The objectives of the Water Research Commission

In terms of section 2(3) of the Water Research Act 1971 (Act No 34 of 1971) the objectives of the Commission are "to co-ordinate, to promote, to encourage or to cause to be undertaken, as determined by the Minister specifically or in broad outline, research in respect of

- the occurrence, preservation, conservation, utilization, control, supply, distribution, purification, pollution or reclamation of water supplies and water;
- the use of water for
  - agricultural purposes;
  - industrial purposes; or
  - urban purposes".

Section 3(1) of the above-mentioned Act describes the functions of the Commission and stipulates *inter alia* that the Commission shall "accumulate, assimilate and disseminate knowledge in regard to the results of such research and the application thereof, and promote development work for the purpose of such application".

SENIOR PERSONNEL

PROFESSIONAL

DEPUTY EXECUTIVE DIRECTOR

Dr WHJ Hattingh (Water and effluent treatment; urban and industrial water utilisation)

RESEARCH MANAGERS

Dr TC Erasmus

Dr OO Hart

Mr G Offringa

Dr MJ Pieterse

Dr HM Saayman

DEPUTY EXECUTIVE DIRECTOR

Mr DS van der Merwe (Water sources; urban water reticulation; water utilisation for agricultural and ecological purposes)

RESEARCH MANAGERS

Mr HC Chapman

Mr HM du Plessis

Dr GC Green

Mr H Maaren

Dr PCM Reid

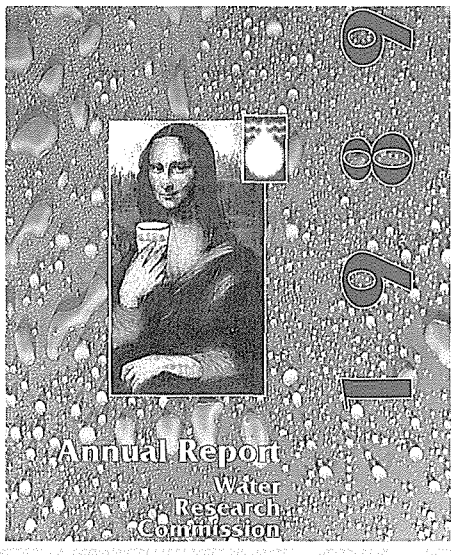
ASSISTANT RESEARCH MANAGER

Mr AG Reynders

ADMINISTRATIVE

DIRECTOR: ADMINISTRATION

Mr PM van der Schyff



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· ANNUAL REPORT ·

· Water Research Commission ·

Members of the Water Research Commission as on 31 December 1989

Back row (from left):
Dr AJ Heyns - Superintendent-general: Department of Agricultural Development. Dr L Alberts - Chairman: Board of the CSIR and former director-general of Mineral and Energy Affairs. Mr EJ Hall - Member: Council for the Environment and former city engineer of Johannesburg. Prof PD Tyson - Vice-principal: University of the Witwatersrand. Dr WL van Wyk - Former deputy director-general: Department of Mineral and Energy Affairs.

Second row:
Mr PE Odendaal - Executive director: Water Research Commission. Mr GCD Claassens (Vice-chairman) - Director-general: Department of Water Affairs.

Front:
The Honourable AJ Raubenheimer (DMS) (Chairman) - Former Minister of Water Affairs.

Absent: *Mr DH Marx - Chairman: Magalies Water Board and former city engineer of Johannesburg. Mr M Erasmus (co-opted member) - Deputy director-general: Department of Water Affairs.*

Water Research Commission
P O Box 824
PRETORIA
0001
4 April 1990

Dear Mr Kotzé

We take pleasure in submitting to you, herewith, the report of the Water Research Commission for the period 1 January to 31 December 1989.

The balance sheet and statement of revenue and expenditure for the financial year to 31 December 1988, as certified by the Auditor General, as well as a receipts and payments account for the year ended 31 December 1989 and a budget for 1990, are furnished under **Financial Statements** of this report.

Yours respectfully

AJ Raubenheimer
CHAIRMAN

PE Odendaal
EXECUTIVE DIRECTOR

Mr GJ Kotzé, MP
Minister of Environment Affairs and of Water Affairs
Private Bag X9039
CAPE TOWN
8000

CONTENTS

THE YEAR UNDER REVIEW

ATER research covers a particularly extensive field as is evidenced by the following list of research areas supported by the Water Research Commission (WRC):

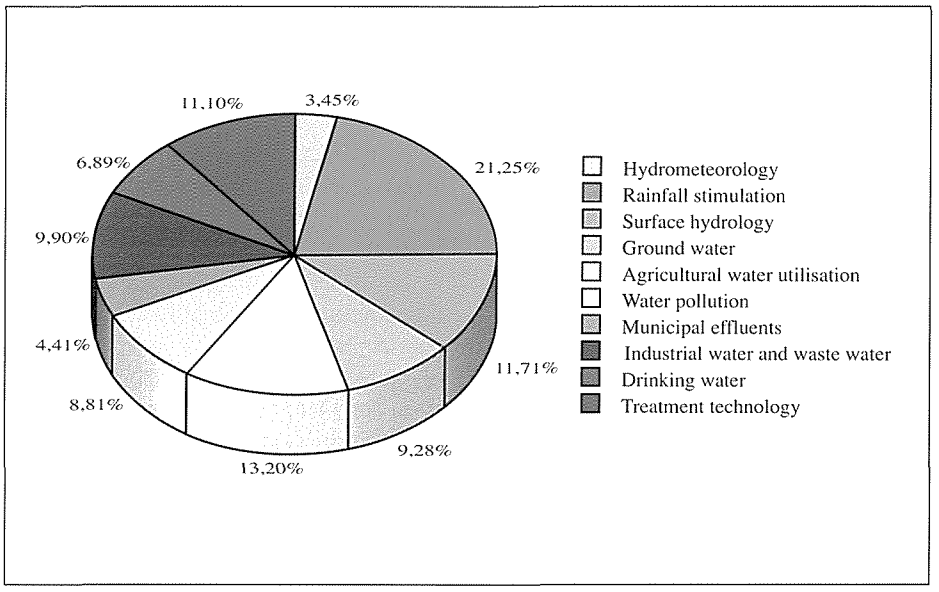
- Hydrometeorology
- Rainfall stimulation
- Surface hydrology
- Ground water
- Agricultural water utilisation
- Water pollution
- Municipal waste water
- Industrial water and waste water
- Drinking water
- Treatment technology
- Socio-economic studies

Because of the wide field it encompasses, water research is pre-eminently a multi-disciplinary activity and therefore the WRC funds research at a large number of organisations. In 1989 the WRC supported 115 projects in terms of research agreements, with the following organisational distribution (occasionally more than one organisation is involved with a particular project):

University departments	60
The CSIR	39
Consulting engineers	9
Government departments	6
City councils	8
Companies	18
	140

In addition to the direct funding of the research projects, the WRC also supports three research support services. These services are directed at increasing the productivity and efficiency of water research and at providing the water industry with easy access to research knowledge and different types of data. These services are the following:

- The SA Water Information Centre (SAWIC)
- The Computing Centre for Water Research (CCWR)
- The Hydrological Information System (HIS): In this case the WRC also makes a significant contribution to the development and extension of this system which is operated by the Department of Water Affairs.



Allocation of funds (%) to the various areas during 1989

WRC RECONSTITUTED

Under the Water Research Act (Act No 34 of 1971) nine Commission members are appointed as follows:

The Director-General of Water Affairs (ex officio)

The Executive Director of the WRC (ex officio)

Seven other members who are appointed by the Minister of Water Affairs by virtue of their expertise in some or other aspect of WRC activities.

The Minister nominates one of the appointed members as part-time chairman of the WRC. Additional members can be co-opted as required. Traditionally appointments are tenable for a three-year term.

The term of service of the appointed members ended on 31 July 1989. The Honourable AJ Raubenheimer (DMS), Dr AJ Heyns, Dr WL van Wyk and Mr M Erasmus (co-opted member) were reappointed, while the following members retired: Dr JP Kriel, Mr JG du Plessis, Dr CF Garbers, Prof DJ Schoeman and Dr N Stutterheim (co-opted member).

The following four new members were appointed:

Dr L Alberts - Chairman: Board of the CSIR and former director-general of Mineral and Energy Affairs

Mr EJ Hall - Member: Council for the Environment, and former city engineer of Johannesburg

Mr DH Marx - Chairman: Magalies Water Board and former city engineer of Pretoria

Professor PD Tyson - Vice-Principal: University of the Witwatersrand.

Mr Raubenheimer was appointed chairman in the place of Dr Kriel.

Dr Kriel has been serving as a member of the Commission since its inception in 1971. During this period he served *inter alia* as vice-chairman, chairman and chief executive officer of the WRC. His contribution towards the establishment and realisation of the WRC and its activities has been invaluable and the WRC would like to express its appreciation to Dr Kriel.

Mr GCD Claassens, director-general of Water Affairs has been reappointed as vice-chairman.

COMPUTER PROGRAM FOR DRY COOLING

In order to generate one kW.h of electrical energy in South Africa, 1,6 to 2,1 ℓ of water are evaporated. The installation of dry-cooling towers practically eliminates these losses. The dry-cooling towers which are being constructed in South Africa at present are more than ten times larger than any other existing similar installation. During the planning stages it is imperative that the capacity of such expensive plants be estimated accurately.

A number of years ago an extensive research programme was launched by the WRC in collaboration with Eskom and the University of Stellenbosch. An experimental and numeric study was undertaken with a view to developing a computer program by means of which the performance characteristics of dry-cooling towers could be predicted accurately. This program is being extended at present to make provision for combinations of dry and wet-cooling towers.

Three dry-cooled power stations are currently being constructed in South Africa. Each of these power stations namely Matimba, Kendal and Majuba, will eventually contribute 4 000 MW electrical power to the national grid.

The outstanding quality of the computer program was confirmed recently when predictions were made regarding the performance of the first cooling tower at the Kendal Power Station. Upon completion of acceptance tests it was found that the tower achieved the predicted cooling within a fraction of a percentage point. Different kinds of cooling towers can be evaluated by means of this program and it can also take cognisance of the influence of atmospheric phenomena such as temperature, pressure, moisture distribution, wind and inversion. Thus the power station's output, for a given weather pattern, can be predicted for a year.

HYDROLOGICAL INFORMATION SYSTEM (HIS) REACHES A MILESTONE

Over the past five years the Department of Water Affairs has been developing the Hydrological Information System (HIS), with the financial support of the WRC.

The development of a user-orientated information system is a never-ending task. However, the HIS has reached a stage this year where the process of using, learning and improving can be started in earnest. The software of the system, including the major user manuals, has largely been completed; the Computing Centre for Water Research and many other users are now directly linked via GOVNET, and PC-based abstractions can now be performed.

The digitising and storage of all historic river flow height measurements have been completed and, although many problems still need to be solved the HIS is ready to provide a much needed service. It will create previously unknown opportunities for decision-makers, researchers, consultants and other potential users.

SOUTH AFRICAN HYDROLOGICAL MODELLING SYSTEM FINDS WIDE APPLICATION

The Department of Agricultural Engineering of the University of Natal has developed the modelling system ACRU which is a unique computerised synthesis of typical South African hydrology and agrohydrology aimed at practical application in water management and planning.

As a result of the multipurpose structure of the ACRU modelling system, it has been applied widely in southern Africa and elsewhere in a number of collaborative projects. In the Winterton area of Natal, for example, ACRU has been used in reconciling irrigation water demand and supply between three irrigation boards "competing" for a finite amount of available surface water, while the Development Bank of Southern Africa has utilised the model, in GIS form, to assess runoff production and the viability of irrigation projects in QwaQwa. In collaboration with the Soil and Irrigation Research Institute detailed statistics for over 2 100 zones in South Africa were produced as a basis for maps of primary productivity, this being a contribution towards the National Food Planning Strategy.

... the ACRU modelling system has been applied widely in southern Africa and elsewhere in a number of collaborative projects.

