, decades of poor catchment management, over-abstraction of water, use of rivers as waste disposal systems, destruction of riparian buffer strips and bulldozing of river beds have contributed to the toll of badly degraded rivers. The costs to the nation of poorly functioning rivers are largely externalised in any development activities. Although they are unknown,they are undoubtedly high.

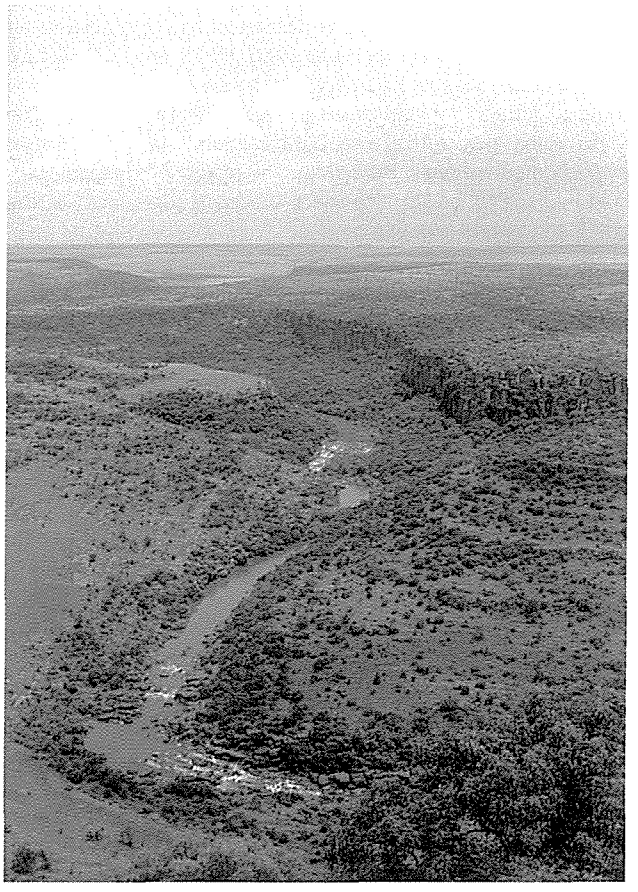
There is, however, an increasing awareness of the problem as seen by the increasing number of approaches to river scientists from government and municipal officials, land developers and land owners, who advise on river rehabilitation. At present, enquiries are dealt with on an *ad hoc* basis, using available specialist knowledge and intuition. Guidelines are needed to indicate how to go about river rehabilitation.

River rehabilitation will form part of integrated water resource management. It will also contribute to the development of land-use plans and plans to upgrade areas where bank erosion is a problem. This project which examines the principles of river rehabilitation will pave the way for the development of the science to:

- Provide a review of the world literature on river rehabilitation, assessing initial problem conditions and remedial actions taken.
- Assess and categorise the physical and ecological degradation of rivers in the Western Cape.
- Evaluate past regional case studies of river rehabilitation.
- Undertake a pilot study of the application of ecological and geomorphological principles for river rehabilitation in one rural and one urban catchment.
- Generate a draft set of ecological and geomorphological principles for river rehabilitation.

Estimated cost: *R1 190 000*
Expected term: *2000-2002*





Ecological and economic evaluation of wetlands in the upper Olifants River catchment, with reference to their functions in the catchment and their management

(No 1162) Afridev (Pty) Ltd.

The upper Olifants River catchment contains numerous temporary and permanent vleis, pans, and floodplains, collectively referred to, for the purposes of this project, as "wetlands". These wetlands play an important role in the hydrological cycle, and are, therefore, important for the river downstream, including the Kruger National Park and Mozambique. The wetlands also provide diverse habitats for aquatic biota, including migrating birds. The upper Olifants River catchment is underlain by extensive reserves of coal. The coal is mined mainly for its use in thermal power generation. This leads to conflict between development and the conservation of wetlands. Major threats to these wetlands include total destruction due to coal mining or agriculture, and changes in hydrology and water quality due to effluent discharge from agriculture, mines, power stations, industry and urban environments. This project will assess the ecological and economic value of wetlands, and in doing so, provide a strategic framework for the conservation and management of these important wetlands. The project will also provide a common currency for conflict resolution. The ecological and economic value of the wetlands in the upper Olifants River catchment is unknown. This information is essential for the development of an integrated management plan for the area. Furthermore, it is not possible to assess the regional and cumulative impacts of a proposed development without knowing the relationship between a potentially impacted site and the area in which it occurs. The need for such a study is supported by the mining industry.

Currently, there are few tools available for resource economists to use, and there is little capacity in the country to use what is available. This project will not only go some distance in providing answers on the management options for the wetlands in this area, but will help to develop capacity in an area where South Africa needs it. The common currency for negotiation referred to above will not only be useful in this geographical area, but it will form the basis of similar interactions elsewhere in the country. This project will integrate wetland management with a resource economic assessment of the goods and services that they provide.

The aims of the project are to:

- Produce an inventory of wetlands (pans, vleis and floodplains) in the upper Olifants River catchment (upstream of the Olifants and Klein Olifants confluence).
- Assess the net economic value derived from these wetlands, based on an evaluation of the goods and services they provide, and the opportunity costs of conserving them.
- Produce a classification of these wetlands in terms of their functional and ecological importance.

Estimated cost: *R585 000*
Expected term: *2000-2001*

Development of an estuarine water quality index for implementation in estuarine water quality management in Southern Africa

(No 1163) University of Zululand – Department of Zoology

The National Water Act embodies the concept of resource use being dependent on resource protection. The definition of water resources includes estuaries. Methodologies for the determination of resource quantity and quality in estuaries have not received the input that have been given to rivers. Consequently, these methodologies are less well-developed.

The proposer has developed a water quality indexing system based on rating curves of selected water quality determinants and the proposed project envisages developing a water quality index for estuaries which is able to interpret water quality variables in terms of ecological/biological resource protection. The index will be incorporated into a decision-support system using ARCVIEW as an environment. This will allow the index to link with other available models (e.g. metal speciation – MINTEQ2E).

DWAF needs an index of water quality for estuaries. This project promises to provide a model which will be useful in the short term, and which can be expanded in the future to incorporate additional information.

The aims of the project are as follows:

- To develop an estuarine water quality index which would assess water quality in terms of biotic resource protection.
- To integrate existing estuarine indices and water quality models into the index.
- To integrate the index into a DSS which would allow for the interlinking between the index, GIS maps of estuaries, an expert system, and catchment information.
- To implement the index to validate the different uses (i.e. classification, spatial and temporal monitoring) of the index in selected estuaries. The selected estuaries would be representative of the different types of estuaries in the country.
- To enhance capacity in the areas of water quality index development and estuarine water quality management.

Estimated cost: *R515 000*
Expected term: *2000-2001*

Hydraulic analyses for the determination of the ecological reserve for rivers

(No 1174) University of the Witwatersrand – Department of Civil Engineering

In terms of the new Water Act, determination of the ecological reserve is a prerequisite for rivers earmarked for development. Currently and in the recent past, a number of WRC projects attended to important facets of ecological reserve determination. Various projects dealt with ecological facets, whilst others are dealing with hydrological and economic facets.

An important precondition, however, is that the methodologies for determining the reserve must be scientifically acceptable following a holistic approach, where possible under the specific circumstances. In this regard, hydraulic analyses serve the purpose of being the link between hydrology, on the one hand, and other facets of the ecological reserve on the other hand.

The techniques available for utilisation in this regard are very engineering-orientated and, therefore, not always altogether acceptable for environmental applications. Especially as far as hydraulic characteristics of low flows in instreamflow requirement are concerned, there is a dearth of information which has been identified as a high research priority.

Against the above background, the following aims are to be addressed in this new project:

- To provide hydraulic methods to link hydrologic river flow characteristics and biotic requirements necessary for setting the full ecological reserve.
- To provide hydraulic methods for setting the preliminary reserve when the hydraulic data are limited.
- To develop three-dimensional habitat modelling to assist in the determination of the ecological reserve for rivers.

- To develop an index of hydraulic characteristics for quantifying habitat availability.

Estimated cost: *R1 050 000*
Expected term: *2000-2003*

Importance and role of water resources in the environment - A training course for social facilitators

(No 1180) Rhodes University – Institute for Water Research

Social facilitators are used extensively in rural upliftment and development projects. These facilitators often have limited ecological background, and may, therefore, be unable to educate rural communities adequately about the implications of South Africa's increasingly limited water resources. Although all South Africans have the right to an environment that is not harmful to their health or well-being (according to the new Bill of Rights), the people of this country also have a moral obligation to ensure that they are not responsible for undermining the sustainable utilisation of our water resources.

The aim of the course is to educate the social facilitators with a view of bringing about an understanding and awareness of the role and services of the environment and the importance of the water resource. The social facilitators will then be better equipped to educate rural communities, in the first instance, about the importance of our water resources. "Water resource management will only be successful if the personnel are developed not only in DWAF, but in all relevant organisations and agencies at all levels. Thus, for CMAs to be successful and to implement sustainable and participatory water management strategies, capacity will have to be built in marginalised and disadvantaged groups as well as at a technical level. Women are an important group, particularly in rural areas, who should be targeted by capacity-building programmes" (*White Paper on a National Water Policy for South Africa*, 1997, p. 31).

Estimated cost: *R68 000*
Expected term: *2000-2001*

Refinement of geomorphological tools for sustainable management of the river environment

(No 1181) Rhodes University – Department of Geography

The health of a river ecosystem depends on the availability of diverse habitats which can support a range of aquatic fauna and flora and the ecological reserve is designed to achieve this. An important objective of an instream flow requirement (IFR) workshop is to recommend flows which provide a satisfactory level of habitat diversity in order to maintain the desired ecosystem state. The need for a more quantitative assessment of habitat than is presently available has been expressed by a number of people in the field. Assessment of changes in habitat quality is also an important component of biomonitoring.

The work of Rowntree and Wadeson has demonstrated the usefulness of a hydraulic biotope classification as a descriptor of physical habitat. Their research has shown how the observed assemblage of hydraulic biotopes was discharge-dependent and that the relationship varied with channel morphology. The proposed project aims to apply these research findings to the development of a practical method by which hydraulic biotope mapping can be incorporated into the reserve assessment.

The geomorphological index developed by Rowntree and Ziervogel will be tested further and refined, particularly with respect to the inclusion of measures of habitat diversity and the rating system for channel condition.

Thus, the aims of this project are to:

- Develop a geomorphological tool to describe discharge-related changes in instream habitat using hydraulic biotope mapping.
- Apply hydraulic biotope mapping techniques for the assessment of the ecological reserve.
- Refine the geomorphological index developed for use in the River Health Programme.

Estimated cost: *R99 000*
Expected term: *2000*

Suspended sediment concentration and its implications on macro-invertebrates in the Umzimvubu River, Eastern Cape

(No 1182) University of Transkei – Department of Zoology

The Umzimvubu River catchment covers about 20 060 km^2 and provides land for more than a million people. The majority of these people rely on untreated river water for consumption. They also keep livestock and practise subsistence crop farming. Both practices contribute to soil erosion. The Eastern Cape is reported to be the second largest transporter of sediment (4 to 881 t/km·yr) in South Africa after the Orange River basin. The catchment is dominated by soils of the Beaufort Series, which have a high erosivity index, and therefore, it experiences high levels of soil erosion. It has been reported that the Colleywobbles Weir, which is 11 m deep in the Mbashe River, lost 10% of its capacity in less than 4 years. Similarly, it has been noted that the Elandsdrift Dam in the Great Fish River accumulated 25% of its capacity of sediment in less than 5 years. This is from a catchment with an estimated sediment yield of between 202 and 223 t/km·yr.