Unique hydrological responses associated with the cracking soils and transmission losses of the Springbok Flats have been simulated by means of ACRU in a project carried out in collaboration with the De-

partment of Water Affairs and a firm of consultants, while the model is applied frequently in decisions regarding afforestation potential and the impacts this may have on downstream water resources.

In Botswana the model has been applied to drainage design decisions in urban development on deep Kalahari sands while a joint project with the Universidad Catolica in Santiago has used ACRU to assess land use change impacts on water resources in Central Chile.

PRECIPITATION STATISTICS

The mammoth task of revising available information on the temporal and spatial distribution of rainfall statistics in southern Africa was started in July 1982 by the Department of Agricultural Engineering at the University of Natal. The final report was published in 1989 together with a series of 1:250 000 isohyetal maps of mean annual precipitation.

Prior to this revision, the basic source of information had been the series of 1:250 000 maps of average annual rainfall compiled in 1965 by the Department of Water Affairs from data obtained by the South African Weather Bureau. Since then, the country's data base had both lengthened considerably and been enriched by data from sources other than the Weather Bureau. Furthermore, the use of sophisticated analysis and interpolation techniques became possible through greatly enhanced computer power. Other products of the research included the mapping of mean monthly rainfall at 1:1 000 000 and the delineation and mapping of 712 regions of homogeneous precipitation distribution in southern Africa. Furthermore, in foreseeing the need for further computer manipulation of spatial rainfall data by a large proportion of users, the researchers have arranged to make statistics available in digital form, through the Computing Centre for Water Research at a spatial resolution of one minute of a degree latitude and longitude.

The need which existed for revising the precipitation statistics has been amply reflected in the exceptional demand for both the reports and maps during the first few months of availability.

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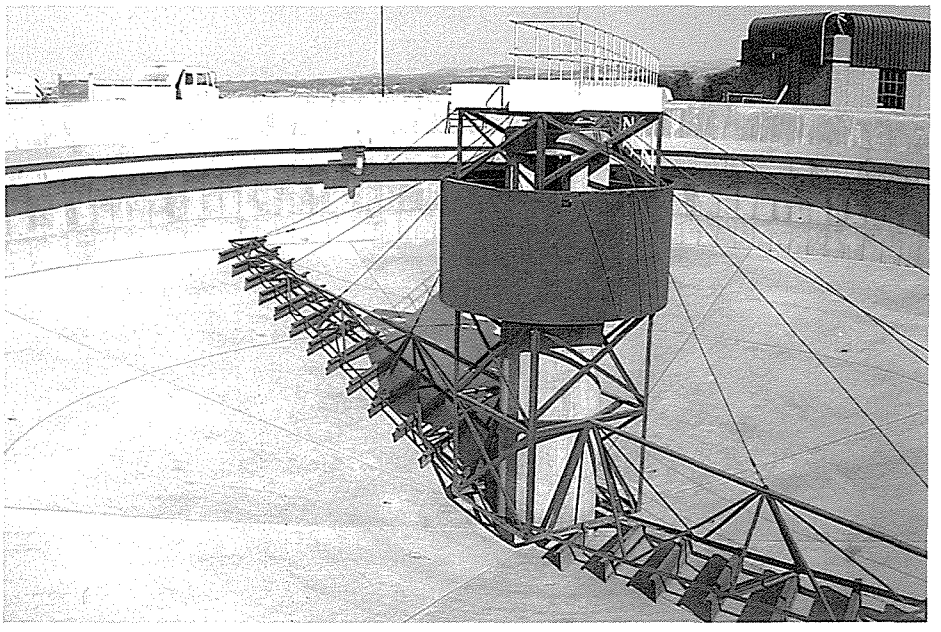
USER-FRIENDLY DATA BASE FOR GROUND-WATER MANAGEMENT

During the development of the National Ground-water Data Base facility, the Institute for Ground-water Studies at the University of the Orange Free State perceived a need to develop a ground-water data base for the personal computer. This was essentially to cater for those who did not have direct access to the mainframe computer at the Department of Water Affairs which houses the national facility. Out of this the commercial package G-Base was born, which has attracted wide interest and usage in South Africa.

G-Base, which formed the basis for the current WRC - funded project on the enhancement of the National Ground-water Data Base, has evolved into HydroCom, a comprehensive user-friendly software package incorporating both an advanced data management and powerful CAD system. This package, which is now being marketed internationally, not only provides the geohydrologist, engineer and environmentalist with a powerful facility for data analysis and presentation, but provides an essential link with the National Data Base.

BIOLOGICAL PHOSPHATE REMOVAL

Since the phosphate content of treated sewage effluents still makes the most significant contribution to enrichment (eutrophication)



An example of the new primary settling tanks which have been commissioned at the Bushkoppies Sewage Works.

of the receiving rivers and dams, research to improve phosphate removal is continuing unabatedly.

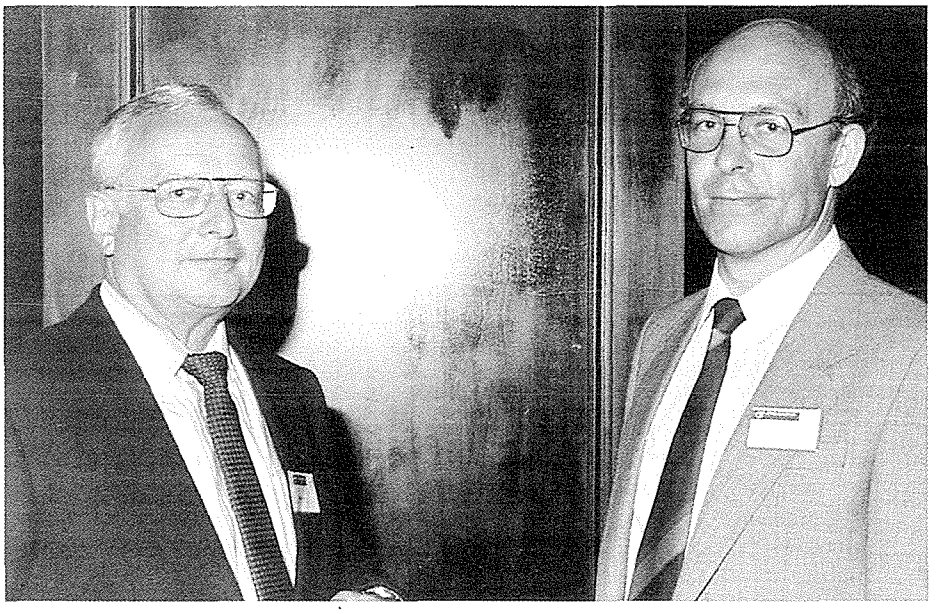
The results of the research, which was completed at the end of 1988 by the City Council of Johannesburg, are already being applied in practice. At the Council's Bushkoppies Sewage Works new primary settling tanks which had been designed specifically to handle higher loads of settled sludge were commissioned in November. Research indicated that controlled fermentation of primary settled sludge produces fatty acids which improve the phosphate removal in the biological reactor. Similar modifications are being made at the Johannesburg Northern Sewage Works although the primary settled sludge is fermented in separate new thickening tanks in order to reclaim the fatty acids for phosphate removal.

NEW INSTRUMENT DEVELOPED

Sludge bulking is a phenomenon which often occurs at sewage works which make use of the activated sludge process. This causes the sludge in the final settling tank to settle poorly so that some of it is carried over in the final effluent. This not only causes a pollution problem but also lowers the efficacy of the purification process.

During this research a unique, automated and computerised instrument was developed ...

At the Department of Civil Engineering at the University of Cape Town studies are being undertaken which are aimed specifically at preventing sludge bulking, by varying certain process parameters and combinations. During this research a unique, automated and computerised instrument was developed which measures the rate of oxygen uptake in the activated sludge process on a continuous basis. This should be of considerable advantage for the control of the process and has already been patented with a view to its commercialisation.



Prof D Strauch (left), an authority on sewage sludge management in Europe, with Mr G Offringa, a research manager at the WRC, at the WISA Conference in Cape Town.

OVERSEAS CONSULTANT ON SLUDGE MANAGEMENT

Professor D Strauch of the University of Hohenheim, Stuttgart, West Germany, visited South Africa at the invitation of the WRC from 9 to 29 March 1989. Professor Strauch is an authority on sewage sludge management, serving on a number of sewage sludge management committees in Europe.

The purpose of his visit was to advise the WRC on improving sludge management practices and to assist in directing research in this field. Professor Strauch visited a number of sludge management plants in South Africa and presented the WRC with an extensive report, including details of current sewage sludge management practices in Europe, as well as a full report and recommendations on sewage sludge management in South Africa.

Professor Strauch also attended the First Biennial Conference of the Water Institute of Southern Africa in Cape Town from 28 to 30 March 1989, and read a paper entitled *The Present Situation of Sewage Sludge Utilisation in Europe.*

RATIONALISATION OF RAINFALL STIMULATION RESEARCH

During the year steps were initiated to rationalise and integrate the two rainfall stimulation research projects in South Africa viz. the Programme for Atmospheric Water Supply, funded by the WRC, which had been confined to the eastern Transvaal lowveld and escarpment areas around Nelspruit and Carolina; and the Bethlehem Precipitation Research Project, funded by the Weather Bureau with contributions from

the WRC, which had been active in the north-eastern OFS around Bethlehem.

A rationalisation committee, consisting of representatives of the Department of Environment Affairs (Weather Bureau included), the Department of Water Affairs, the WRC, the CSIR and the Commission for Administration met in April. It recognised the importance of an already scheduled review workshop on rainfall enhancement research in South Africa as a source of guidelines for structuring a national research programme. This workshop, held in August, was attended by project leaders and researchers, overseas specialists acting as independent assessors, and several persons responsible for decision-making and policy matters concerning rainfall stimulation research.

As a result of recommendations put forward by the workshop, unification of the two projects is due to take place at the beginning of 1990. The resulting research programme, to be led by a senior scientist of the Weather Bureau, will incorporate certain changes of emphasis which the workshop identified as being necessary to expedite progress.

UNIQUE LOCALLY DESIGNED ULTRAFILTRATION SYSTEM: MEMTUF

Membratek, a division of Bintech (Pty) Ltd, has developed a low-cost ultrafiltration system with the assistance of the WRC.

The main incentives for the development of the MEMTUF system were to:

- develop and manufacture locally an ultrafiltration system of which the capital and operating costs were comparable to those of conventional fine filtration;
- expand the use of ultrafiltration to applications which previously could not sustain the cost of ultrafiltration;
- combine ultrafiltration with other purification processes in order to achieve synergism.

The MEMTUF system was successfully industrialised and offers unique membrane technology to solve complex filtration problems in the South African industry.

DEVELOPMENT OF DESALINATION MEMBRANES

The application of reverse osmosis for the treatment of industrial effluents with a high salt content, and for the production of freshwater from brackish water is becoming increasingly important in the South African context. Reverse osmosis is a pressure-driven membrane process in which freshwater moves through the membrane while salts are retained.

The application of reverse osmosis for the treatment of industrial effluents is becoming increasingly important in the South African context

The Institute for Polymer Science at the University of Stellenbosch has already had considerable success with the development of membranes which can compete successfully with imported membranes. Cellulose acetate membranes have already for a considerable time been manufactured and marketed successfully by the firm Bintech.

New improved membranes have since been developed: *thin-film membranes which* render higher salt rejection and water permeability at lower pressure than cellulose acetate membranes; thin-film composite membranes for special applications; and nanofiltration membranes, i.e. membranes which reject divalent ions selectively but which let through monovalent ions, which function at a pressure considerably lower than 1 000 kPa.

Evaluation of the new membranes for the treatment of various types of water and effluent is now in progress.

FOCUS ON PLANT ROOT ZONE

The theory and application of a mathematical model describing the dynamic reactions of nitrogen fertilisers, pesticides and inorganic salts in the root zone of soil, were discussed during a week-long workshop held in Pietermaritzburg from 16 to 20 January 1989 in collaboration with the Computing Centre for Water Research.

The course was led by Professor RJ Wagenet, head, and Dr JL Hutson, a senior researcher of the Agronomy Department of Cornell University, USA, both of whom are world-renowned leaders in the field. About equal time was devoted to the transfer of the theoretical basis of the model, its possibilities and restrictions, as to the gaining of practical experience in the use of the model with test data, as well participants' own data.

About 40 participants from all over South Africa attended the workshop, representing a variety of disciplines, *inter alia* soil scientists, agricultural engineers, geohydrologists, agronomists and botanists.

AGRICULTURAL USE OF SEWAGE SLUDGE

In addition to certain soil-conditioning properties, sewage sludges also contain significant quantities of the major plant nutrients such as nitrogen and phosphorus, as well as other minor nutrients such as calcium, magnesium and other trace elements.

Sludges destined for agricultural use should not only be properly disinfected to remove pathogens, but should also be monitored for the presence of inorganic contaminants which may have adverse effects on crops or in the subsequent food chain.

Recently the CSIR's Division of Water

Technology completed an extensive investigation relating to the inorganic chemical characterisation of South African municipal sewage sludges. Over a period of a year samples of sludge were collected from 77 sewage works and analysed for their inorganic chemical nutrient and possibly contaminant concentrations.

The results of this study were used to draw up a set of suggested guidelines to assist in determining the suitability of various municipal sludges for use in agriculture and horticulture in the RSA.

The report recommended to the WRC that a committee be set up representing relevant organisations to evaluate these guidelines in order to prepare maximum limits for the concentration of inorganic contaminants in sludges for application to agricultural land.

"PROFILE-AVAILABLE WATER CAPACITY" AS IRRIGATION MANAGEMENT AID

The concept of "Profile-available Water Capacity" (PAWC) was developed and defined by former researchers of the Department of Soil Science at the University of Fort Hare. Facets of it were the main topic of three research projects over the period 1976 to 1988 which were carried out by this department with the financial support of the WRC.

This indication of the amount of water which a specific soil profile can make available to vegetation is not only dependant on the relevant soil type, but also on the root development pattern of the relevant crop as well as the climate in which the crop will be cultivated. This therefore implies that, though the value of the concept has been proven in practice, extensive experimental determinations are required to provide planners and irrigation managers with the necessary information. This cumbersome procedure has to a large extent been done away with through mathematical modelling. Presently therefore the concept forms the corner-stone of an exceptionally successful and practical irrigation scheduling approach developed by the

Presently the concept forms the corner-stone of an exceptionally successful and practical irrigation scheduling approach

Department of Soil Science at the University of the OFS. By entering into a new agreement with the Department of Soil Science at the University of Pretoria also to research the upper boundary layer of plant-available water, the research on this concept will be completed and refined.

MANAGEMENT OF WATER NETWORKS

Research into municipal water supply and distribution networks has been conducted over the past decade under the auspices of the WRC. This has led to an increased awareness of the need for an upgraded management approach to water supply systems by integrating all the various components into a dynamic system. Pumping rates, pressures, storage location, elevation and capacity, trunk main sizing and velocities, potential for expansion, leakage, etc. are all aspects which need to be considered simultaneously when faced with decision-making alternatives.

Through contact with local authorities concerning the work they are doing and the problems they are facing, it became apparent that the time was ripe to pool and review knowledge and experience. This took the form of a joint workshop with the Water Institute of Southern Africa (WISA) in Pretoria on August 30, 1989. The workshop titled *Management and Analysis of Municipal Water Supply*, included papers on computer-aided design, data capture, analysis and management, and the application of network models. The audience comprised about 120 delegates from all over southern Africa, and the workshop was successful to the extent that a decision was taken to establish the Technical Division: Distribution Networks under the auspices of WISA.

EXPERT ON WATER NETWORKS IN SOUTH AFRICA

Professor Johannes Gessler, associate department head in the Department of Civil Engineering at Colorado State University, Fort Collins, USA, is visiting South Africa on sabbatical leave and has accepted a lecturing post at Natal University for the second half of 1989.

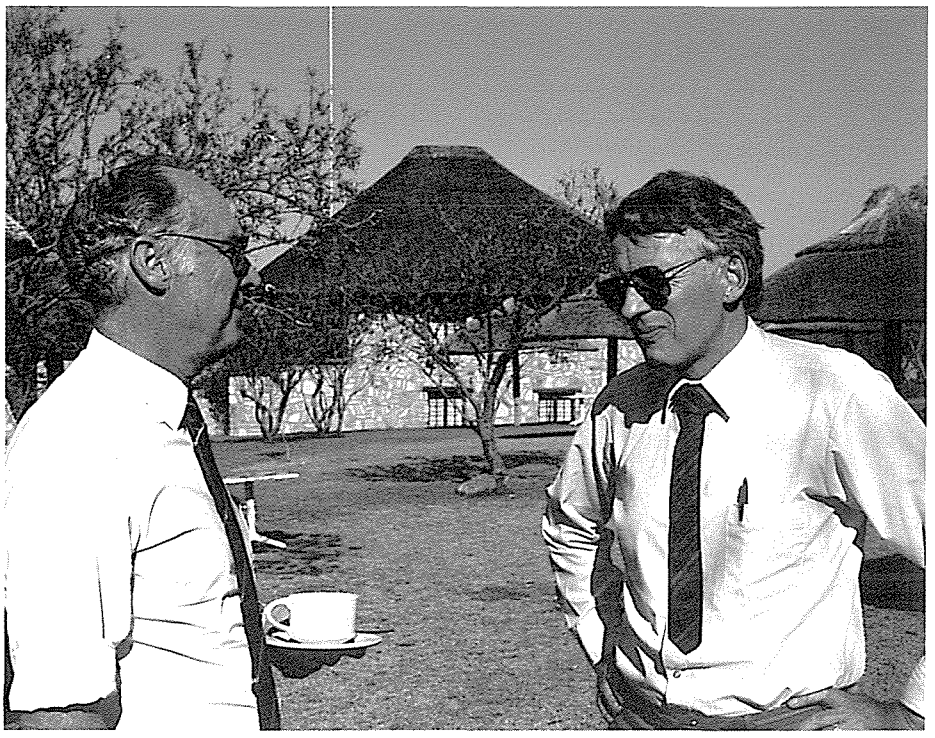
As part of his agreement with the Commission, he spent some time with local authorities in South Africa which included two weeks with the Johannesburg City Engineer's Department and brief visits to the Pretoria, Port Elizabeth and Durban City Engineers' Departments where he was able to make practical suggestions regarding the use of computers in network design and management, based on his years of experience both in the USA and elsewhere in the world.

While in Durban he also accompanied engineers from the Stormwater Drainage Section to advise them on the problems of failures of canal embankments experienced in the area. The Natal Parks Board hosted Professor Gessler at the Richards Bay and St Lucia sanctuaries where he was able to advise them on sediment and other management practices affecting the areas.

Professor Gessler also acted as the keynote speaker at the workshop reported on in the previous section.

TRIHALOMETHANES IN WATER

In spite of the considerable advantages of disinfecting drinking water with chlorine, certain compounds such as trihalomethanes (THM) still form and have in the past few years created great interest. The reason for this is that some of these THMs at high concentrations have a carcinogenic effect



Prof Johannes Gessler of the Colorado State University (right) in conversation with one of the delegates at the WISA workshop in Pretoria.

on certain animal types. Although these compounds can appear in drinking water in minute quantities and will most probably not have a detrimental effect on the health of man, it is not clear what their exact influence will be on humans after a lifetime of intake.

In a research project recently completed by the Division of Water Technology of the CSIR on behalf of the WRC, drinking-water samples were collected country-wide over a two-year period and analysed for THM concentration and factors affecting the formation of THMs. The average THM concentration of the drinking-water samples over this period was 45 µg/ℓ. On the whole the results were reassuring when compared for example to the United States Environmental Protection Agency limit of 100 µg/ℓ.

EPIDEMIOLOGICAL SURVEILLANCE RELATED TO CHANGING DRINKING- WATER QUALITY

It is estimated that known freshwater supplies for the Cape Town metropolitan area will be fully committed by the year 2007. Thereafter the reclamation of purified sewage effluent to augment supplies is a distinct possibility. Therefore, an epidemiological survey was launched in the area by the Department of Community Health of the University of Cape Town, to establish early baseline data. This was done by establishing a data bank consisting primarily of information on mortality rates, morbidity as seen by general practitioners and birth defects.

In addition to the extensive data base of the prevailing health patterns in the Cape Town area which has now been established, valuable methodologies for conducting epi-

In addition to the extensive data base of the prevailing health patterns in the Cape Town area valuable methodologies for conducting epidemiological surveys have been developed

demiological surveys have been developed. In fact, the birth defect surveillance programme which originated with the project has now been taken over by the Department of National Health and has formed the basis for the Department's national birth defect surveillance system. The Department also hopes to institute a mortality surveillance system in the near future, based on the pioneering work done by the university.

This research will provide the basis and model for future comparative health studies in other geographic areas.

PROTEIN FROM WASTE WATER

The Chair of Water Utilisation Engineering of the University of Pretoria has devised a unique method to purify problem effluents while simultaneously creating a protein source.

The process which has already been patented, consists of the culture of a virtually pure culture of a fungus *Geotrichum candidum* by making use of a crossflow microscreen and a pH shock technique. This fungus is also more resistant to shocks resulting from variations in effluent quality than the average bacteria and it has been found to be very successful in treating industrial effluents containing contaminants which are not easily degradable. Further utilisation of the fungus for the reclamation of protein, fats and fine chemicals, with simultaneous purification of effluents, is being investigated on laboratory and pilot scale.

LARGE SAVINGS FOR TEXTILE INDUSTRY

The textile industry is traditionally a 'problem industry' as regards water and wastewater management, and from as far back as 1974 the WRC has already been financing research in this regard at the Pollution Research Group (PRG) at the University of Natal. This group is housed in the Department of Chemical Engineering.

The results of the research and the expertise emanating from it have already led to a considerable reduction in water use and in pollution output, with concomitant financial benefits as illustrated by the following cases:

Case 1:

Savings in the use of chemicals, colorants, energy and water amount to more than R230 000 a year. The effluent quality was considerably improved.

Case 2:

The water intake was reduced from 30 kℓ/h to 6 kℓ/h - a saving of 80%.

Case 3:

Rationalisation in the use of sodium hydroxide led to a saving of about R2 million a year.

Case 4:

Condensate was reclaimed to the tune of R80 000 a year.

Case 5:

Savings were effected in the use of water, sodium hydroxide and power to the value of R950 000 a year.

The WRC has over the years taken various initiatives to determine research needs and priorities within specified water research fields

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Case 6:

Savings were brought about in the use of sodium hydroxide to the tune of R1,5 million a year.

Case 7:

By applying the data contained in one of the manuals developed by the PRG for the WRC, extensions were made to a spinning and weaving mill designed specifically for a water consumption of 30 ℓ/kg - one-third of that of a conventional mill.

Case 8:

A 40% saving in water consumption was effected.

Case 9:

Savings in colorants to the amount of R300 000 a year and a considerable improvement in effluent quality were effected.

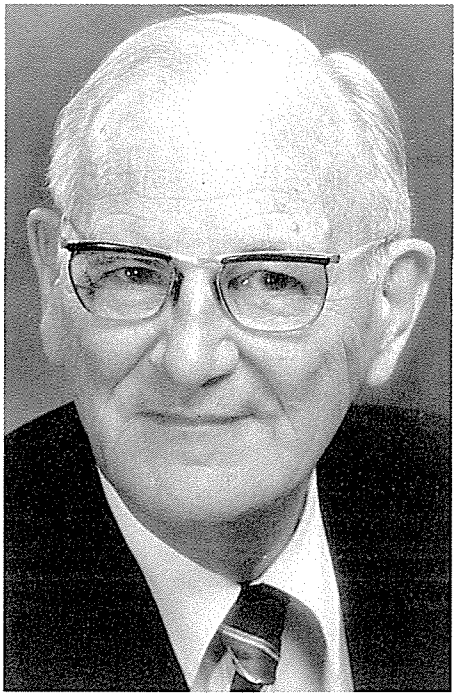
Case 10:

A reduction of about 45% in water intake with a corresponding reduction in effluent volume, with a saving of R800 000 a year were effected.