There is little literature available on the effects of excessive sediment on aquatic fauna. The work on the effects of turbidity on macro-invertebrates (WRC Project 716: **Water quality and aquatic faunal studies in the Umzimvubu catchment, Eastern Cape, with particular emphasis on species as indicators of environmental change**) which is currently in progress, is expected to contribute to this field.

The National Water Act requires that environmental water requirements be catered for as the second priority after water for basic human needs. This project will contribute to the knowledge of the quantity of sediment carried by the Umzimvubu River.

With the above in mind, the aims of this projects are to:

- Establish reliable estimates of suspended sediment concentrations in selected tributaries of the Umzimvubu River.
- Establish the particle size composition of suspended sediments.
- Establish the effects of suspended sediments (silt) on macro-invertebrates.

Estimated cost: *R90 000*
Expected term: *2000-2002*

Managing rivers in rural regions through community involvement and community awareness programmes. Phase one: determining the influences and interactions of the factors affecting biotic integrity through an investigation of habitat requirements

(No 1197) University of Venda – Department of Zoology

In underdeveloped rural communities, such as those that rely on the Luvuvhu River, the role or uses of a river differ from what is traditionally encountered in developed areas. These communities have a low *per capita* income and, thus, there is a high level of dependency on natural resources from the river and its catchment.

These uses, highlighted in the recently completed Mutshindudi River survey (WRC project 714: **Socio-biological study of the aquatic resources and their utilisation in an underdeveloped rural region, the Mutshindudi River catchment**) include: Water for human and animal consumption and irrigation of crops; fish as an important food source and plants used as food, fuel and medicine. The riparian zone also plays a significant role in the social and cultural lives of the people. Another finding of the previous project was a generally low level of awareness of the influence of poor water quality on human and ecosystem health, either locally or more remotely (e.g. the Kruger National Park or future possibilities for ecotourism).

The study will comprise two phases: The first phase will consist of identification of the factors that affect loss of diversity and will include an identification of the characteristics of biotopes, and an assessment of nutrient pathways and niche differentiation and partitioning. During the second phase the thresholds of probable concern will be determined, a management plan for the river will be developed, a joint report will be prepared, material for an aquatic system awareness programme will be compiled and an aquatic system awareness drive will be launched.

With the above in mind, the objectives of this study are to:

- Explain the influence of anthropogenic factors on the loss of biodiversity in the aquatic biota found in rheophilic biotopes through an understanding of habitat requirements, niche partitioning and nutrient pathways.
- Improve the managerial process through the determination and implementation of SAM through the determination of thresholds of probable concern.
- Establish community involvement in the decision-making processes as far as the utilisation of water and related resources is concerned.

Estimated cost: *R100 000*
Expected term: *2000-2001*

River systems in South Africa: A strategic analysis

(No 1198) University of Natal – Institute of Natural Resources

The philosophies and principles of water resource management in South Africa have changed dramatically. For the first time, social, economic and environmental processes are being integrated into water resource management. This is a significant challenge, especially as previously marginalised individuals and communities are brought into water resource management, and as water scarcity becomes chronic.

How will managers and researchers adapt to these changes? Change occurs within a context. Characterisation of the context will provide an important foundation for managers and researchers facing the immediate challenges resulting from new policy and legislation, as well as from those which lie ahead. Context has past, present and future dimensions. It has much to do with social, economic and environmental processes. Commonly, strategic reviews and analyses address one or, at most, two of these. However, some processes are often not addressed at all. At best, the linkages are weakly developed.

This strategic analysis will provide an integrated reference text which will be useful to researchers, managers and educators alike in carrying out their duties, because it will provide a thorough overview of the situation in the country. It will contribute to the insight that people need in order to make informed decisions in management and training. This is especially important in areas where it has become necessary to integrate disciplines which previously have been treated separately in order to solve and manage the complexity of problems which South Africa now faces with its changes in demographics combined with the implementation of new legislation. The contribution of this work to the development of an understanding of integrated water resource management will assist managers, researchers or educators to meet the challenges that lie ahead.

In order to achieve this, the specific aims of the project are:

- A strategic analysis which provides context, insight and direction for research and management of river systems in South Africa.
- Alignment with foresight reports to facilitate integration of river systems management into the broader context of water resource management.
- A modularised training programme which enhances capacity for management of river systems in South Africa.
- A reference text with a lifespan of 10 years, reflecting progress over the past 20 years, which will also review anticipated trends.

Estimated cost: *R187 000*
Expected term: *2000-2001*

Research projects

Completed

- **525** Natural and unnatural factors regulating the structure and functioning of estuarine systems (Institute for Natural Resources)
- **577** Decision-support system for the integrated management and conservation of estuaries (Institute for Natural Resources)
- **601** Freshwater requirements of plant communities in different types of estuaries (University of Port Elizabeth – Department of Botany)
- **665** Assessment of the ecological impacts of inter-basin transfer schemes in dryland environments (University of Cape Town – Department of Zoology)
- **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)
- **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)
- **874** Technology transfer of the building-block methodology for instream flow assessments (University of Cape Town – Department of Zoology)
- **986** Development of methodologies to promote interaction between the Kruger National Park Rivers Research Programme (KNPRRP) and catchment stakeholders (University of the Witwatersrand – Centre for Water in the Environment)
- **988** Development of a programme for water quality research and technology transfer on the rivers flowing through the Kruger National Park (KNP) (University of the Witwatersrand – Centre for Water in the Environment)

Current

- **754** Linking abiotic and biotic data on South African rivers (University of Cape Town – Department of Zoology)
- **756** Decision support for the management and conservation of estuarine systems: Phase 2 (Institute for Natural Resources)
- **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)
- **812** Botanical importance rating of estuaries in the former Ciskei and Transkei (University of Port Elizabeth – Department of Botany)
- **849** Geomorphological research for the conservation and management of Southern African rivers (Rhodes University – Department of Geography)
- **850** Regional implementation of DWAF's National Bio-monitoring Programme (CSIR – Division of Water, Environment and Forestry Technology)
- **856** Interaction of reed distribution, hydraulics and geo-morphology in semi-arid rivers (University of the Witwatersrand – Centre for Water in the Environment)
- **877** Verification of estimates of water use by riverine vegetation on the Sabie River in the KNP (CSIR – Division of Water, Environment and Forestry 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)
- **884** Hydrological modelling to manage the environmental reserve within the KNP (University of Natal – Department of Agricultural Engineering)
- **915** The impact of herbicides used in water hyacinth control on natural enemies released against the weed for biological control (Agricultural Research Council)
- **916** Invertebrates of South Africa – Identification keys (Umgeni Water (for the South African Society of Aquatic Scientists))
- **917** Promotion of scientifically based estuaries management through the development of an estuaries management handbook (Institute for Natural Resources)
- **955** Use of indigenous riverine organisms in applied toxicology and water-resource quality management (Rhodes University – Institute for Water Research)
- **956** Development of numerical methods for assessing water quality in rivers, with particular reference to the "instream flow requirements" process (University of Cape Town – Department of Zoology)
- **957** Ecological risk assessment in water resource management: Research priorities, process development and implementation guidelines (CSIR – Division of Water, Environment and Forestry Technology)
- **975** Assessment of the implications of inter-basin water transfers for the genetic integrity of donor and recipient river basins using selected taxa (University of Cape Town – Department of Zoology)
- **1017** Development of a biomonitoring method, using protozoans, for assessment of water quality in seasonal/ephemeral rivers and groundwaters (University of Cape Town – Zoology Department)
- **1018** Development of management policies, procedures and structures for Eastern Cape estuaries (Institute for Natural Resources)
- **1019** The Orange River blackfly, *Simulium chutteri*: Investigations into the physiology of the aquatic and non-aquatic stages so as to adjust the existing control programme to overcome summer outbreaks (Agricultural Research Council – Onderstepoort Veterinary Institute)
- **1045** Evaluating the environmental use of water-selected case studies in the Eastern and Southern Cape (University of Port Elizabeth – Department of Economics)
- **1063** Rule-based modelling of riparian vegetation and technology transfer to enable strategic adaptive management of Kruger National Park rivers (University of the Witwatersrand – Department of Botany)

- **1064** Decision-support system for rehabilitation and management of riparian systems (Institute for Natural Resources)
- **1065** Rule-based modelling of fish: Facilitating strategic adaptive management of the Kruger National Park rivers through model development and technology transfer (Rhodes University – Institute for Water Research)
- **1096** Information management and facilitation in the Kruger National Park Rivers Research Programme (KNPRRP) (University of Natal – Computing Centre for Water Research)
- **1097** Multi-party strategic adaptive management (SAM) of the Sabie River (University of the Witwatersrand – Centre for Water in the Environment)
- **1101** Development of monitoring methods for the ecological reserve (quantity) for rivers (Rhodes University – Institute for Water Research)

New

- **1107** Benthic diatoms in the rivers and estuaries of South Africa (University of Port Elizabeth – SAB Institute for Coastal Resource Management)
- **1108** Integration of water quality tools for the ecological reserve into a risk-based DSS (Rhodes University – Institute for Water Research)
- **1109** Removal of marine sediment in South African estuaries with specific application to Eastern Cape estuaries (University of Port Elizabeth – SAB Institute for Coastal Resource Management)
- **1159** Development of DRIFT, a second-generation methodology for instream flow assessments (Southern Water Research and Ecological Consulting cc)
- **1160** Development of a computer-based decision-support system for quantifying the components of the ecological reserve (Rhodes University – Institute for Water Research)
- **1161** Ecological and geomorphological principles for river rehabilitation (University of Cape Town – Department of Zoology)
- **1162** Ecological and economic evaluation of wetlands in the upper Olifants River catchment, with reference to their functions in the catchment and their management (Afridev (Pty) Ltd.)
- **1163** Development of an estuarine water quality index for implementation in estuarine water quality management in Southern Africa (University of Zululand – Department of Zoology)
- **1174** Hydraulic analyses for the determination of the ecological reserve for rivers (University of the Witwatersrand – Department of Civil Engineering)
- **1180** Importance and role of water resources in the environment – A training course for social facilitators (Rhodes University – Institute for Water Research)
- **1181** Refinement of geomorphological tools for sustainable management of the river environment (Rhodes University – Department of Geography)
- **1182** Suspended sediment concentration and its implications on macro-invertebrates in the Umzimvubu River, Eastern Cape (University of Transkei – Department of Zoology)
- **1197** Managing rivers in rural regions through community involvement and community awareness programmes. Phase One: Determining the influences and interactions of the factors affecting biotic integrity through an investigation of habitat requirements (University of Venda – Department of Zoology)
- **1198** River systems in South Africa: A strategic analysis (University of Natal – Institute of Natural Resources)

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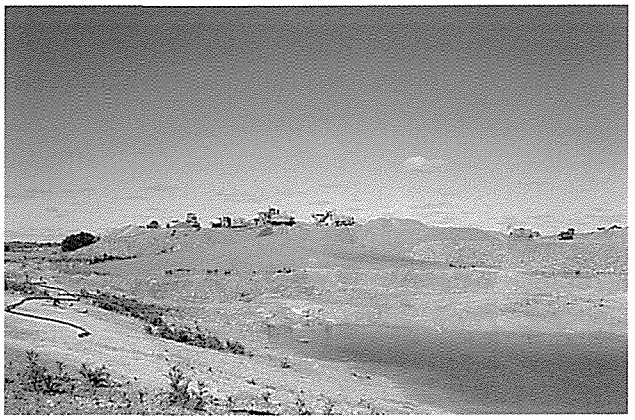
17 Mine-water management

By its very nature and scale, mining makes a marked and visual impact on the environment. Fortunately, the overall use of our water resources by the mining sector is relatively low and is unlikely to increase significantly in future because of declining mining activities and the high degree of reuse within the industry.