COMPUTING CENTRE FOR WATER RESEARCH EXPANDS SERVICES

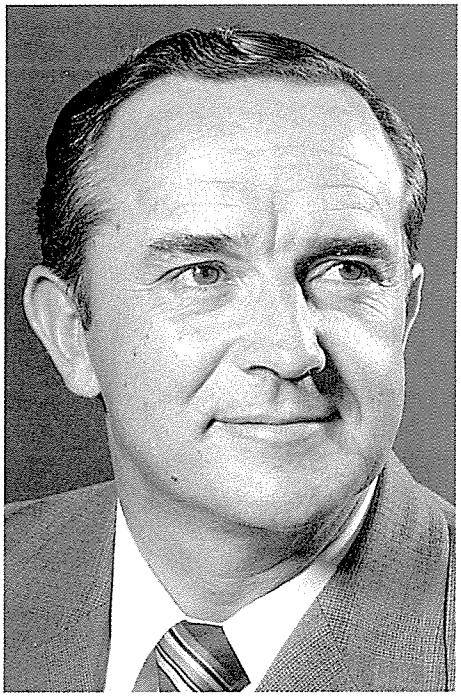
A number of milestones were again achieved in 1989 by the Computing Centre for Water Research (CCWR). Established in 1986 by the WRC, IBM (SA) (Pty) Ltd (now ISM (Pty) Ltd) and the University of Natal, the CCWR has this year continued to promote usage through the various national networks. The Universities of the Witwatersrand, Potchefstroom and Pretoria and the Rand Afrikaans University are now able to access the CCWR through UNINET. Several users now access CCWR regularly through dial-up to CSIRNET in Pretoria and Stellenbosch and MUNET (Natal University Network) in Pietermaritzburg and Durban.

Two introductory courses for consultants were held, one in Pretoria and the other in Pietermaritzburg, each attended by 12 participants. A number of consultants immediately recognised the potential of the CCWR and signed up as users. Accessibility to the Hydrological Information System (Department of Water Affairs) through GOVNET will encourage greater participation by consultants in the future. The CCWR in collaboration with the WRC, hosted a workshop on modelling root zone and chemical budgets in 1989. This was attended by over



Dr JP Kriel

Dr N Stutterheim



Dr CF Garbers

40 participants and served to promote the concept of the CCWR amongst the hydrological community. The fact that 15 224 file transfers have taken place since its inception bears testimony to its vital and soon indispensable role amongst water researchers and consultants alike.

RESEARCH NEEDS AND PRIORITIES

The WRC has over the years taken various initiatives to determine research needs and priorities within specified water research fields. Such priorities, however, need to be brought up to date from time to time in view of changing circumstances and new needs.

During the year under review workshops were organised amongst others and other actions were taken to evaluate the research needs and priorities in the following areas:

- ground water
- salinisation
- water quality and health aspects, and
- municipal effluents.

In each of the actions input has been obtained from the country's foremost experts in the relevant field of research and its application.

HONORARY AWARDS TO COMMISSION MEMBERS

Special honorary awards were made to three Commission members in 1989:

Dr JP Kriel:

State President's Order for Meritorious Service, Class 1: Gold; Gold Medal of the SA Institute of Civil Engineers for exceptional service to the Institute and the civil engineering profession.

Dr N Stutterheim:

Award of the Federation of Associations of Professional Engineers for service to the engineering profession.

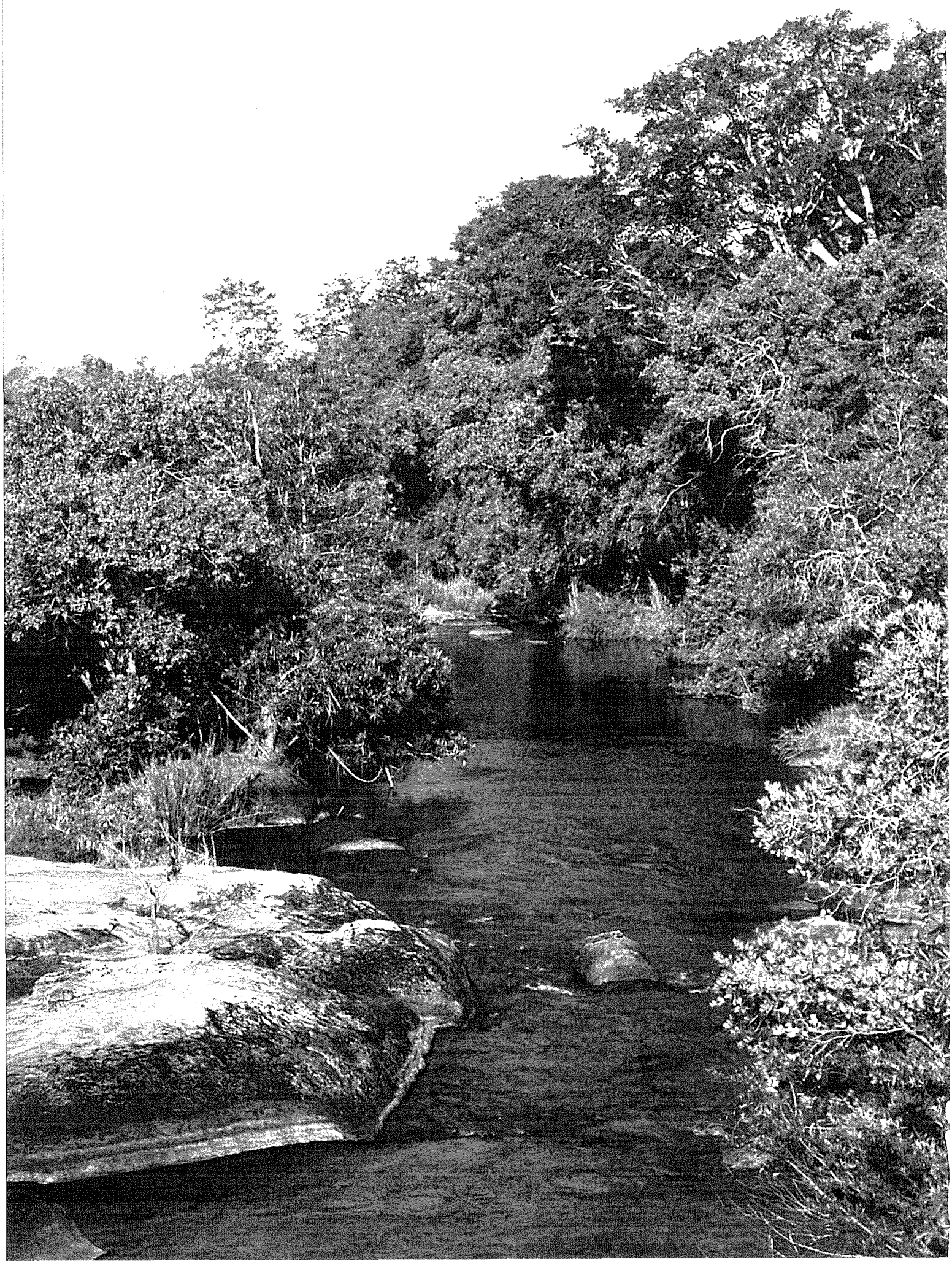
Dr CF Garbers:

State President's Order for Meritorious Service, Class 1: Gold.

LIAISON WITH USER ORGANISATIONS

Various actions were taken during the year to obtain closer co-operation with water boards and the SA Agricultural Union (SAAU).

The Executive Director and senior personnel visited Umgeni Water, the OFS Goldfields Water Board and the Western Transvaal Regional Water Company, while the Executive Director and the Chairman, Dr JP Kriel, informed the Rand Water Board of the WRC's activities. Liaison with the water boards will undoubtedly be furthered now that Mr DH Marx, the chairman of the Magalies Water Board and vice-chairman



of the Committee of Water Boards, has been appointed a member of the Commission.

The Irrigation and Water Affairs Committee of the SAAU by invitation held one of its scheduled meetings at the WRC during which officials of the WRC informed the Committee of the Commission's agricultural-related activities. A representative of the SAAU was also involved in the WRC's Co-ordinating Committee for Irrigation Research.

WATER REQUIREMENTS OF THE KRUGER NATIONAL PARK

In *Management of the Water Resources of the Republic of South Africa*, published by the Department of Water Affairs in 1986, the major water demand of estuaries, lakes, wetlands, riverine habitats and conserved areas is identified for environmental management. The Department estimates that about 13% of the country's total water demand in the year 2000 will be required for this purpose. This estimate is a first approximation and extensive research is necessary to arrive at a more accurate figure.

The Kruger National Park, probably the country's most important ecosystem, is already under considerable stress as far as its water supply is concerned

The Kruger National Park (KNP), probably the country's most important ecosystem, is already under considerable stress as far as the quantity and quality of its water supply is concerned. It therefore presents an ideal study area in which to develop and test methodologies for estimating ecological water requirements.

A small group of specialists compiled a document incorporating proposals for an integrated and co-operative research programme to assess the water requirements of the KNP. The document was considered and the proposals were unanimously supported by a Policy Committee under the chairmanship of the National Parks Board and with representation from the Department of Water Affairs, the Department of Environment Affairs, the CSIR and the WRC.

Dr PCM Reid, research manager at the WRC, has been appointed programme manager for the integrated programme. The WRC will commence funding of a number of projects contributing to the overall programme in 1990.

LEFT: The Sabie River in the Kruger National Park.

ciently strong and stable and are supported by an understanding of underlying physical mechanisms. The aims of this three-year project, being carried out by the Department of Oceanography of the University of Cape Town, are to identify specific areas in the summer rainfall region where links between rainfall and ocean surface temperature patterns are strongest; to develop methods for near real time monitoring of sea surface temperatures in key ocean areas; and to develop and test appropriate statistical models for describing summer rainfall variability in terms of sea surface temperatures and other variables.

LIST OF RESEARCH PROJECTS

COMPLETED PROJECT

- Research on the revision of the temporal and spatial distribution of precipitation statistics in southern Africa (The University of Natal - Department of Agricultural Engineering)

CURRENT PROJECTS

- Research on the development of a stochastic daily climate model for South African conditions (The University of Cape Town - Department of Mathematical Statistics)
- Research on the reconstruction of the climatic history of the last 2 000 years in the summer rainfall regions of southern Africa (The South African Museum)
- Research on precipitation and airflow in cumulus clouds (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology (EMATEK))

NEW PROJECTS

- Research on relationships between lightning and precipitation (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology (EMATEK))
- Research on the prediction of South African summer rainfall variability from ocean surface temperatures (The University of Cape Town - Department of Oceanography)

RAINFALL STIMULATION

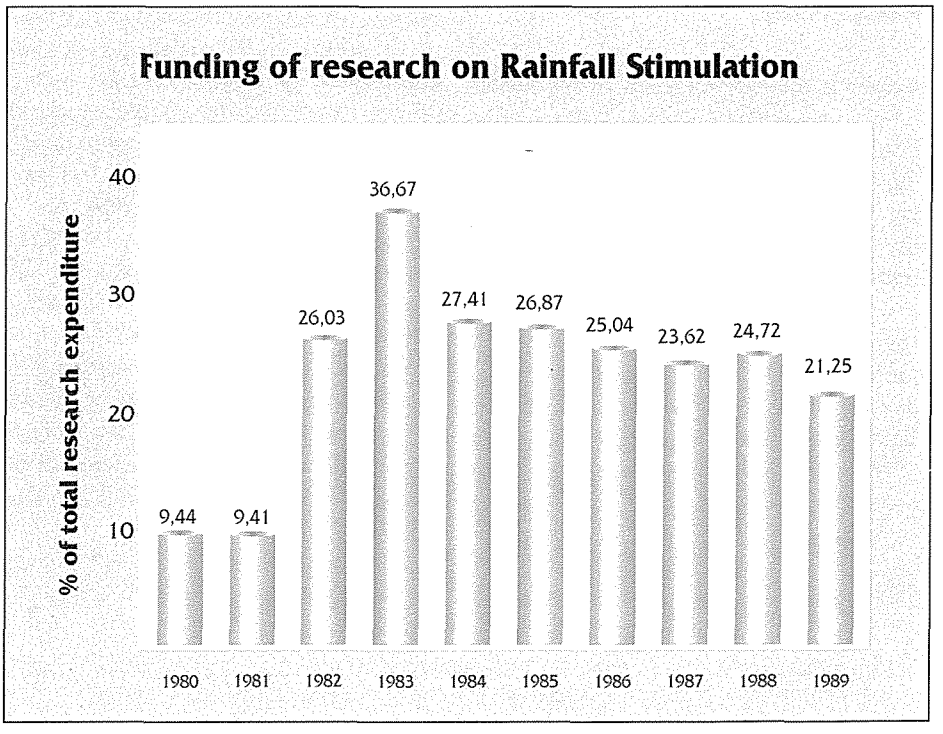
RAINFALL stimulation research, which forms part of the broader field of hydrometeorology, merits a separate chapter because of the concentrated support which it has received from the WRC, especially over the past seven years. This support has consisted of total funding of the programme for atmospheric water supply (PAWS) and contributions to the funding of the Bethlehem precipitation research project (BPRP). Support for BPRP entered a new phase in January 1989 in terms of a new three-year research contract between the Weather Bureau and the WRC.

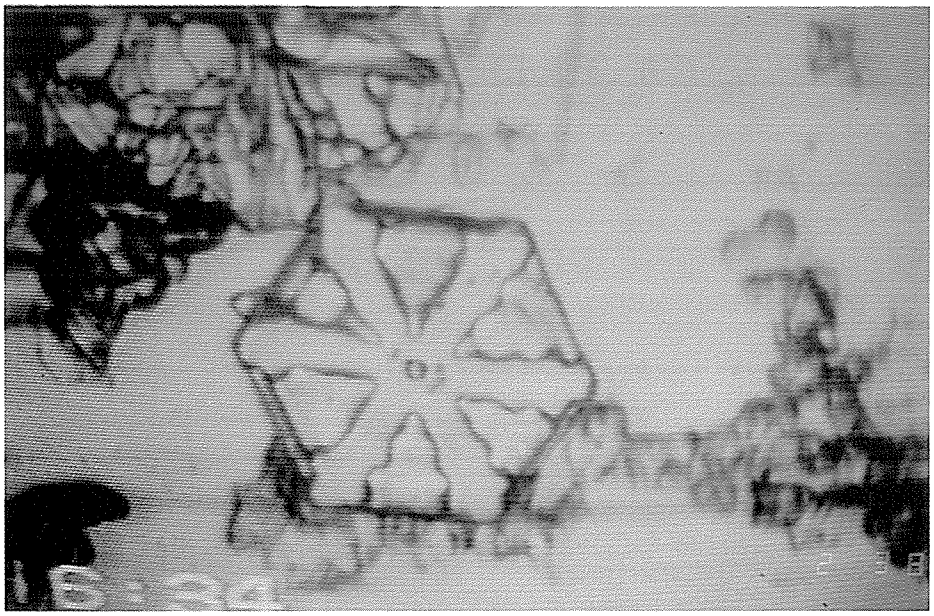
With South Africa facing a steadily increasing and potentially crippling demand on its limited water resources, no potentially viable option of augmenting these resources should be left uninvestigated. Rainfall stimulation is one of the most attractive options, assuming that it may be possible to develop methodologies to exploit, at relatively modest cost, some proportion of the vast quantity of atmospheric water which does not naturally become available as rain.

Research to assess the feasibility of enhancing rain from convective storms continued to be addressed by PAWS and BPRP in two areas of South Africa: the one including parts of the eastern Transvaal lowveld, escarpment and highveld around Nelspruit and Carolina, and the other being the north-eastern Orange Free State around Bethlehem. The corridor which links these two areas may well one day be the prime candidate for application of a rainfall stimulation technology, since it incorporates the head water catchments of the majority of South Africa's important rivers. The present research locations are also well situated for studying the whole spectrum of cloud conditions and precipitation development processes likely to be encountered along this hydrologically important corridor.

Much has been learnt from the research to date. Certain essential measuring techniques for use with research aircraft have been developed and refined. Cloud climatologies based on radar observations have been compiled and a large number of storms characterised in detail with respect to dynamic behaviour and microphysical properties. Formal exploratory randomised seeding experiments, conducted over several seasons, have indicated that seeding is likely to modify cloud properties in a manner consistent with an increase in rainfall. The research has not reached the stage of providing confirmation that cloud seeding will, in fact, significantly enhance rainfall on the ground.

Funding of research on Rainfall Stimulation expressed as a percentage of total WRC research expenditure (1980 to 1989).





A hexagonal plate ice crystal captured on an oil-coated slide at - 10 °C in the cloud
(Courtesy of RT Bruintjes)

REVIEW WORKSHOP ON RAINFALL STIMULATION RESEARCH

Research contracts in terms of which the programme for atmospheric water supply (PAWS) was undertaken with WRC funding in the eastern Transvaal, terminated at the end of 1989. Shortly before termination and partly because of it, a national review workshop was held to assess progress of both PAWS and the Weather Bureau's Bethlehem precipitation research project (BPRP) and to plan the continuation of rainfall stimulation research in South Africa. The workshop, held in August 1989, concluded that in order to maintain a satisfactory rate of progress, unification of the two projects and a change of approach to the research had become necessary.

The change in research approach was indicated by the fact that the randomised seeding experiments in their existing form would not necessarily produce results which in the near future could be considered conclusive beyond dispute. Some seasons need to be spent in researching the physical processes which give rise to precipitation in multicellular storms occurring in different synoptic and mesoscale conditions, and how these processes respond to human intervention. The new approach will, in all probability, ultimately shorten the period required to establish conclusively whether a beneficial rainfall stimulation technology is feasible or not. Unification of the research was considered necessary because the individual resources of the PAWS and BPRP research teams were inadequate to enable them to tackle the new approach on a separate basis.

CONSULTANTS

Having access to unbiased expert opinion is of great value during a major review such as the one described above. In order to obtain such input, the following four leading cloud physicists from the USA were invited to serve as consultants at the workshop:

Dr Terry Clark of the National Center for Atmospheric Research (NCAR), Boulder, Colorado - Numerical cloud modelling;

Dr W Al Cooper of NCAR - Airborne instrumentation and in-cloud precipitation processes and microphysics;

Dr G Brant Foote of NCAR - Storm structure and general cloud physics; and

Dr Paul L Smith of South Dakota School of Mines and Technology - Radar studies of cloud and mesoscale phenomena.

The active participation of these consultants contributed greatly to the successful achievement of the goals of the review workshop.

LIST OF RESEARCH PROJECTS

CURRENT PROJECTS

- Bethlehem precipitation research project (The Department of Environment Affairs - Weather Bureau)
- Programme for atmospheric water supply (The Company for Research on Atmospheric Water Supply (CRAWS), subcontracting the Division of Earth, Marine and Atmospheric Science and Technology (EMATEK) of the CSIR and CloudQuest (Pty) Ltd)

SURFACE HYDROLOGY

THE CONFLICTING demands on surface water resources are reaching crisis proportions in places. There is an ever-increasing need for synthesising a more detailed picture of the availability and usage of our surface water resources. Supporting the role of water in development, the Co-ordinating Committee for Hydrological Research (CCHR) accepted that in a typical mix of first and third-world economies of southern Africa probably more attention could be paid to the research needs of the less developed communities.

Since the Water Research Commission initiated research in small catchment hydrology some 15 years ago there has been a gradual change in objectives. The original objectives were aimed mainly at providing information and mathematical models for use in the design of small structures. Although the latter is still a fairly problematic subject, mathematical models and data currently available meet the requirements. For this reason there has been a shift in emphasis of WRC-funded hydrological research projects.

The overall goal of research on surface water resources is to aid the optimum development and management of these resources in southern Africa. The objective therefore is to provide the water resources manager with all the required hydrological data of any locality in the Republic of South Africa. In this regard irrigation, afforestation, urbanisation and informal settlements all play an important role. Consequently an evaluation of the effects of alternative development scenarios is becoming the main focus point in research on hydrology funded by the WRC. An investigation of the role that geographic information systems can play in this regard has also been initiated.

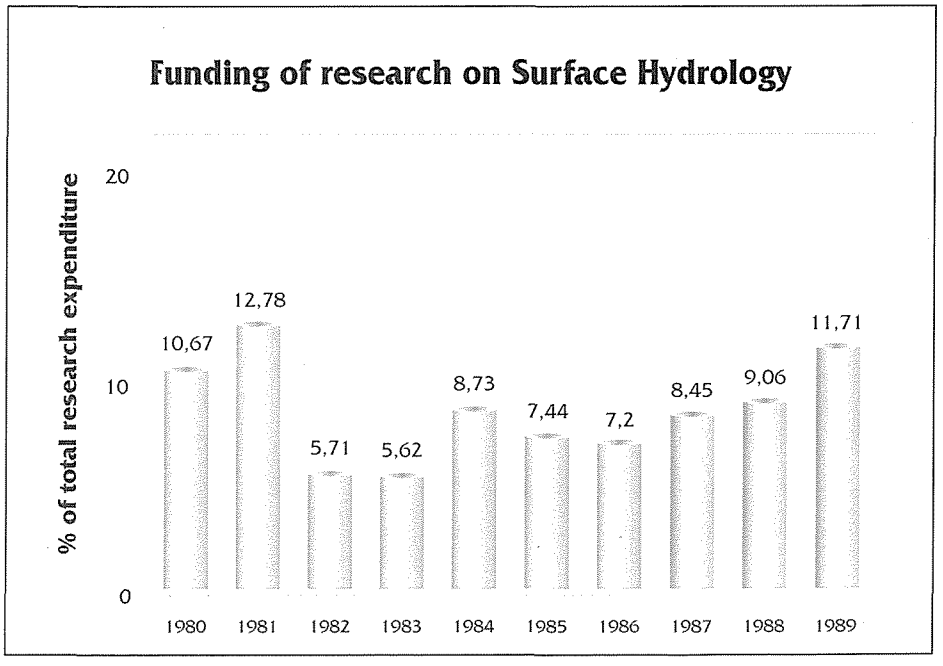
The gratifying development of project integration which had started in 1988, continued during 1989. The project on the Mgeni catchment systems model is an example of this development. Not only do the various research organisations co-operate, but there is also interaction at the grass-roots level with the user organisations such as the Umgeni Water Board, the Department of Water Affairs and the Institute of National Resources (University of Natal).

IMPACTS OF RAINFALL AUGMENTATION

Assessment planning of the possible impact of artificial rainfall augmentation has been started. As part of this planning a broad spectrum of experts was invited to a workshop held on 21 September 1989 in Pretoria at the Watko building. The major issues in agriculture, forestry and water resources resulting from rainfall augmentation were addressed.

The workshop achieved two important results. Firstly, it created an opportunity to

Funding of research on Surface Hydrology expressed as a percentage of total WRC research expenditure (1980 to 1989).



bridge the existing communication gaps between researchers in cloud physics, weather modification, hydrology and plant growth modelling. Perceptions and expectations of each discipline were brought somewhat closer together. Secondly, it was agreed that a daily rainfall modification scenario would be the starting point of any impact assessment.

CONSULTANT

For a period of two weeks during and after the fourth Hydrological Symposium in November 1989, the WRC had the opportunity to consult with Prof DH Pilgrim of the School of Civil Engineering, University of New South Wales, Australia. Prof Pilgrim is an expert on Australian rainfall, runoff and flood relationships and has made valuable contributions to clarifying issues and programmes in the flood studies presently undertaken by local research organisations and the Department of Water Affairs.