Mining, especially gold- and coal-mining activities, contributes significantly to water pollution in catchments with significant mining activities. There is a time lag before these effects are manifested and, unless properly managed, the effects may continue to be manifested long after mining activity has ceased.

Acid mine drainage (AMD) is the main water pollution problem associated with mining activities worldwide. AMD forms when the pyrite in ore and rock is exposed to air and water as a result of mining activities. Oxygen in the air, in the presence of water, reacts with pyrite to form dilute sulphuric acid, the main constituent of AMD. Metals, such as iron, aluminum and manganese, which dissolve under acidic conditions, are usually also present in AMD. Water-rich countries that have the means and the resources to dilute the accompanying salinity, identify pH and metal contamination as their major causes for concern. Because of our limited dilution capacity, the high salinity associated with AMD is an additional cause for concern for South Africa. Additional pollution originates from the metallurgical refinement and other beneficiation activities on mines.

The WRC is funding a fairly large portfolio of projects in the mine-water field. The emphasis is on research projects which are relevant under local conditions. Excellent co-operation is maintained with responsible government departments and mining houses concerning the identification of research needs and the execution of projects. Several projects are being co-funded by more than one organisation. The Co-ordinating Committee for Mining-Related Water Research (CCMRWR), which consists of representatives of government, industry, NGOs and local expertise, plays a direction-giving role in this regard. The CCMRWR held its third workshop to identify future research and technology transfer needs on 16 and 17 November 2000.

Mining-related projects which are being conducted presently aim to:

- Better delineate and quantify the magnitude of problems associated with mine-water management.
- Improve our ability to predict the long-term effect of present management and other interventions.
- Identify and test techniques and management options to prevent or minimise undesirable consequences associated with mining.
- Identify and test options to reuse or otherwise utilise undesirable products.
- Identify and test appropriate and cost-effective options to treat AMD.

Completed projects

Occurrence of bacteria-causing acid mine drainage in the outer layers of coal waste dumps

(K5/454) University of Stellenbosch – Department of Microbiology

AMD is caused by a combination of chemical and bacterial reactions when pyrite, which is commonly found in mining waste, is exposed to oxygen and water. The natural oxidation of pyrite is a slow process, but it is greatly facilitated by the action of specific bacteria. This project studied the occurrence of acid-forming bacteria in experimental coal discard dumps of DWAF, which were covered with a selection of soils in a combination of layers of different thicknesses. The soil covers were designed to create a range of percolation rates and degrees of aeration in the coal discard underlying the soil covers. The oxygen content and acid-generating bacterial activity were found to be well-correlated with each other and were found to increase as soil-cover thickness decreased. Acidophilic iron-oxidising bacteria, rather than thiosulphate – and/or sulphur oxidising bacteria, were found to be dominant under conditions of acid generation. Soil covers with a total thickness of 1 m were effective in creating anaerobic conditions and preventing acidification most of the time. Even under these covers, the underlying coal discard turned aerobic temporarily when the soil cover developed cracks during drought conditions.

Cost: *R207 470*
Term: *1992-1997*

Economic and technical evaluation of regional treatment options for point source gold-mine effluents entering the Vaal Barrage catchment

(No 800) Stewart Scott Inc.

Calculations based on previous studies indicated that four gold mines are contributing more than 25% of the salt load from point sources entering the Vaal Barrage. This load is contained in only 5% of the total flow, indicating that treatment or management of this source should be a high priority in terms of reducing the salt load into the system. This study found the contribution to be closer to 35% (80% of which was from one mine), which was contained in 6% of the flow. Budget costs were estimated for various treatment options in order to obtain an indication of the most cost-effective process to reduce salinity to a common value. Savings to downstream users were estimated to provide an indication of the benefits that would result from implementation. For a 5-year dry cycle the expenses were calculated to be up to six times greater than the savings accruing to downstream users. This ratio improved significantly when potential income from the sale of potable water and by-products (where applicable) was also taken into account. Overall, the most promising strategy in terms of total benefit was the installation of a by-pass channel which would conceptually reduce the volume of contaminated water by reducing inflow into a mine.

Cost: *R349 000*
Term: *1997-1999*

Development of an Internet service centre on water modeling systems for the mining industry

(No 901) Pulles, Howard and De Lange Inc.

Predictive models are increasingly being used within the mining industry to cover issues ranging from mine planning through to mine closure. Modelling of various water-related issues is important not only for identifying what may happen in future, but also what changes can be expected as a result of the implementation of a given management strategy. One of the problems faced by mine managers and regulators is how to select the most appropriate model for a given application. This project identified those models which are currently in use in South Africa, as well as those which could be used, but which are currently only used internationally. These models were evaluated and the evaluation was made available on an Internet site at the Computing Centre for Water Research (CCWR). Models were identified in the areas of hydrology, water quality, geochemistry, groundwater and salt and water balances. Information available on the Internet site allows the user to:

- Identify the range of models available for a particular water-related aspect
- Ascertain its applicability to the specific circumstances
- Evaluate the information and system requirements
- Identify where the model can be obtained, or who can undertake the modeling for the user
- Identify local and international case studies.

Cost: *R300 000*
Term: *1998-1999*

New projects

Assessment of short-, medium- and long-term impacts on groundwater quality associated with the filling of dolomitic cavities

(No 1122) Metago Environmental Engineers (Pty) Ltd.

Dewatering of the dolomitic aquifers overlying ore-bearing reefs has, since the 1960s, resulted in the formation of large numbers of cavities in the dolomitic compartments on the West Rand. Some of these cavities have in the past been filled with, *inter alia*, various mine waste materials including slimes and waste rock. The State Technical Committee for Sinkholes had raised the alarm about the potential for groundwater contamination as a result of this practice. Filling of cavities is necessitated both for safety reasons as well as to prevent further inflows of surface water which would lead to aggravated ground instability and accelerated recharge of the mine void and, hence, increased pumping costs. Slimes material is the most economical material which is available for filling cavities and, until its impact is proven to be harmful or irreversible, the State cannot intervene to prevent this practice.

This investigation will focus both on the impacts arising from the future filling of cavities as well as on the assessment of the effectiveness of alternative fill materials and methods in reducing those impacts. Impacts will be assessed over short-, medium- and long-term periods.

Estimated cost: *R440 000*
Expected term: *2000-2001*

Ponds in the Vaal River flood plain (Longlands) as a result of small-scale diamond mining.

Small-scale diamond miners sorting alluvial sediments at Gong Gong on the Vaal River.

Predicting the environmental impact and sustainability of irrigation with gypsiferous mine water

(No 1149) Coaltech 2020

The coalfields in the Highveld of Mpumalanga generate significant quantities of surplus neutralised acid mine water which is gypsiferous by nature. Because of their high salinity, these waters cannot be discharged freely to river systems. However, irrigation with these waters has the potential to significantly reduce the salt load emanating from mine drainage, while simultaneously, extracting value from water which would otherwise be a polluting agent. An initial rough estimate is that up to 10 000 ha of land could potentially be irrigated with coal-mine waters in the Mpumalanga Highveld.

This project will build on successful previous and current field-scale research based on the use of gypsiferous water for irrigation, by addressing the following aims:

- Determine the impact of irrigation with several gypsiferous water/soil combinations on soil conditions and groundwater quality.
- Develop further and refine the soil-water-balance model for use in predicting gypsum precipitation, crop response, water quality and water balance.
- Predict the likely long-term impact of gypsiferous irrigation waters on the groundwater system.
- Determine whether these waters can be used to produce crops on a commercial basis.
- Utilise the information gained to predict the sustainability of irrigation with gypsiferous water.

Estimated cost: *R4 400 000*
(R1 530 000 contributed by the WRC and R2 870 000 by the mining industry)
Expected term: *2000-2003*

Water-related impacts of small-scale mining – Nature of the impact and development of management options

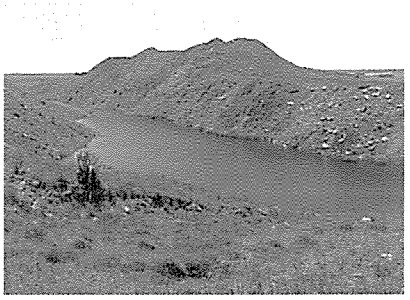
(No 1150) Pulles, Howard and De Lange Inc.

Small-scale mining already takes place widely in South Africa. The White Paper on Mineral Development in South Africa, identifies small-scale mining as an important sector of the mining industry. The interests of the country and the community, however, require that all forms of mining, whether large, small or micro, should be subject to the same requirements with respect to licensing, safety, health and the environment. It is also the view of Government that small-scale mining, like the rest of the mining industry, will be required to adopt measures that will promote environmental sustainability by means of the application of consistent standards and acceptance of the concept. All the policy principles concerning environmental management will also apply in the case of small-scale mining This project will aim to:

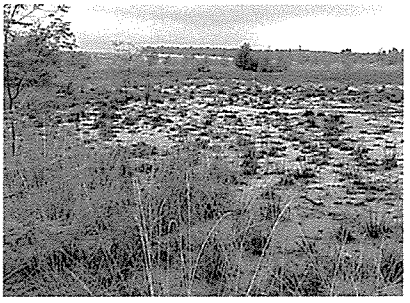
- Identify and characterise the critical water-related impacts of small-scale mining.
- Develop and recommend appropriate tools to assist in the environmental management of small-scale mining

The primary focus of this project will be on the water-related issues of peat extraction, clay-mining for brick making and other mining activities associated with gravels, alluvial sands and sediments.

Estimated cost: *R738 000*
Expected term: *2000-2001*



Old opencast mine filled with water.



Seepage from a rehabilitated opencast mine.

Opencast coal mining on a windy day.

Research projects

Completed

- **454** Occurrence of bacteria-causing acid drainage in the outer layers of coal waste dumps (University of Stellenbosch – Department of Microbiology)
- **800** Economic and technical evaluation of regional treatment options for point source gold-mine effluents entering the Vaal Barrage catchment (Stewart Scott (CE) Inc.)
- **901** Development of an Internet service centre on water modelling systems for the mining industry (Pulles Howard and De Lange Inc.)