REPORT ON A COMPLETED PROJECT

Research on applied hydrological process and modelling studies for the determination of water and sediment yield

In June 1989 this five-year project was completed successfully by the University of Natal. The project represents almost the end of an era, since it concluded the development of the ACRU modelling system. This modelling system can now simulate a great variety of hydrological and agrohydrological situations such as:

- assessments of irrigation water needs under a variety of water supply schedules;
- crop yields under both irrigated and dry land conditions;
- effects of land-use change on run-off; and
- reservoir yield analyses on small dams.

The important model components have been verified on a limited number of real world test cases and it is hoped that the model will now enter an era of extensive testing in practice because the utility of hydrological models can only be proved if they stand the test of time in practice. The strength of the modelling system lies in the fact that it caters for a variety of input data options.

DISCUSSION OF A NEW PROJECT

Research on hydrological systems model development

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

LIST OF RESEARCH PROJECTS

COMPLETED PROJECT

- Applied hydrological process and modelling studies for the determination of water and sediment yield (The University of Natal - Department of Agricultural Engineering)

CURRENT PROJECTS

- Research on the effects of urbanisation on catchment water balance (The University of the Witwatersrand - Department of Civil Engineering, Water Systems Research Programme)
- Development of methods to assess the impact of agricultural practices on water resources in southern Africa (The University of Natal - Department of Agricultural Engineering)
- The investigation of the hydrological response to Third-world settlements in the peri-urban areas of Natal/Kwazulu (The University of Zululand - Department of Hydrology)
- The development of a systems model for the Mgeni catchment (The University of Natal - Department of Agricultural Engineering)
- Hydrological modelling studies in the eastern Cape (Rhodes University - Department of Geography)
- Development of a model to simulate flow in alluvial rivers (A firm of consulting engineers: Bruinette, Kruger and Stoffberg Inc.)

NEW PROJECT

- Research on hydrological systems model development (The University of Natal - Department of Agricultural Engineering)

The evualation of the effects of alternative development scenarios is becoming the main focus point in our hydrological research.

GROUND WATER

N 1981 a master plan for geohydrological research was formulated by the Water Research Commission in collaboration with the Department of Water Affairs. It was decided at the time that the research fields covered in the master plan, and the priorities associated with them, would be revised on a regular basis to ensure that the research and development programmes are progressively adjusted to meet the immediate and future needs.

During the past eight years a number of ground-water projects have been completed and the priorities associated with research fields have changed somewhat. Consequently a decision was taken by the Co-ordinating Committee for Geohydrological Research (CCGR) that the master plan be revised and for this purpose a workshop took place during the latter part of November 1989.

Prof David McWhorter of the Engineering Research Centre, Colorado State University, visited the RSA during 1989 and was contracted by the WRC to assist in the planning of an investigation into the deterioration of ground-water quality in the Olifants River catchment above Loskop Dam. Prof McWhorter is an authority on water quality changes related to coal mining activities and seepage from tailings impoundments, and was therefore able to make valuable inputs into the development of the above-mentioned research proposal.

During 1989 the Commission supported 12 ground-water research projects, of which five commenced during the year.

DISCUSSION OF NEW PROJECTS

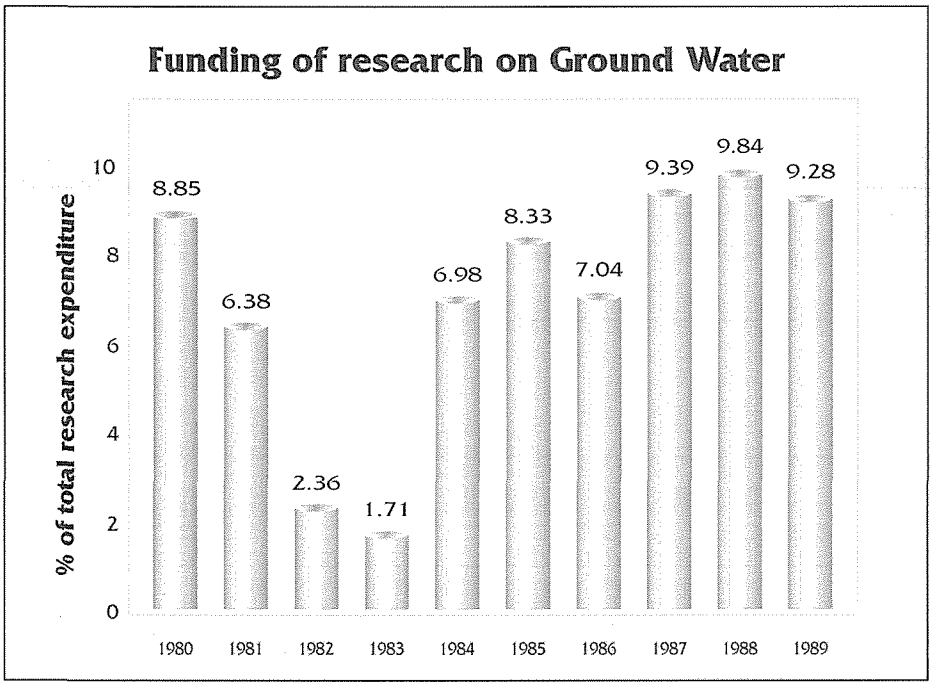
An investigation of the potential use of NOAA satellite remotely sensed data for identification of regional-scale fracture zones for ground-water supply purposes in southern Africa

Ground water is often the most cost-effective source of water in rural, semi-arid areas. However, approximately 60 per cent of southern Africa is covered by Karoo formations which characteristically exhibit poor yield potential for domestic and municipal water supply. The majority of high yielding aquifers in the Karoo and various other geological formations throughout southern Africa are associated with fracture zones. It is, therefore, necessary to identify and evaluate fracture zones on a regional scale in order to optimise the utilisation of ground-water resources with respect to location, quantity and cost.

With remote sensing techniques it is possible to obtain structural and lithological information more efficiently and cost-effectively for large areas than can be achieved on the ground. The potential of these techniques for the identification of regional-scale fracture zones is to be investigated by the consulting engineering firm Steffen, Robertson and Kirsten in terms of a one-year contract with the WRC.

A preliminary survey of pesticide levels in ground water from a selected area of intensive agriculture in the western Cape

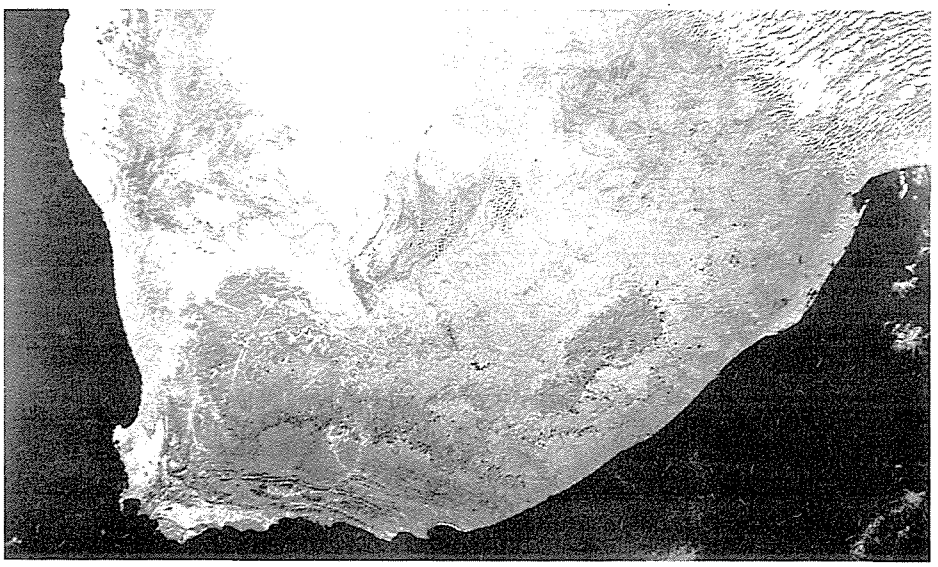
Overseas experience indicates that the newer generation of pesticides that are supposed to break down on contact with soil and have relatively short half-lives



Funding of research on Ground Water expressed as a percentage of total WRC research expenditure (1980 to 1989).

Evidence of pyrite oxidation in a shrinkage crack on a gold mine tailings impoundment.

could still cause contamination of ground water. Although limited studies have been undertaken in South Africa to determine possible pollution of ground water with the older more persistent chlorinated pesticides, no investigations concerning the newer generation of pesticides have been undertaken. This preliminary survey by the CSIR to determine the pesticide levels in ground water is consequently very timely.



NOAA satellite remotely sensed data are being used to identify regional-scale fracture zones for ground-water supply purposes in South Africa.

The eighteen-month study is being carried out in an area of intensive agriculture in the Western Cape where extensive use is made of pesticides during farming activities.

The evaluation and development of geophysical techniques for characterising the extent and degree of ground-water pollution

This project is to be executed by the CSIR in terms of a two-year contract with the WRC.

Contamination of ground water by diffuse and point sources is causing increasing concern in South Africa. Contamination is mostly detected and monitored with the aid of boreholes sunk for this specific purpose. Electrical and geophysical techniques are increasingly being applied world-wide as an aid in the detection and monitoring of ground-water and soil contamination. These techniques are also increasingly used to locate pollution plumes in ground water and the judicious siting of boreholes. The overseas experience in this regard is, however, almost exclusively limited to aquifers in unconsolidated sediments, while South Africa has mainly secondary or "hard rock" aquifers. This project is, therefore, aimed at the investigation and development of geophysical methods which can be used to map pollution plumes more efficiently and cost-effectively than an extensive borehole network.

A comparative study of two and three-dimensional ground-water models

This three-year project was initiated during the year in terms of an agreement between the WRC and the University of the Orange Free State. It aims to compare the capability of two and three-dimensional models in the simulation of ground-water occurrences. Although ground water occurs in three spatial dimensions, it has up to now been largely modelled using two-dimensional models. This simplification of the physical system may account for discrepancies between observed values and simulated values obtained from the models. In addition to model refinement, advantages resulting from the research will be the development of more effective methods for the estimation of unknown values required in model development and improved graphical representation of ground-water data.

An investigation into the oscillation method for the determination of aquifer transmissivity

This eighteen-month contract is being undertaken by the University of the Orange Free State.

The oscillation method, which provides a rapid cost-effective means of determining aquifer transmissivity, was developed during the 1970s in Germany. The project aims to investigate the suitability of the method for determining aquifer transmis-

sivity under South African conditions. Results will be compared against existing conventional pumping test data. Software, to process data obtained from the tests, will be developed and the results, together with a handbook describing the procedure, will be published.

LIST OF RESEARCH PROJECTS

CURRENT PROJECTS

- Modelling of the ground-water quality in the Atlantis aquifer (The University of the Orange Free State - Institute for Ground-water Studies)
- The exploitation potential of Karoo aquifers (The University of the Orange Free State-Institute for Ground-water Studies)
- The evaluation and development of techniques for the determination of geohydrological parameters by use of geo-electrical methods (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology (EMATEK))
- Research on the use of electromagnetic exploration techniques for the development of ground-water resources (The University of Pretoria - Department of Geology)
- Research on the enhancement of the National Ground-water Data Base facilities (The University of the Orange Free State - Institute for Ground-water Studies)
- A geohydrological investigation and evaluation of the Zululand coastal aquifer (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology (EMATEK))
- Research on the development of techniques for the evaluation and effective management of surface and ground-water contamination in the Orange Free State Gold Fields (The University of the Orange Free State - Institute for Ground-water Studies)

NEW PROJECTS

- An investigation of the potential use of NOAA satellite remotely sensed data for identification of regional scale fracture zones for ground-water supply purposes in southern Africa (A firm of consulting engineers: Steffen, Robertson and Kirsten)
- A preliminary survey of pesticide levels in ground water from a selected area of intensive agriculture in the Western Cape (The CSIR - Division of Water Technology)
- The evaluation and development of geophysical techniques for characterising the extent and degree of ground-water pollution (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology (EMATEK), and Division of Water Technology)
- A comparative study of two and three-dimensional ground-water models (The University of the Orange Free State - Institute for Ground-water Studies)
- An investigation of the oscillation method for the determination of aquifer transmissivity (The University of the Orange Free State - Institute for Ground-water Studies)

AGRICULTURAL WATER UTILISATION

THE TENDENCY in WRC irrigation projects since 1987, viz. that the research is aimed more directly at the end user and his problems, has been continued during 1989. The good results emanating from the current research projects, as well as the objectives of the research projects which were launched during the year under review, confirm this approach.