Current

- **647** Application of isotope chemistry to quantify the contribution of gold and coal mines to salt pollution load in groundwater and rivers (CSIR – Division of Water, Environment and Forestry 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 Free State – Institute for Groundwater Studies, Chamber of Mines of South Africa and DWAF)
- **700** Pilot-scale development of integrated passive water treatment systems for mine effluent streams (Pulles, Howard and De Lange Inc., Chamber of Mines of South Africa, Eskom and Sasol Coal)
- **745** Suitability and impact of power station fly ash in mining rehabilitation (University of the 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)
- **801** Compilation of 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 (CSIR – Division of Water, Environment and Forestry Technology)
- **899** Quantitative evaluation of water utilisation in different rehabilitation methods on gold slimes dams (Envirogreen and Freegold)
- **900** Development of a management strategy for the controlled release of saline mine water during flood conditions in the Witbank Dam catchment (Wates, Meiring and Barnard (CE) Inc. and Ninham Shand (Cape) Inc.)
- **1001** Guideline for the development of rehabilitation management strategies for reclaimed gold mine dump sites in South Africa (Pulles, Howard and De Lange Inc.)
- **1002** Understanding and modelling of water flow through soil covers used for rehabilitating coal discard dumps and open-cast mines (Wates, Meiring and Barnard (CE) Inc.)
- **1003** Investigation of water usage at gold and platinum mine flotation plants (Technikon Pretoria – Department of Environmental Engineering)
- **1004** Field testing of real-time continuous flow and water quality monitoring instrumentation (Wates, Meiring and Barnard (CE) Inc.)
- **1055** On-site and laboratory investigations of spoil in opencast collieries and the development of acid-base accounting procedures (University of the Free State – Institute for Groundwater Studies)
- **1056** Investigation into the long-term impact of inter-mine flow in the Mpumalanga collieries (University of the Free State – Institute for Groundwater Studies)
- **1057** Neutralisation of acid mine water and sludge disposal (CSIR – Division of Water, Environment and Forestry Technology)
- **1078** Development and piloting of the integrated biodesalination process for sulphate and heavy metal removal from mine drainage water incorporating co-disposal of industrial and domestic effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **1079** Investigation into sulphur chemistry with specific application to biological sulphate removal processes (University of Cape Town – Department of Civil Engineering)
- **1080** Mechanism and kinetics of biological treatment of metal-sulphate-containing effluent (University of Cape Town – Department of Chemical Engineering)
- **1095** Tier 1 risk assessment of radio nuclides in selected sediments of the Mooi River (CSIR – Division of Water, Environment and Forestry Technology)

New

- **1122** Assessment of short-, medium- and long-term impacts on groundwater quality associated with the filling of dolomitic cavities (Metago Environmental Engineers (Pty) Ltd.)
- **1149** Predicting the environmental impact and sustainability of irrigation with gypsiferous mine water (Coaltech 2020)
- **1150** Water-related impacts of small-scale mining – Nature of the impact and development of management options (Pulles, Howard and De Lange Inc.)

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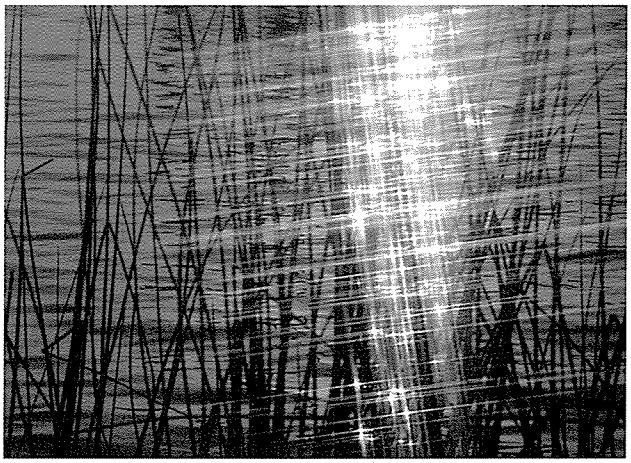
18 Water policy

Over the past 20 to 30 years it has become increasingly clear that publicly financed water supply schemes have not performed according to expectations.



Due to fiscal constraints and because of pressures to reduce budgets, governments in many countries are implementing programmes to transfer the responsibility of the management of public water supply schemes to local water user associations (WUAs). In some cases, this transfer involves the actual sale or disposal of all the public assets to the WUA, which effectively acquires ownership of the assets and complete privatisation takes place. In most cases, however, partial transfer of responsibility for the operation and maintenance of the water supply scheme is negotiated with the WUA, while the government agency retains control of water sources and the main storage and distribution network.

The involvement of water users in local water management very often leads to an improvement of water delivery services and a reduction in the costs of operation and maintenance. Monitoring of water use is undertaken and forums are created for the resolution of disputes. Loans and contributions of private capital by members are mobilised for the rehabilitation or refurbishment of water supply schemes. Applications for apportionment or transfer of water rights are usually channelled through the WUA. In all these instances, the initial success and long-term sustainability of WUAs depend on sufficient incentives for members to participate in water management.

As has been mentioned in previous reports, the focus of water policy research lies mainly in water valuation, water policy instruments and water organisations. In this year in particular, the completed projects provide information on, *inter alia*, setting water tariffs and applying tariffs to manage the use of scarce water resources in urban areas. Furthermore, guidelines have been developed for financial planning of water supply services and service delivery in selected rural areas has been evaluated. In the new projects, the emphasis is on benefit cost analysis of e.g. rehabilitating waterworks and to determine the role of the WUA in water management. In line with the international trends, it is envisaged that much more research needs to be done on the functions and structure of WUAs in order to comply fully with the requirements of the National Water Act of 1998.

Completed projects

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 metered water effectively is knowledge of its price elasticity of demand. However, no recent research effort has been undertaken in South Africa regarding this subject.

The objective of this research study was to estimate the residential price elasticities of demand for water for different income groups by means of the contingency valuation method (CVM).

The literature on this subject shows that CV values are good surrogates for actual behaviour and that CV measures from surveys can be compared directly with economic values attained from trends in the market place.

This study was undertaken in the residential areas of Alberton and Thokoza. The methodological approach was undertaken by means of a two-stage interview survey.

- Survey No 1: Consisted of establishing a water usage profile for different income groups in Alberton and Thokoza.
- Survey No 2: Consisted of a CV experiment and analysis.

During these surveys, it was found that people were not aware of how they used water, nor were they aware of how they could save water. Consequently, it was necessary to design an educational programme as part of the complete process in order to arrive at a meaningful result. Surveys 1 and 2 were, therefore, used in conjunction with each other, and the end result of the analysis yielded defensible estimates of the price elasticity of demand for domestic water usage amongst residential consumers in Alberton and Thokoza. >From the results it can be seen that the price elasticity of demand for total water usage in Alberton and Thokoza is -0.17. It, therefore, follows that if the price of metered water for residential use is increased by 10%, the total quantity of water demanded would be reduced by 1.7%.

Cost: *R473 400*
Term: *1997-1999*

Financial planning and modelling for regional water supply service providers

(No 896) Palmer Development Group

The provision of water supply services to rural communities is perhaps the most important objective of the RDP, given the extent to which the service can improve the health, quality of life and economic opportunities of people in these communities.

In providing such services, proper financial arrangements are of paramount importance: technical and level of service decisions need to be made within a context of financial constraints and the ability of the service provider to generate sufficient income to manage the service in the long term is an important factor.

There is inadequate knowledge in this field, although DWAF has taken a first step by funding a study, co-ordinated by Palmer Development Group to investigate the cost structure and tariff options for five districts in South Africa. The intention of this study was to build on this work and to develop a model which is useful to service providers such as water boards and district councils. The outputs from this study resulted in:

- A software model called Regional Water Suppliers Services Model (RWSSM) and an associated user manual were developed.
- A research report emanating from the application of the model on two regional water service providers, identified key factors affecting the viability of regional water service providers. Findings from these case studies are as follows:
- Application of the model to Lepelle Northern Water (LNW) indicated that the viability of the institution is dependent on:
  - The ability of LNW to effectively manage a 24% expansion of its operation over the next 10 years.
  - The ability of the LNW to raise loans in the order of R700 million over this period.
  - The ability of its retail water service providers to expand their customer base.
  - Ability of these providers to pay for this service.
- (In the case of Bloem Water, it was evident that Bloem Water is not faced with serious threats to its viability, because they have:
  - A relatively strong urban base
  - Good current service level coverage
  - Not had to face rapid expansion of its supply area.

The findings of the study have clearly shown the support that emerging water boards require for the long-term viability and indicates the enormous challenges faced by rural-based water boards. The value of the model that has been developed has been proven and it is hoped that it will be used widely in the water service sector.

Cost: *R144 000*
Term: *1998*

Guidelines for water supply tariffs for industrial and commercial consumers

(No 992) Palmer Development Group

Commerce and industry represent a major grouping of water consumers in most local authorities, consuming up to 50% of the water supplied in larger municipalities. These enterprises also made significant impacts on the local economy, society and the environment. Yet, surveys have revealed significant inconsistencies in the manner in which municipalities set tariffs for these consumers.

The WRC has already established a guideline for setting water tariffs in the form of a module in the *Management Guidelines for Water Service Institutions* (No TT 98/98). However, this module concentrates mainly on water tariffs for residential consumers. These guidelines have, therefore, been developed to assist water managers in setting tariffs for non-residential water use, focusing specifically on commercial and industrial water tariffs.

The guidelines have been written for water managers in Water Services Authorities (WSAs) and Water Services Providers (WSPs) who are involved in setting retail water tariffs, that is, water tariffs to the end-user.

A key conclusion of the research is that there is no practical system to implement inclining block water tariffs for non-residential consumers.

The guidelines also describe some tariff refinements for special cases, such as the use of new development charges; seasonal tariff setting; drought tariff setting and commodity price-linked tariffs.

Finally, the guidelines review a number of international and local case studies as a way of offering insights into the circumstances of other local authorities.

Cost: *R194 200*
Term: *1998-1999*

Rural service delivery – A case study of current water policies in relation to rural people's experience of implementation – case studies from the Eastern Cape

(No 1066) Rural Support Services

The study has identified several key issues with regard to rural people's experience of the implementation of water policies:

- *Demand responsive and supply oriented approaches* – This study indicates that the demand- response approach may not be appropriate for rural areas
- *Non-functioning schemes* – The reasons for this problem were local political disputes and lack of community ownership of the schemes owing to a lack of consultation during the project implementation phase
- *A supply of 25 l/cap·d* – 77% of respondents felt that this basic level of service was adequate for their daily needs
- *Poverty and payment for water* – Respondents supported payment for water on a sliding tariff scale. However, cross-subsidy or payment in kind was recommended for the very poor households
- *Unemployment and dependency on grants and pensions* – Lack of employment opportunities and poverty remain the greatest obstacles to the affordability of water

The study has recommended that an integrated approach to rural development be considered i.e. new water schemes must be linked to other local development projects.

Cost: *R113 000*
Term: *1999*

New projects

Security, ecology, community: Contesting the "water wars" hypothesis in Southern Africa

(No 1106) University of the Western Cape – Centre for Southern African Studies

The needs of ecological and political systems often come into conflict with each other. This was especially so in Southern Africa, where state-creation often ignored aquatic ecosystems in the establishment of political boundaries. For example, major river systems served as a convenient means to demarcate new states and to divide people and territory, not on the basis of natural affinities but to reflect colonial needs. As a result, watercourses have become sites of exclusion and division as opposed to inclusion and provision.

There is much speculation that waterways and water itself will become predominant sources of regional conflict as climate patterns change, populations increase and people compete for scarce fresh-water sources.

If peace, human security and sustainable development are to be realised in the Southern African region, it is crucial that people and policy-makers begin to see water as a potential source of human security and co-operation, rather than a breeding ground for conflict in Southern Africa during the 21st century.

To this end, this project intends to focus on issues such as water resource usage and management practices in three regional river basins. Issues and practices which are currently sources of trans-boundary conflict will be examined. Democratic decision-making procedures, institutional options for resolving conflict and the possibilities of using water issues to unite people in the common cause of seeking sustainable livelihoods, will be considered.

Specific aims are to:

- Gain a fuller understanding of decision-making processes concerning the allocation and usage of scarce resources within three SADC river basins.
- Challenge the currently prominent "resource scarcity and acute conflict" hypothesis.
- Move the security discourse away from its present state-centric bias, toward that of both human and common security.
- Facilitate broadly-based education and training of graduate students in the University of the Western Cape's new Water Management Programme.
- Begin a broad-based dialogue among relevant stakeholders regarding the sharing and management of scarce resources in the SADC region.