Two major advantages have resulted from this approach.

- Contact between the researcher and the end user is furthered. The lack of contact between these two parties has often in the past been identified as a shortcoming in the South African irrigation set-up. The immediate result of this closer contact with irrigation practice, is that it enables the researcher to identify high-priority research needs in practice and to focus attention on those needs. The fact that irrigation farmers co-operate actively in the executing of the research enables them to become acquainted with new techniques and approaches, thereby enhancing the ultimate application of results.
- Basic research which may be deemed necessary while implementing user-oriented research, can be executed more purposefully. The end-result is that scientifically justified equipment and procedures become available at an earlier stage for general practical application, thereby enhancing the efficient and optimal application of water for irrigation purposes.

The irrigation research projects which were launched during 1989 can be divided into two broad categories, viz.:

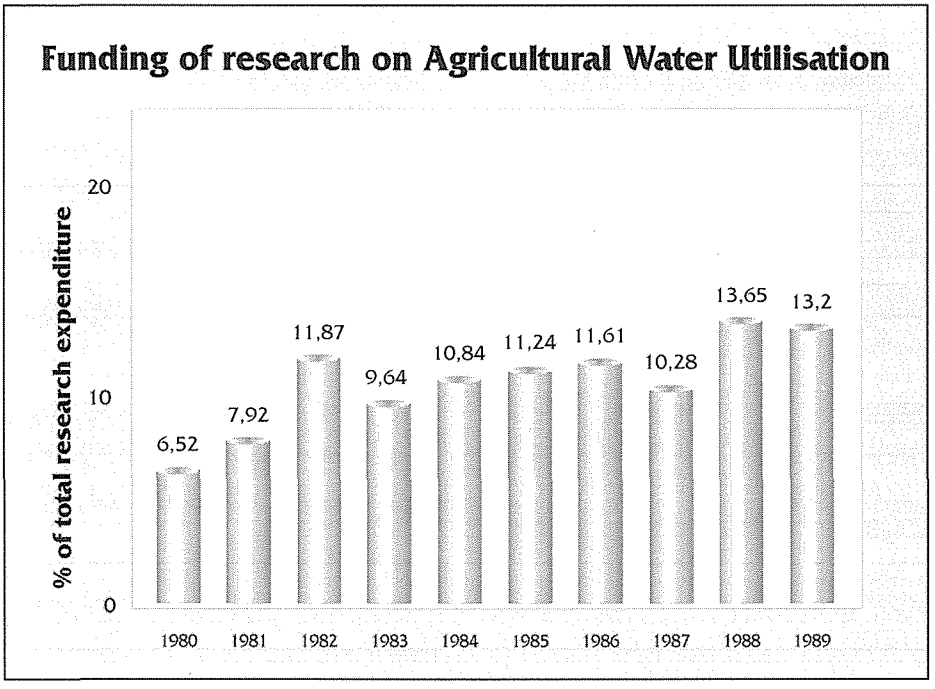
- follow-up research projects which are aimed at rounding off research which had been founded in previous projects; e.g. the project on the upper boundary area of plant-available water and the project on crop factors; and
- research projects which are aimed at existing equipment and procedures, e.g. the projects on water sensors and flood irrigation design.

The number of irrigation research projects supported by the WRC amounted to 21 during 1989. Of these two projects were completed while four new research agreements were entered into.

LIAISON WITH THE SA AGRICULTURAL UNION (SAAU)

Although the WRC submitted copies of irrigation research reports to the Irrigation and Water Affairs Committee of the SAAU right from the start, no formal liaison existed between the WRC and the Committee. On the invitation of the WRC the Committee visited the WRC during the year under review. The visit, in the form of a meeting at the WRC, was followed by an information session during which the Committee was briefed by WRC personnel on WRC activities relating to agriculture. Through this action the foundation was lain for closer liaison between the WRC and the SAAU.

Funding of research on Agricultural Water Utilisation expressed as a percentage of total WRC research expenditure (1980 to 1989).



OVERSEAS CONSULTANT

During November 1989 the WRC hosted a visit to South Africa by Prof S Miyamoto of the Texas A and M University in El Paso, Texas. Prof Miyamoto is the author of more than 100 professional papers and is regarded as a world authority in the field of salinity and plant/water relationships of subtropical fruit trees, specifically as regards pecan nuts. Prof Miyamoto attended the ISHS International Symposium on the Culture of Subtropical and Tropical Fruits and Crops, held in Nelspruit from 6 to 10 November 1989. At the congress Prof Miyamoto read the introductory paper *Irrigation Scheduling for Pecans* in the Water Relations/Nutrition session, and chaired the workshop *Irrigation Research Strategy*, during which future subtropical and tropical fruit and crop irrigation research was decided upon. After the congress Prof Miyamoto visited the horticulture departments of the Universities of Natal, Stellenbosch and Pretoria. During these visits departmental research projects were discussed and various field trips undertaken, and Prof Miyamoto read a further three technical papers.

A complete weather station at Riet River to monitor irrigation treatment and physiological reactions of crops.

REPORT ON COMPLETED PROJECTS

Research on correction factors for the evaporimeter coefficients used in the irrigation scheduling of wheat

This project, which commenced in January 1985, was completed in August 1989 by the University of the Orange Free State. The final report entitled *Correction Factors for Evaporimeter Coefficients Used for Scheduling Irrigation of Wheat* contains results proving conclusively that the use of a single crop evaporation coefficient per crop per season, is incorrect. Furthermore, a new concept namely atmospheric evaporative demand (AED), was introduced and defined.

The generality of AED, as defined, makes universal acceptance of this concept desirable. This description of upper limit evaporation eliminates much of the confusion which had existed in the past as to whether to use maximum, potential, basal or reference evaporation to express upper limit evaporation.

The Penman-Monteith equation, weather data from an automatic weather station and a canopy surface conductance value of 0,08 m s^{-1} could be used to estimate reference evaporation (E_o) accurately. This estimate, together with the crop evaporation coefficient defined in this work must now be regarded as the most accurate method of calculating AED. This approach greatly facilitates and improves the scheduling of irrigation.

Evaporimeters, such as A-pan and Piché or carborundum atmometers, proved useful alternatives for estimating E_o. Implementation of A-pan measurements required measurement of air and water temperatures, whilst application of atmometers required measurement or estimation of radiation and air temperature. Atmometers, however, proved to be more accurate than the A-pan.

Research on improving irrigation management based on soil water monitoring and detailed knowledge of profile available water capacities

This project, which commenced in January 1985, was completed in December 1988 by the University of Fort Hare. The final report *Research on Improving Irrigation Management Based on Soil Water Monitoring and Detailed Knowledge of Profile Available Water Capacities* contains the results of investigations on plant available water capacities (PAWC) for wheat, durum wheat and maize crops and the effect of soil water stress, at various growth stages, on the yield of these crops.

It was found that moderate stress, defined as the extraction of 100 per cent of PAWC, did not reduce the yields of either maize or wheat, but had a marked detrimental effect on durum wheat yield.

The study clearly indicated that pre-dawn leaf water potential (PLWP) is a reliable parameter for the identification of first material stress (FMS) in both immature and mature plants. A standardised procedure for PLWP measurements, described in the report, proved to be very reliable and yielded highly reproducible results. The study, therefore, offers a reliable technique for PAWC determinations for a crop at any growth stage.

The study also proved that deficit irrigation can be applied successfully during peak demand periods without reducing yields or irrigation water-use efficiencies. In fact, deficit irrigation generally gave higher irrigation water-use efficiencies than full irrigation. The fact that deficit irrigation at soil water contents close to FMS had no harmful effects on yield and water-use efficiencies is ample proof of the validity of the PAWC concept for irrigation scheduling.

DISCUSSION OF NEW PROJECTS

Research on moisture sensors to facilitate water management

Thin-film polymer techniques have recently been employed successfully in the manufacture of humidity sensors.

This three-year research project, undertaken by the University of Stellenbosch, will refine the above-mentioned sensors to a point where such instruments will meet cost, accuracy and reliability criteria of water researchers in agriculture, forestry and hydrology. A second research aim is to employ thin-film techniques in the manufacture of soil moisture measuring instruments. Currently available instruments are characterised by high cost, as well as by laborious labour and management procedures.

The use of polymer techniques is a totally new approach which, if successful, will lead to a considerable breakthrough in the production of economical, accurate, easy-to-use moisture sensors which can be widely replicated.

Research on the relationship between climate and crop factors

Judicious irrigation scheduling requires knowledge of atmospheric evaporative demand, which is calculated by means of crop factors and evaporation from a reference crop. As the determination of crop factors not only depends on climate, but is also sensitive as regards crop and growth stage, crop factors have to be determined over a wide range of climatic areas, which is an expensive, slow and sometimes impracticable approach.

A three-year research project which is being undertaken by the University of the Orange Free State, will investigate an alternative approach to the determination of crop factors. Research will focus on hourly observations of lysimeter determinations of evaporative demand, reference crop evaporation and climatological inputs. This will facilitate the determination of crop factors over a wide range of "climates" by equating the climate which prevailed during the specific hour under consideration to analogue climates in other areas.

Should this approach be successful the determination of crop factors will be simplified and expedited, thereby furthering scheduling techniques.

Studies on soil/plant/water relationships in the upper reaches of plant available soil water

The profile available water capacity (PAWC) concept has been researched and refined over a number of years and is also the basic concept for a highly successful irrigation scheduling programme. This research, however, showed clearly that uncertainties still exist regarding the soil/ plant/ water relationships in the upper reaches of plant available water (or the area known more commonly as "field capacity").

A five-year project by the University of Pretoria will investigate not only the soil/plant/water relationships in the upper reaches of plant available water, but also other factors such as the uptake of plant nutrients and the occurrence of root diseases in the upper reaches of soil water.

A critical evaluation of flood irrigation design procedures and the computerisation of the most suitable

Although sophisticated irrigation techniques are fairly extensively used in irrigated agriculture, flood irrigation is the most common method of irrigation and indications are that this will remain the case in the foreseeable future. The general standard of flood irrigation in South Africa is, however, not satisfactory, and low application efficiencies of approximately 45 per cent can be observed in practice.

A three-year research project is being undertaken by the University of Pretoria to investigate, firstly, management and other guidelines for the appropriate application of irrigation water during flood irrigation and secondly, to develop computerised design procedures for this method of application.