Cost: *R400 000*
Term: *2000-2001*

Updating of the 1989 manual for cost benefit analysis in South Africa to 2000 with specific reference to water resource development

(No 1132) Conningarth Consultants

The decision-maker in the public sector is often confronted with the problem of considering requests for the funding of a number of projects within a limited budget. This requires that the relative merits of each project be determined in order to obtain maximum net benefits for society as a whole. The evaluation of projects is often a difficult task since costs and benefits are spread over time and are not always quantifiable. Difficulties also occur when a choice has to be made between mutually exclusive projects that strive towards a common goal. These problems are not limited to capital projects, but are also apparent in current expenditure programmes. The method of cost benefit analysis (CBA) provides a logical framework and a means by which projects can be evaluated as an aid in the decision-making process.

Over the last 15 to 20 years, CBA has been applied mainly to the evaluation of the economic viability of the investment of public capital in infrastructure such as storage dams and canals on irrigation schemes. Even though the emphasis has now shifted away from supply side management, CBA will, in future, be necessary for the rehabilitation of existing water works and e.g. water supply schemes for domestic users in rural areas. Due to increasing fiscal constraints, investment in water infrastructure will have to be compared with alternative investments in schools, hospitals, roads, etc.

The 1989 CB manual was compiled by an inter-departmental task team under the guidance of the former Central Economic Advisory Services. It deals with the basic principles, uses and limitations of CBA in order to explain the conceptual framework. The manual addresses both theoretical and practical aspects with the aim of achieving uniformity in the application by different organisations in the public sector. Updating of the CB manual is essential, owing to recent changes in economic opportunities which necessitate that a new set of shadow and surrogate prices be developed. Specific attention will be given to water resource development which covers a range of infrastructural projects such as storage, distribution, sanitation, irrigation, transportation, electrification, etc. Support for this research has, therefore, been expressed in writing by both the Development Bank of Southern Africa and DWAF.

The aims of the research project are as follows:

- Verifying the principles underlying the 1989 theoretical approach so that it conforms to current international principles and theories and, if required, make the necessary changes.
- Updating and expanding shadow and surrogate prices to provide the user with a set of standardised, i.e. uniform parameters, to ensure that CBA is scientifically valid for the purpose of interpretation as well as comparison.
- Provision of practical examples for evaluating infrastructural projects e.g. existing dams, irrigation projects and water supply schemes to domestic users.
- Provision of the methodology for linking CBA to macro-economic impact studies.

Estimated Cost: *R419 000*
Expected term: *2000-2001*

An evaluation of the role of water user associations in water management in South Africa

(No 1140) Pula Strategic Resource Management

The general review of South Africa's water law culminated in the publication of a White Paper for a National Water Policy in 1997, followed by the promulgation of the National Water Act (Act No. 36 of 1998). The Act was purposefully formulated as a framework Act, to minimise the complexity of technical details and to achieve economy of drafting time and effort.

The institutional arrangements for water resource management adopted in the new Policy and Act represent one of the significant changes compared to the previous water law in South Africa. This is based on the delegation of many water resource management functions (particularly resource protection and allocation) to institutions within a Water Management Area (WMA), namely CMAs and WUAs, and to thereby involve local communities in decision-making. A significant amount of work is being done on the establishment and role of CMAs, whereas the role of WUAs has received limited attention.

WUAs are supposed to operate at a restricted localised level, to facilitate co-operative associations of individual water users who wish to undertake water-related activities for their mutual benefit. Although they are water management institutions, the Act indicates that their primary purpose is not water management. However, they are likely to be delegated powers to allocate water between water users within specified parameters, as well as to be responsible for the operation of certain water resource infrastructures, in order to ensure the sustainable provision of water to their members. Thus, WUAs may have a management and/or operational role. The objectives of this study are to:

- Investigate the implications of alternative institutional arrangements for WUAs with respect to CMAs in South Africa and to develop a framework for their functioning.
- Evaluate the functioning of a number of established WUAs against this framework and the particular needs of the local conditions.
- Formulate guidelines for the institutional and management arrangements around WUAs in South Africa.

Estimated Cost: *R380 000*
Expected term: *2000-2001*

Research projects

Completed

- **790** Estimation of the residential price elasticities of demand for water by means of a contingent valuation approach (Economic Project Evaluation (Pty) Ltd.)
- **896** Financial planning and modelling for regional water supply service providers (Palmer Development Group)
- **992** Guidelines for water supply tariffs for industrial and commercial consumers (Palmer Development Group)
- **1066** Rural service delivery – A case study of current water policies in relation to rural people's experience of implementation – case studies from the Eastern Cape (Rural Support Services)

Current

- **512** Development of procedures for decision support in water resource management (University of Cape Town – Department of Statistical Sciences)
- **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)
- **887** Development of a tool for evaluating the effect of alternative funding options (with different risk profiles) on water tariffs (PAA Ramsden, Private Consultant)
- **949** Development of a framework for the introduction of waste discharge charge systems in South African catchments (Stewart Scott (CE) Inc. and Development Planning and Research)
- **977** Human resource needs assessment – tertiary level: South African water sector up to 2015 (University of the Witwatersrand – Department of Civil Engineering)
- **978** Incorporation of economic considerations into quantification, allocation and management of the environmental water reserve (Institute for Natural Resources)
- **987** Modelling the value of water as an economic resource in selected catchment areas of South Africa: Great Fish and Sundays Rivers (University of Natal – Department of Agricultural Economics)
- **989** Modelling the value of water as an economic resource in the Great Letaba River catchment (Economic Project Evaluation (Pty) Ltd.)
- **990** Modelling the value of water as an economic resource in selected catchment areas of South Africa: Vaal River (Greengrowth Strategies CC)
- **994** Preparation of guidelines and a model for the financing of district council's water supply functions (Palmer Development Group)
- **1021** Gender dimension of the water policy and its impact on water and sanitation provision and management in the Eastern Cape: The case for Peddie district (University of Fort Hare – Department of Development Studies)
- **1044** Development of guidelines for the financing of catchment management in South Africa (Palmer Development Group)

New

- **1106** Security, ecology, community: Contesting the "water wars" hypothesis in Southern Africa (University of the Western Cape – Centre for Southern African Studies and Department of Earth Sciences)
- **1132** Updating of the 1989 manual for cost benefit analysis in South Africa to 2000 with specific reference to water resource development (Conningarth Consultants)
- **1140** Evaluation of the role of water user associations in water management in South Africa (Pula Strategic Resource Management)

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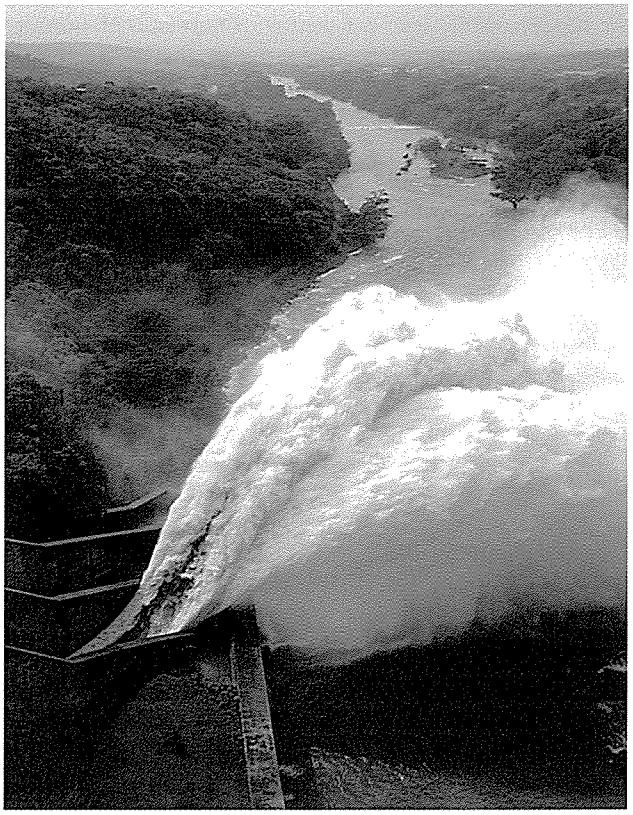
19 Hydraulics

Although the WRC started to report on its research projects in the field of hydraulics by means of a separate chapter in our Technical Report *only in 1997, the WRC has since 1971 funded or is funding 90 projects dealing with facets of hydraulics.*



October 2000 artificial environmental flood release from Pongolapoort Dam, which peaked at about 700 m³/s with a total flood volume of more than 300 million m³.

However, the nature of hydraulics *per se* and of water research in general is such that well-established theories and principles of hydraulics are being applied in the majority of the projects funded by the WRC.

Hydraulics is defined as that branch of science and technology concerned with the mechanics of fluids, especially liquids. In spite of the above statement regarding hydraulics being an integral part of just about all facets of water-related research, it does happen from time-to-time that a specific research topic by way of its very nature or importance, is such that it justifies recognition as a hydraulics research project in its own right, regardless of the field in which the expected research results are to be applied.

The latter view was confirmed by the outcomes of a workshop on research needs in the field of hydraulics which was held during 1998. The needs that were identified during this workshop also guided new research projects which were launched during 1999 and 2000. In view of these new projects and those completed since the 1998 Workshop, it has become necessary to revisit the research needs of this field, especially against the background of the requirements of the stakeholders – mainly DWAF, Environmental Affairs and Tourism; Water Boards; Metropolitan Councils and local authorities and consulting engineers.

The 1998 Workshop formulated the following as the primary goal of hydraulics research in South Africa:

> **To acquire adequate understanding of all facets of hydraulics in order to develop appropriate technologies, required for the solution of those problems impacting on the assessment, management and sustainable equitable utilisation of Southern Africa's water resources**.

The formulation of this primary goal was so generic that it is still valid two years and 20 research projects later. As stated earlier, it has the potential to continue guiding hydraulics research in South Africa, but in view of new needs and priorities of stakeholders, the secondary goals may require re-consideration and re-formulation.

Those secondary goals that did receive substantial research support during recent years and in which significant progress has been made, are the following:

- Sediment properties, sediment transportation, sedimentation in reservoirs and dams, and desilting.
- River hydraulics with special emphasis on river morphology.
- Eco-hydraulics, i.e. the hydraulics requirements of rivers and estuaries.
- Conveyance and distribution infrastructure: Economic and functional optimisation of tunnels, pipelines and distribution systems.
- Flow measurement in pipes, canals, tunnels and rivers: Construction, cost and reliability.
- Hydraulics problems associated with water and wastewater treatment infrastructure.
- Hydro-informatics and data processing required for, *inter alia*, integrated catchment management, flood management and computational fluid dynamics.

In line with the first paragraph of this chapter, a number of projects dealing with some of the secondary goals are not dealt with in this chapter, but rather in those chapters where the results are relevant and significant.

Completed projects

Engineering properties of important Southern African rock types with special reference to the shearing strength of concrete dam wall foundations

(No 433) Technikon Pretoria – School for Civil Engineering

This project set out to investigate the shear strength of joints in a number of rock types, and to link these strengths to the condition of the surfaces of the rock joints. Results were obtained for dolorite, granite, mudstone and quartzite and, to some extent, for basalt and sandstone. Furthermore, the characteristics of the most common Southern Africa rock types were also determined in order to serve as preliminary design parameters.

The report on the project is a very comprehensive source of engineering characteristics of Southern African rock types. It describes

the strength, deformation and general characteristics of quartzite, shale, sandstone, dolorite, mudstone, granite, rhyolite and fillite in detail. Emphasis was placed on the shear strength of discontinuities in rock. In this regard, the report also describes the design and construction of a large shear box apparatus built for testing large specimens, the test procedures followed, as well as the results of shear testing large specimens.

Strength determinations were done in three phases. Peak shear strength was determined in the first phase, whilst the residual shear strength parameters under dry and submerged conditions were determined in the second and third phases. The shear strength parameters of joints in rock are mainly influenced by the hardness and the roughness of the joint. A method was developed to present a three-dimensional image of the topography of a joint surface that could be used to quantify joint roughness. Roughness was also expressed by determining the volume of material above the lowest point on the shear surface. The roughness index (equal to the volume of material above the lowest point, divided by the surface area of the specimen tested) was defined and investigated as a measure of joint roughness.

Emphasis was placed on the shear strength parameters of joints, especially the angle of friction. Two types of joints are recognised in nature:

- Joints with no or little fill material where the shear strength is strongly influenced by the characteristics of the rock material.
- Joints with fill material where the shear strength is determined by the characteristics of the fill material.

The major part of this research concentrated on joints with no or little fill material. The three major characteristics determining the shear strength parameters of this type of joint are:

- The base shear strength of the rock material
- The roughness profile along the joint surface
- The hardness of the material on the joint surface.

Cost: *R469 400*
Term: *1992-2000*

Monitoring reservoir-induced crustal deformation using satellite-borne interferometric imaging radar

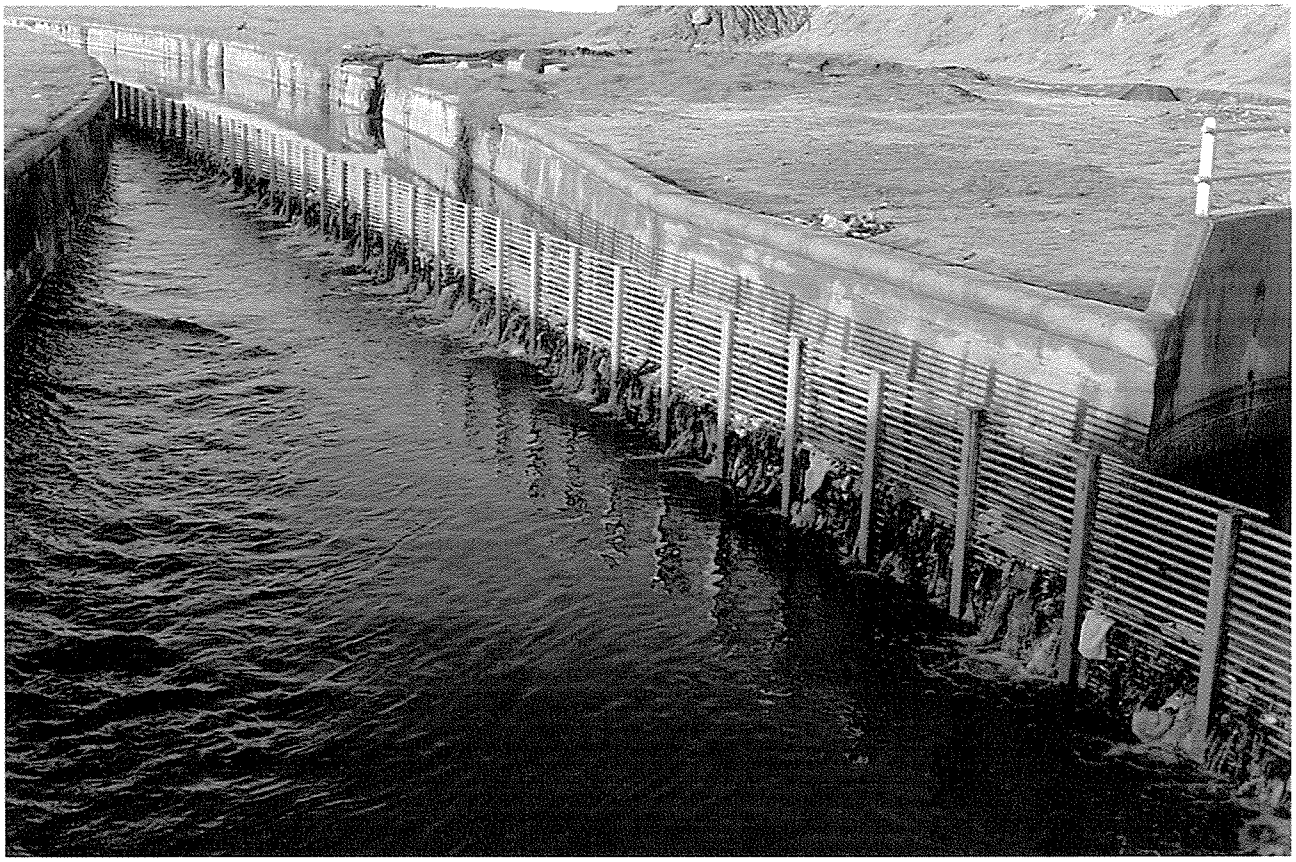
(No 910) University of Cape Town – Department of Electronic Engineering

Synthetic aperture radar interferometry (InSAR) and differential InSAR (dInSAR) are relatively new remote sensing techniques, which can be used to derive topographic height and height change information over large areas. The technique has potential for various uses such as the detection of subtle ground deformations due to earthquakes and mining subsidence.

The focus of this project was the mapping by dInSAR of deformations due to reservoir loading in the Katse Dam in Lesotho. However, during the course of the project, the processing techniques were also tested on some data from the Earth Resource Satellites (ERS) for the Western Cape.

In the case of the Katse Dam, it was observed that information obtained from conventional geodetic monitoring of the dam site indicated that the actual deformation had, in fact, been almost of a magnitude which was less than was expected. This put the deformation outside the detection limits by dInSAR.

However, although no ground deflection was detectable, the technique worked far better than expected, given the terrain and the time separation between images (3 years).



"Enviroscreen" with trash sticking to the screens. Cape Town City Council.

In the case of the Western Cape, a digital elevation model (DEM) was produced. A comparison of the DEM with independently (optically) derived height information showed a number of anomalies in the InSAR-derived DEM. The anomalies can be attributed to refracture variations within the atmosphere at the time of image acquisition. Work is currently under way to develop techniques for combining data sets so as to minimise such errors.

As a result of this project, an important centre of expertise has now been strengthened at the Radar Remote Sensing Group at the University of Cape Town, while close co-operation has been established with the University of the Western Cape.

Cost: *R310 000*
Term: *1998-1999*

New projects

Quantifying the influence of air on the capacity of large diameter water pipelines and developing guidelines for effective de-aeration

(No 1177) Ninham Shand (Pty) Ltd.

In any major water supply development, the utilisation of large-diameter pipelines is unavoidable. Even though de-aeration has always been a problem, it would still appear that current practices in this regard do not always meet the objectives. These problems result in decreased capacities, which, in turn, result in increased operational costs and even augmentation schemes. In addition, areas of accumulated air are subject to increased corrosion with the accompanying negative effects.

The need for research on acceptable and reliable practices with regard to de-aeration in large-diameter pipelines was also identified during a workshop on research needs in the field of hydraulics in March 1998. The project addressed a need, the importance of which can only increase in future water transfer schemes in South Africa.

In order to achieve the objective of guidelines for effective de-aeration of pipelines, the project will attend to, *inter alia*, the following:

- Field determination of the current hydraulic capacity of large-diameter pipelines and comparing it to design capacities.
- Laboratory investigations into the effect of localised air bubbles on the magnitude of the transient waves and stresses in the pipeline, hydraulic transportability of free air in pipelines and the dynamics of air bubbles at apex points.
- Establishing the requirements for effective air release from pipelines, the dimensions of accumulators in terms of the pipeline characteristics and the air valve operational features.

It is worth mentioning that significant contributions were made by three parties: Rand Water, Umgeni Water and Vent-O-Mat (Pty) Ltd. These contributions, together with the availability of Rand Water's B8 pipeline, are providing a unique opportunity to address this problem without disrupting normal activities.

Estimated cost: *R750 000*
Expected term: *2000-2002*

Removal and disposal of sediments from pump intakes in rivers by means of permanently installed jet pump type dredge systems

(No 1187) Prestedge Retief Dresner Wijnberg (CE)

In a previous WRC project (**Removal of floating and suspended materials from streams**) (Project No 691) a relatively small subsection addressed the problem of sediment removal from pump intakes. A major reason for the problem lies in the fact that local conditions often differ from those in regions where many of the classical extraction layouts have been developed. In Southern Africa discharges are highly variable, often carrying heavy loads of suspended sediments.

Sand River pump station: Sediment management at intake pumping stations.

Two distinctive situations are common, namely:

- Streams which carry loads of predominantly fine sediments (major portion of the particles typically smaller than 0.3 mm diameter).
- Steep rivers that carry heavy sediment loads which may include gravel, cobbles etc.

In both cases, intake structures are necessary for pump inlets. These usually result in complex three-dimensional flow patterns, the investigation of which often requires physical model studies in order to design layouts for optimal efficiency.

This project proposes a novel approach which should provide an economically sustainable solution to the problem of sedimentation (fine and coarse) at pump inlets. The intention is to develop a scaled-down version of the jet pump principle utilised for off-shore diamond mining. Although it is a well-established principle, it requires adaptation to the pump station situation and right-sizing it to the specific conditions. The end-result (i.e. a generic guideline on the utilisation of the system) would address a problem encountered in many parts of the country.

Estimated cost: *R469 000*
Expected term: *2000-2001*

Determination of the accuracy whereby the flow rate of electrically-driven pumps can be calculated when use is made of the measurement of electric power supplied to the electric motor

(No 1190) MBB (CE) Inc.

Improved management of South Africa's water resources forms the foundation of the new Water Act. In this regard, water metering is one of the most important aids to assist the water user in making optimal management decisions.

Water metering is, however, poorly implemented in the agricultural sector. An investigation in a specific area in the Western Cape Province indicated that only 32% of the pump stations are equipped with water meters (and of these, approximately 40% are inoperable). Even if all these meters were fully operational, they would be measuring only about 11% of the combined capacity of these pump stations.

This project is based on the hypothesis that the equation used to calculate electrical power requirements, together with the characteristics of the pump, could be utilised for flow determination. Theoretically, this hypothesis is sound, on the condition that electrical current and voltage measurements, as well as hydraulic head measurements, are easily made and are of acceptable accuracy.

Based on this hypothesis, the research team (comprising MBB (CE) Inc. and Cape Technikon) conducted a preliminary investigation into the proposed approach during 1999. This investigation concluded that the relationship between flow rate of a pump and the electrical power supplied to the pump does have the potential for flow rate determination, and that an in-depth research project was justified. Indications are that the cost of suitable instrumentation would compare favourably with that of conventional flow meters. In addition, it will have major advantages with regard to the ease of installation.

The main aim of the project, therefore, is to develop a procedure and supporting instrumentation, whereby water which is pumped with an electrically-driven pump, could be measured indirectly. This requires the measuring unit to be of acceptable accuracy, to be tamper-proof, simple to install and at a cost comparable to that of conventional meters.

Estimated cost: *R600 000*
Expected term: *2000-2001*

Research projects

Completed

- **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)
- **910** Monitoring reservoir-induced crustal deformation using satellite-borne interferometric imaging radar (University of Cape Town – Department of Electrical Engineering)

Current

- **502** Plunge pool scour reproduction in hydraulic models (CSIR – Division of Water, Environment and Forestry Technology)
- **911** Sediment-induced density current formation in reservoirs (University of Pretoria – Department of Civil Engineering)
- **979** The hydraulic characteristics of ecological flow requirement components in winter rainfall rivers (University of Stellenbosch – Department of Civil Engineering)
- **980** Measurement of high flow in rivers (Sigma Beta (CE))
- **1051** The reduction of urban litter in drainage systems through integrated catchment management (University of Cape Town – Department of Civil Engineering)
- **1088** Hydraulic analysis of tunnel ageing and possible remedial measures (Ninham Shand (CE) Inc.)
- **1098** Sediment transport through hydraulic structures in rapidly varied open channel flow (University of Cape Town – Department of Civil Engineering)
- **1102** Hydraulics of the impacts of dam development on the river morphology (University of Stellenbosch – Department of Civil Engineering)

New

- **1177** Quantifying the influence of air on the capacity of large-diameter water pipelines and developing guidelines for effective de-aeration (Ninham Shand (Pty) Ltd.)
- **1187** Removal and disposal of sediments from pump intakes in rivers by means of permanently installed jet pump type dredge systems (Prestedge Retief Dresner Wijnberg (CE))
- **1190** *Determination of the accuracy whereby the flow rate of* electrically-driven pumps can be calculated when use is made of the measurement of electric power supplied to the electric motor (MBB (CE) Inc.)

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20 Research support services

WATERLIT

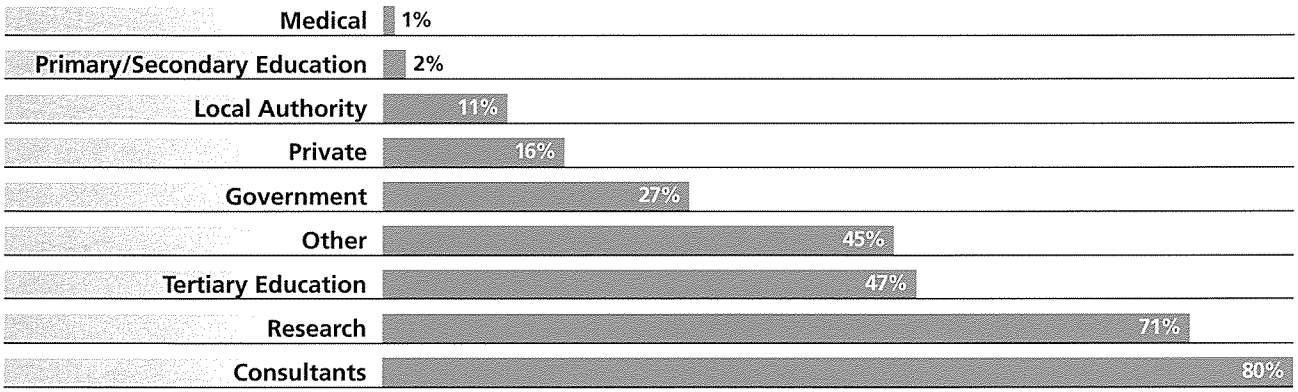
When the WRC took over the responsibility of the development and maintenance of the ***Waterlit*** database in 1999, there were many sceptics wondering whether such a drastic move could be successful at all. After being in place for more than a year, the results indicate that the move has been a resounding success. Not only are other libraries participating enthusiastically by making their information resources available to the database builders for inclusion into ***Waterlit***, but indexers have also successfully taken on greater responsibilities in the whole process. Since January 2000, the database is also run from a computer at the WRC and is no longer based at the CSIR. After a trial period of a few months where database searches required no formal registration, a system for user-registration, followed by the allocation of an ID number and password, was introduced successfully. Currently there are 300 registered users of the database, together with two international paying subscribers. A breakdown of their individual occupations presents the following interesting information:

The total number of references in the database is now fast approaching the **330 000** mark, with approximately **14 500** references being added during the past year. Currently there are eight indexers working in the Pretoria region, one in Pietermaritzburg and one in Stellenbosch. Two more indexers will soon join the team to cover the greater Cape Town region.

Waterlit now also forms part of the set of South African databases offered by SABINET Online (Pty) Ltd, the local company offering access to a wide range of Internet-based information products. Users searching for information on this set of databases, automatically also search ***Waterlit***. For the period December 1999 to October 2000, a total of **66 418** searches on this database set, were registered.

Internationally, ***Waterlit*** is still published on CD-ROM by NISC (Pty) Ltd. under the title ***Water Resources Worldwide***, and sold to a wide range of water-related institutions. This CD-ROM is made up of ***Waterlit***, Canada's ***Aquaref***, the Netherlands' ***Delft Hydro*** and the aquatic subset of ***CAB Abstracts***.

Occupations: Waterlit users



Computing Centre for Water Research (CCWR)

The Presidential Imperatives and Constitutional Requirement for Co-operative Governance require co-operative science as one of its critical foundations. One of the WRC's services in support of these imperatives is the CCWR.

The rationale for the CCWR's role is the WRC's belief that implementation of the goals of integrated water resource management requires that the scientific basis for such management be also integrated. Much of the water science knowledge is encapsulated in simulation models. It is in the area, i.e. model and information integration, that the CCWR plays a key role. The CCWR does so by assisting and affording water researchers and practitioners who wish to integrate their endeavours, the opportunity to do so, on a common computer. Sharing software, hardware and human resources makes good business sense in our country. Furthermore, the benefits for synergy and achieving critical mass are important.

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 because these experts need to specialise, but at the same time, they also need to integrate their highly complex, multi-faceted and inter-dependent fields of water science. The CCWR's activities are supported by the WRC in order to creatively and cost-effectively minimise the disadvantages and to maximise the advantages of the geographic separation of our limited scientific intellect. The incredible growth in wide-area computer networking technology has enabled the WRC to create a virtual centre in the CCWR where scientists from throughout Southern Africa, and indeed the world, can interact to co-create new perspectives. These, in turn, lead to more effective actions in the search for equitable and sustainable solutions.

The CCWR's small staff of 6 professionals serves the on-line, medium- and long-term needs of more than 205 registered users who are based at no fewer than 118 departments within 69 institutions. In addition to the service role implied above, the CCWR is involved in several innovative and highly relevant endeavours to serve future CMAs and stakeholder groupings with systems software.

Models (which are, in essence, a sequence of assumptions) link the water science with the social process of water mangement. This is a vital link and the CCWR is operating daily, with a wide range of

stakeholders at the forefront of knowledge and implementation in this area in South Africa.

A wise blend of creativity, innovation and control is needed in our integrated water resource software systems as we move into the uncertainty of the 21 st century. The CCWR has focused this past year on adopting free world-class, well-supported software which provides the inter-operability standards to enable systemic innovation to flourish. The CCWR has striven, with some success, to link the modelling and information efforts of numerous groups in the public and private sectors to the skeleton core.

The CCWR's activities during 2000 focused on:

- ***guiding*** integration needs between organs of state, between other potential stakeholder groupings in the emerging CMAs and at DWAF
- ***facilitating*** the two-way flow of data and information between all stakeholders in the state and other sectors
- ***providing*** an incentive to change to greater integration, where necessary, within the above organisations
- ***recommending*** *de facto* standards and create a fertile climate for other standards and tools to emerge
- ***lowering*** barriers to information exchange
- ***empowering*** stakeholders to interact more meaningfully
- ***providing*** world-class free open-source software and hence, lowering the financial barriers of entry into the process of allocation bargaining
- ***lifting*** professionalism of scientific personnel within all sectors interacting on water issues
- ***providing*** a role model for neighbouring countries to follow
- ***delivering*** speedily to a broad base of stakeholders and water resource interest groups
- ***enhancing*** the scientists' ability to engage in interest-based bargaining
- ***providing*** more impetus and focus within the range of stakeholders and, particularly, organs of state charged with "delivery" in these matters

The WRC commissioned a professional independent survey of the CCWR. The survey was a hybrid combining a customer satisfaction survey with a needs analysis and positioning study. The survey yielded an overall score of 81% which compares favourably with the recommended score of 83% for world-class companies.

The survey (November 1999) revealed that the current CCWR users believed that the CCWR's main role and purpose should be to:

- Be the custodian of **accurate** and **relevant** hydrological data
- Effectively disseminate this information
- Manage databases
- Provide software which is user-friendly and links users to the databases
- Facilitate the interaction between users
- Provide modelling systems for water research
- Act in an advisory capacity.

Survey respondents indicated that the CCWR is delivering service in a capable and professional manner in order to meet the above needs. Furthermore, that the CCWR's focus on installed modelling systems as a delivery mechanism for the above, was supported by 75% of respondents.

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21 Information services (IS) and transfer of information and technology

In a world where the development and application of information technology have changed the way that we think and operate, organisations such as the WRC have found new and innovative ways of disseminating their information to an ever-growing international audience.

Not only have personal computers become faster and more powerful, but the Internet has become an essential communication tool.

These technological developments allowed the WRC to fulfil its mission to promote the transfer of information and technology, especially among the residents of South Africa.

Information services

The WRC website on the Internet: http://www.wrc.org.za

During the past year, the WRC's website continued to be used as an effective means of making information available to users all over the world. Although the basic design of the website remained the same, a number of extra features were added. Copies of WRC press releases have been made available, while important announcements, policy documents and other topical information which no longer deserve a place on the home page, are now listed under 'Reference information' on the website.

The website is also increasingly used for the downloading of software and models which were developed as products of research projects. In a few cases, the actual report, together with the relevant software, have been made available on the web page. The full text versions of the three official WRC publications, ***Water SA***, the ***SA Waterbulletin***, and the WRC ***Technical Report***, are also available on the web.

For the third consecutive year, the WRC used their website as a vehicle for the annual submission of project proposals in April by individual researchers. The same system was also used later in the year for the submission of proposals for the Partnership Fund. An interesting observation was that the number of problems experienced by researchers during the input of their proposals via the Internet have dropped dramatically. Researchers have obviously learned how to use the system and require less assistance in doing so.

On average, the number of visitors to the WRC website, showed limited growth when compared to the figures for the previous year. Staff changes, unfortunately, prohibited regular updating of the website which may be the reason for the lack of growth in website visits. As could be expected, the visits peaked during April when new project proposals had to be submitted via the Internet. The number of visits to the WRC website during 2000 follows:

Web user statistics for 2000 on the WRC

MONTH	TOTAL SITE HITS	TOTAL WATERLIT HITS
January	59 958	146
February	78 765	11 659
March	50 369	18 042
April	166 293	11 381
May	126 119	25 266
June	81 326	18 271
July	46 861	16 387
August	50 369	14 034
September	59 900	11 900
October	45 195	11 134
November	51 528	11 423
December	29 392	4 211

Computer network management

Towards the end of 1999, precautions were taken to ensure that the WRC computer network would be Y2K compliant. Fortunately, no problems were experienced when we moved into the new millennium!

Early in 2000, the WRC Project Management System was upgraded. This upgrade required that the existing computer equipment used by research managers and their secretaries also had to be upgraded. Computers previously used by research managers and their secretaries were then allocated to staff who were using obsolete equipment. In total, the whole computer network within the organisation has now been upgraded.

SA Water Research Database (SAWaR)

The South African Water Research Database (SAWaR) is a database developed by the WRC to keep track of research undertaken in South Africa on all water-related subjects. Research projects funded by the WRC as well as other prominent organisations and agencies

are listed in the database. During 2000 the database was updated and re-published on the web, no longer providing just a long list of projects, but equipped now with a search facility to make comprehensive information retrieval possible. Access to the database is free.

WISA 2000 Biennial Conference

The WRC provided support to the WISA 2000 Biennial Conference by assisting the conference organisers in publishing the conference proceedings on CD-ROM. A staff member of the WRC's Information Management Division processed just over 300 papers as well as other related information, and prepared the master for duplication.

Intranet

During the last year, the Intranet design remained virtually the same as before. A number of official staff documents were added to the Intranet, making it a useful reference source for all staff members.

Water-related enquiries

During the course of the year, many water-related queries had to be addressed. Queries came from literally all over the country, with quite a number coming from overseas sources. Many queries were received via the telephone. Approximately 40% of enquirers used the website link to submit their questions or requests for information. A wide variety of questions were asked, ranging from calls for assistance with ***Waterlit*** searches, to requests for information on water quality standards, the capacity of local wastewater treatment plants, the status of the membrane industry in South Africa, opportunities for investment in the local water industry, etc. Students, educators and learners seeking assistance in finding suitable information for their water-related projects or assignments, also formed an important group of enquirers.

Marketing the WRC

In the past, the WRC never had a policy of marketing itself and pro-actively informing the outside world about the activities of the organisation. In January 2000, a self-supporting exhibition shelf scheme together with a set of posters were acquired for this purpose and were used at several exhibitions during the year. At these exhibitions, official WRC publications, brochures and products were distributed, the website was displayed, the bibliographic database ***Waterlit*** was demonstrated and a wide variety of pertinent questions on the organisation as a whole, were answered. Conference delegates also had the opportunity to order copies of WRC reports and other publications. The WRC had formal exhibits at the following events:

- **23 to 28 January 2000**
  BioY2K Combined Millennium Meeting, Grahamstown
- **23 to 26 May 2000**
  Managing Water and Waste in the New Millennium – The Challenges for Developing Areas, Midrand
- **28 May to 1 June 2000**
  WISA 2000 – Biennial Conference and Exhibition, Sun City
- **26 June 2000**
  SAAMOTI (SA Association for Management of Technological Innovation) Launch, Sheraton Hotel, Pretoria
- **23 to 26 October 2000**
  International Commission on Irrigation and Drainage (ICID): 51st IEC Meeting and MICRO 2000: the 6th International Micro-Irrigation Congress, Cape Town
- **25 to 27 October 2000**
  IMESA 2000: 64th Biennial Conference of the Institution of Municipal Engineers of Southern Africa, Durban
- **26 November to 1 December 2000**
  International Association of Hydrogeologists: XXX Congress 2000. Groundwater Division: Geological Society of South Africa. Groundwater: Past Achievements and Future Challenges, Cape Town.

As an additional marketing initiative, the close relationship with the **Foundation for Water Research** (FWR) in the United Kingdom was developed further during 2000. The FWR used a set of WRC posters as part of their exhibition at several international events, including the World Water Forum in the Hague, the Netherlands, the Water Berlin Congress and the International Water Industry exhibition, Berlin, Germany, etc. According to the Reciprocal Report Exchange Agreement between the FWR and the WRC, titles of WRC reports were announced on the FWR website, while a direct link from the FWR website to the WRC Publications Division facilitated the process of ordering of publications. Titles of the latest WRC reports were also listed in the FWR's regular quarterly *Newsletter*.

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: 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. Thereafter, a decision is taken on whether or not the article should be published. In 2000 67 articles were published in ***Water SA*** by a total of 134 authors.

Water SA has an extensive local as well as overseas readership. Currently there are 3 208 subscribers to ***Water SA*** of whom 890 are abroad. It also enjoys world-wide coverage by all the major international abstracting services who publish and distribute summaries of articles which appear in ***Water SA***.

Since 1997 the full text version of the journal is also available on the Internet via the WRC website (http://www.wrc.org.za).

SA Waterbulletin

SA Waterbulletin is a bilingual bi-monthly periodical. Within the broad spectrum of water research it aims to:

- Furnish information on water and water research in a popular scientific manner to the different interest groups in the water field
- Promote the transfer of technology by announcing the availability of reports, manuals, guides etc. which emanate from water research

- Promote communication between the WRC and authorities and individuals, such as researchers, engineers, technicians, government departments, local authorities and the industrial and agricultural sectors
- Convey social news and matters of interest (e.g. about conferences and personalities) to the water research community.

Manuals, guidelines and reports

At the conclusion of a project, and also while research is still under way, results are evaluated in respect of possible use and application and, depending on the nature of the results, a decision is taken on publication, dissemination and application thereof. More information on these publications appears in the relevant chapters and in the **Annexure**.

List of WRC publications

The **Annexure** to this annual report contains a list of publications (articles, papers and published reports) which appeared during 2000 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: 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.

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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 2000, as well as a complementary list of 1999.

Requests for articles and papers should be directed to the authors.

Rural water supply

Articles and papers (2000)

- Pybus PJ and Bhagwan JN (2000) Benchmarking water service activities of local authorities in South Africa. Paper presented at Union of African Water Supply Authorities 10th Congr., Durban. February.
- Pybus PJ and Bhagwan JN (2000) Benchmarking in municipal water services practice. Paper presented at WISA Bienn. Conf., Sun City. May.
- Pybus PJ and Schoeman G (2000) Performance indicators in water and sanitation for developing areas. Paper presented at Int. Water Assoc.: Speciality Group for Water and Waste Technol. and Manage. Strategies for Developing Countries, Conf. on Managing Water and Waste in the New Millennium, Midrand. May.

Reports (2000)

- Jacobs EP, Pillay VL, Pryor M and Swart P (2000) Water Supply to Rural and Peri-Urban Communities Using Membrane Technologies. WRC Report No 764/1/00.
- National Community Water and Sanitation Training Institute (2000) Background and Overview of Management of Community Water and Sanitation Training Programme for Local Government Training Programme. WRC Report No 880/1/00.
- Swartz CD (2000) Guidelines for the Upgrading of Existing Small Water Treatment Plants. WRC Report No 738/1/00.

Report (1999)

- Olivier J and Van Heerden J (1999) The South African Fog Water Collection Project. WRC Report No 671/1/99.

Water services: Institutional and management issues

Article and paper (2000)

- Manson N (2000) Asset management in the South African water industry. *Proc. Managing Water and Wastewater in the New Millennium: The Challenges for Developing Areas*. IWA. 23-26 May.

Report (2000)

- Rossouw AMM and Crous PC (2000) Rapid Capacity-Building for Water and Waste Management at Local Authority and District Council Level. WRC Report No 982/1/00.

Integrated urban water management

Articles and papers (2000)

- Bhagwan JN and McKenzie RS (2000) Managing unaccounted-for water in potable water distribution system. Half day workshop at WISA 2000 Bienn. Conf. and Exhib., Sun City. May.
- Blight GE, Fourie AB, Morris JWF and Röhrs LH (2000) The effects of climate and waste composition on leachate and gas quality: An updated report of work in South Africa. *Waste Manage. and Res.* **18** 393-401.
- Griffin NJ and Grobicki AMW (2000) Community income generation through cultivation of high value plants in degraded urban wetlands. *Proc. of WISA 2000*, Sun City. 28 May – 1 June.
- Grobicki AMW and Griffin NJ (2000) Turning liabilities into assets: The beneficial use of polluted urban stormwater in degraded wetlands. *Proc. of Managing Water and Waste in the New Millennium Conf.*, Midrand. 23-26 May.
- McKenzie RS and Bhagwan JN (2000) Some recent developments in water demand management in South Africa. Paper presented at WISA 2000 Bienn. Conf. and Exhib., Sun City. May. Also at IWA Conf., Chang Mai, Thailand. November.
- McKenzie RS, Bhagwan JN and Wegelin WA (2000) Some recent developments in water demand management in South Africa. Paper presented at 4th Bienn. Congr. of the Afr. Div. of the Int. Assoc. of Hydraul. Eng. and Res. on Conserv. and Sharing Water Resources in a Water Scarce Environ., Windhoek, Namibia. June.
- McKenzie RS, Rhoher K and Wegelin WA (2000) Leakage reduction through pressure management in the Greater Johannesburg Area. Paper presented at IWA Annu. Conf., Denver Colorado, USA. June.
- Röhrs LH, Fourie AB and Blight GE (2000) Is 30 years an appropriate after-care period for municipal landfills? *Proc. WasteCon 2000*, Somerset West. September. **2** 369-378.

Report (2000)

- Blight GE and Fourie AB (2000) Graded Standards for Landfilling in South Africa: Establishing Appropriate Affordable Standards for Disadvantaged Communities. WRC Report No 670/1/00.

Potable water treatment

Articles and papers (2000)

- Buyeye M, Hughes JC, DorasamYV and Hlabisa D (2000) The environmental implications of land disposal of water-treatment sludge. II. Soil chemistry and fertility aspects. Paper and poster presentation at the 5th Int. Symp. on Environ. Geochem., Cape Town. April.

Annexure *(continued)*

- Du Toit CG (2000) Computational fluid dynamics – A numerical laboratory and design tool. *Proc. of the Bienn. Conf. of WISA 2000*, Sun City. 28 May – 1 June (CD-ROM).
- Du Toit CG and Lemmer TN (2000) The application of computational fluid dynamics in the design and operation of rectangular sedimentation tanks in potable water treatment. *Proc. of the Bienn. Conf. of WISA 2000*, Sun City. 28 May – 1 June (CD-ROM).
- Huijts RF (2000) Optimization of sedimentation tank. Work experience report, School for Mech. and Materials Eng., PU for CHE, Potchefstroom. January.
- Lawler D and Tobiason J (2000) Particle counting and characterisation in drinking water treatment. One-day workshops in Cape Town, Durban and Johannesburg. 30 October – 1 November.
- Meyer JP, Smith C and Coetzee PP (2000) Scale prevention in a hot-water storage tank with a magnetic physical water treatment device. *Proc. of the ASME-ZSITS Int. Thermal Sci. Sem.*, Bled, Slovenia. 295-300. 11-14 June.
- Momba MNB (2000) Influence of chloramination on bacterial regrowth in a chlorinated surface water laboratory-scale system. In: Global Network (ed.) *Research Advances in Water Research*, Kerala, India.
- Momba MNB and Tyali T (2000) Use of monochloramine as secondary disinfectant for the inhibition of bacterial regrowth and accumulation on indicator micro-organisms in a laboratory scale system model receiving chlorinated water. Paper presented at 1st World Congr. of IWA, Paris, France. 3-7 July.
- Moodley M, Hughes JC, Johnston MA and Titshall L (2000) The environmental implications of land disposal of water-treatment sludge. I. Effects on soil physical quality. Paper and poster presentation at the 5th Int. Symp. on Environ. Geochem., Cape Town. April.
- Pryor MJ and Ceronio AD (2000) Particle counting in South Africa – Instruments, accuracy, calibration, applications. Poster presentation at the WISA Bienn. Conf. and Exhib., Sun City. May.
- Smith C, Coetzee PP and Meyer JP (2000) Treatment devices for preventing scale fouling in hot water storage tanks. In: Adali S, Morozov EV and Verijenko VE (eds.) *Proc. of the Int. Conf. on Appl. Mechanics*. SACAM 2000. 11-13 January. 635-640.
- Van Antwerpen HJ (2000) Modelling of rectangular sedimentation tanks using computational fluid dynamics. Final year project report. School for Mech. and Materials Eng., PU for CHE, Potchefstroom. October.
- Van Duuren B-J (2000) Simulation of a sedimentation tank. Work experience report, School for Mech. and Materials Eng., PU for CHE, Potchefstroom. July.

Articles and papers (1999)

- Barrett R (1999) Magnetic treatment in static and flowing systems. Paper presented at MAG3 Int. Conf. on Antiscale Magnetic Water Treatment, Cranfield Univ., UK. April.
- Da Veiga R, Coetzee PP and Meyer JP (1999) The effect of a permanent magnet on scale formation in a tube. *Proc. of the ASME-ZSITS Int. Thermal Sci. Sem.*, Bled, Slovenia. 11-14 June. 301-307.

Reports (2000)

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