LIST OF RESEARCH PROJECTS

COMPLETED PROJECTS

- Research on correction factors for the evaporimeter coefficients used in the irrigation scheduling of wheat (The University of the Orange Free State - Department of Agrometeorology)
- Research on improving irrigation management, based on soil water monitoring and detailed knowledge of profile available water capacities (The University of Fort Hare - Department of Soil Science)

CURRENT PROJECTS

- Development of a computer program to simulate the flow of water in distribution canals (The Rand Afrikaans University - Department of Civil Engineering)
- An investigation into methods of developing operational rules for individual irrigation systems (The University of Stellenbosch - Department of Civil Engineering)
- Research on economic evaluation of alternative irrigation scheduling strategies for wheat in the irrigated area of the Orange Free State (The University of the Orange Free State - Department of Agricultural Economics)
- Research on the development of criteria for sprinkler irrigation systems to combat surface sealing of soils (The Potchefstroom University for CHE - Department of Pedology and the University of Pretoria - Department of Agricultural Engineering)
- Research on the development of an adjustable low pressure flow-rate control valve for flood irrigation (The University of Pretoria - Department of Agricultural Engineering)
- Research on the practical scheduling of irrigation in the northern Transvaal (The University of the North - Department of Crop Production)
- Research on quantification and limita-

The effect of optimal and sub-optimal irrigation treatment on crop growth can be seen clearly.

tion of water losses associated with centre-pivot irrigation systems. (The University of the Orange Free State - Department of Agricultural Engineering in collaboration with the Department of Agronomy)

- Investigation into water use and productivity of crops under conditions of water stress and the modelling thereof (The Department of Agriculture Development - Soil and Irrigation Research Institute)
- Research on drip irrigation of tomatoes (The University of Pretoria - Department of Plant Production)
- Research on maximising irrigation project efficiency in different soil/climate/irrigation situations (The University of the Orange Free State - Department of Agrometeorology)
- Research on the storage and utilisation of rain water in the soil for the stabilisation of plant production in semi-arid areas (The University of the Orange Free State - Department of Soil Science)
- Research on the factors affecting the water-use efficiency of irrigated crops, with special reference to the physiological responses of these crops (The University of the Orange Free State - Department of Agronomy and Hortology)
- Research on estimation and evaluation of moisture stress in crops by means of remote control aerial surveillance (The University of the North - Department of Soil Science)
- Research on the water-use efficiency of certain irrigated temperate pasture species (The University of Pretoria - Department of Plant Production)
- Development of a manual to be used with the IDES computer programs for the design of irrigation systems (A firm of consulting engineers: Murray, Biesenbach and Badenhorst Inc.)

NEW PROJECTS

- Research on moisture sensors to facilitate water management (The University of Stellenbosch - Institute of Polymer Science)
- Research on the relationship between climate and crop factors (The University of the Orange Free State - Department of Agrometeorology)
- Studies on soil/plant/water relations in the upper reaches of plant available soil water (The University of Pretoria - Department of Soil Science)
- A critical evaluation of flood irrigation design procedures and the computerisation of the most suitable (The University of Pretoria - Department of Agricultural Engineering)

WATER POLLUTION

ITH the exception of a relatively high salt content in its interior, South Africa can boast of a good natural water quality. Certain areas, however, exhibit a gradual to serious deterioration in the quality of surface water sources, causing the water to become less fit for consumption. When the water quality deteriorates to the extent that it exceeds certain threshold values, which differ for the various uses, the consumer of water has to bear the escalating costs associated with the deterioration.

Virtually all uses of water lead to one or other form of pollution. This explains why the deterioration in the quality of water is for the greater part associated with industrial, urban and irrigation development. The relative scarcity of water in South Africa necessitates even better control over limited water resources. This promotes the more intensive use and reuse (and the concomitant deterioration in quality) of water. In the long term the deteriorating water quality and the resulting decline in its usefulness can become a bigger problem than the availability of water.

In South Africa water pollution occurs predominantly as salinisation and eutrophication. Salinisation is the accumulation of salts in water by the use and reuse of water, causing the salt content of the water to rise, thus creating additional costs for the user. Eutrophication occurs when the water is enriched with plant nutrients, thus promoting the excessive growth of algae and water plants. This, in turn, impedes the treatment of water for drinking purposes and hampers its utilisation for recreational purposes.

In 1989 the Commission financed five salinisation projects. One project was launched and no projects were concluded. Eight eutrophication projects were financed, of which two were completed during the year and three were initiated.

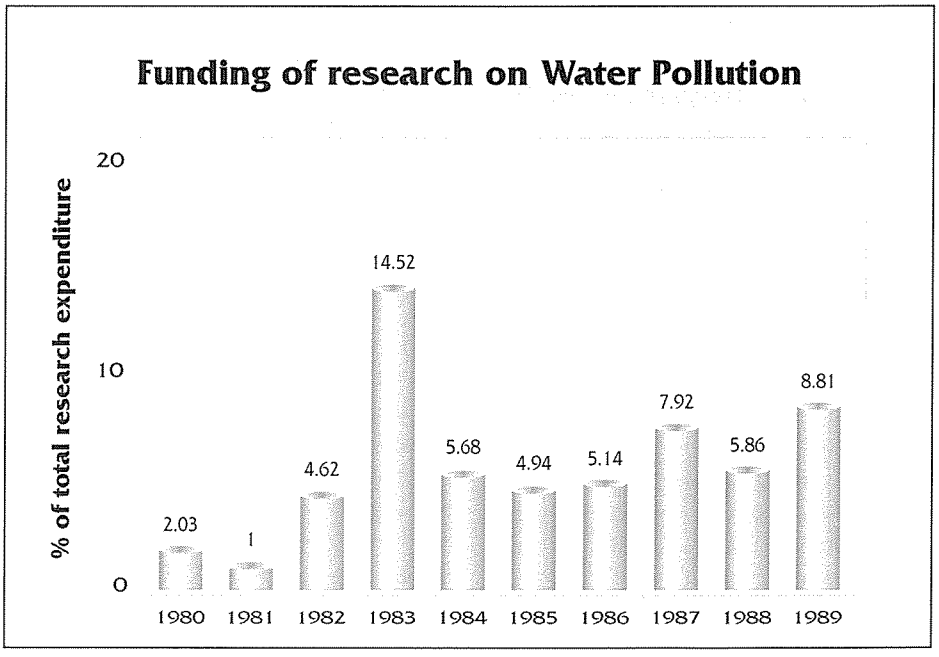
The great capacity of the sea to assimilate certain waste products causes most of the communities living at the coast to make use of it to some or other extent to dispose of their effluents. It is essential that only non-toxic waste which can be assimilated effectively by the marine environment, be discharged. Guidelines in this regard are available. During the year the Commission financed two projects with regard to marine discharge, of which one was completed.

The increasing awareness of the role which quality has to play in the utilisation potential of water, coupled with the gradual deterioration in water quality, has created the need to devise a strategy in terms of which the major aspects of water quality can be monitored. The Commission is at present financing one project in this regard.

SALINISATION

The Commission met with a number of experts in the field of salinisation in November 1989, as part of its co-ordinating function, to discuss priorities for salinisation research. This prioritisation came about as a result of papers presented on the different goals for salinisation research. The severity of the problem and the present state of knowledge were thoroughly discussed. It is expected that several other organisations which are involved in salinisation research, besides the Commission, will adapt their activities in view of this prioritisation.

Funding of research on Water Pollution expressed as a percentage of total WRC research expenditure (1980 to 1989).



WORKSHOP ON THE MODELLING OF CHEMICAL AND WATER BALANCES IN THE ROOT ZONE OF SOIL

The theory and application of a model describing the dynamic reaction of inorganic salts as well as nitrogen fertilisers and pesticides in the root zone of soil were discussed during a week-long workshop which took place in January 1989. The workshop was presented by the Commission in Pietermaritzburg in co-operation with the Computing Centre for Water Research, and with the assistance of two world-renowned leaders in the field, viz. Prof RJ Wagenet, head, and Dr JL Hutson, a senior researcher of the Department of Agronomy at Cornell University. About the same amount of time was devoted to the transfer of the theoretical basis of the model, its possibilities and limitations, as to the acquiring of practical experience in the use of the model with test data as well as data of the participants themselves.

The workshop was attended by about 40 participants from all over South Africa representing a variety of disciplines, *inter alia* soil scientists, agricultural engineers, geohydrologists, hydrologists, agronomists and botanists.

DISCUSSION OF A NEW PROJECT

Evaluation of the four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions

This project is being carried out by the University of Natal over a period of three years.

Salinisation of soil is a problem experienced by virtually all irrigation schemes in South Africa. Little is, however, known of the extent and the degree of salinisation, as well as the salinisation trend in course of time. In the main the reason for this is the fact that laboratory analyses for the traditional salinisation surveys are time-consuming and costly. Should there be a continued tendency for surface waters (and therefore also irrigation water) to salinise gradually as well as the tendency to improve irrigation effectivity, it is to be expected that the salt content of irrigated land will increase at the same time. Irrigation farmers will therefore experience a constant move towards the threshold value where soil salinisation starts to affect crop production and they will feel a growing need to be kept informed regularly on the saline status of their lands. There is consequently a definite need for methods to determine soil salts rapidly and cost-effectively. The experience gained in the USA, Australia and Israel using four-electrode electrical conductivity and electromagnetic induction techniques for the rapid determination of soil salts looks very promising. This project aims at determining the relationships between measurements with these instruments and standardised measurements. The validity of these relationships will be tested on a series of irrigation scheme soils under practical conditions. Guidelines for the use of these techniques will also be drawn up.

EUTROPHICATION

A DISCUSSION OF NEW PROJECTS

Research on the extension of the management-orientated models for eutrophication control

The CSIR is carrying out this three-year project.

The Department of Water Affairs has decided on a policy of addressing the causes rather than the effects of eutrophication. It is for this reason that a 1 mg/ℓ P standard has been set for a number of sensitive catchments. Management-orientated eutrophication models are used to compare the effects of alternative measurements. Thus answers to the question of whether the implementation of the P standard will have the desired effect on water quality are obtained. The decision support system (DSS) used up to now for this purpose, however, only simulates the transport and fate of phosphate P, since it has been found that phosphate is the limiting plant nutrient in most freshwater systems.

During a recent application of the DSS to test the effect of eutrophication control measures in sensitive areas, it was, however, found that the effect cannot always be adequately predicted. It transpired that the growth-limiting factors in these cases were the low levels of nitrogen compounds for light penetration (in highly turbid dams). Water quality managers of the Department of Water Affairs are of the opinion that it is important to expand the DSS for the control of eutrophication in order also to include nitrogen compounds and light penetration (in addition to phosphate P) as growth-limiting factors, as is the intention with this project.

Research on the management of phosphate concentration and algae in the Hartbeespoort Dam

This project is being carried out by the CSIR over a period of fifteen months.

It has been found that the problem of eutrophication in the Hartbeespoort Dam cannot be solved simply by enforcing the effluent standard of 1 mg/ℓ P. Additional measures are therefore required to combat the problem. The Department of Water Affairs consequently decided to apply full-scale aeration/destratification with a view to improving the quality of the water and the removal of dominant and undesirable *Microcystis* algae.

In planning the aeration experiment, it, however, transpired that the phosphate concentration in the dam had decreased to exceptionally low levels over the past few years and that *Microcystis* was also no longer the dominant alga.

In view of these improved conditions it was decided not to continue with the aeration experiment for the moment. Consequently

The project aims at obtaining useful chemicals from this green algal scum.

the Department of Water Affairs requested the Commission to initiate a research project in order to ascertain what had given rise to the reduced phosphate concentration and the decrease in the *Microcystis* algae in the dam. The results of this project could possibly make a contribution to the management of the phosphate concentration and algal species in Hartbeespoort Dam and others. It may also shed light on the advisability of aeration as a management strategy.

Research on harvesting Hartbeespoort Dam algal scums for fine chemicals

This project will be carried out by the CSIR over a year.

South African dams are increasingly subjected to enrichment with plant nutrients such as nitrogen-containing compounds and phosphate. The resulting algal bloom causes several problems. Algae are, however, also known to produce chemical

compounds which are pharmacologically active and which can be used as a feed supplement due to their high protein content.

This project will investigate the possibility of harvesting the algal scum which collects on Hartbeespoort Dam and to reclaim a number of chemicals from it. Should this investigation prove successful the problems currently being experienced with the algae can be partially turned into an advantage.

REPORT ON COMPLETED PROJECTS

Evaluation of the impact of the effluent phosphate standard on the water quality and trophic status of Hartbeespoort Dam

The Hartbeespoort Dam is known to be one of the most highly eutrophied impoundments in South Africa and a three-year project with the CSIR with the overall objective of evaluating the impact of the effluent phosphate standard of 1 mg/ℓ on the water quality and trophic status of the dam, was completed during the year.

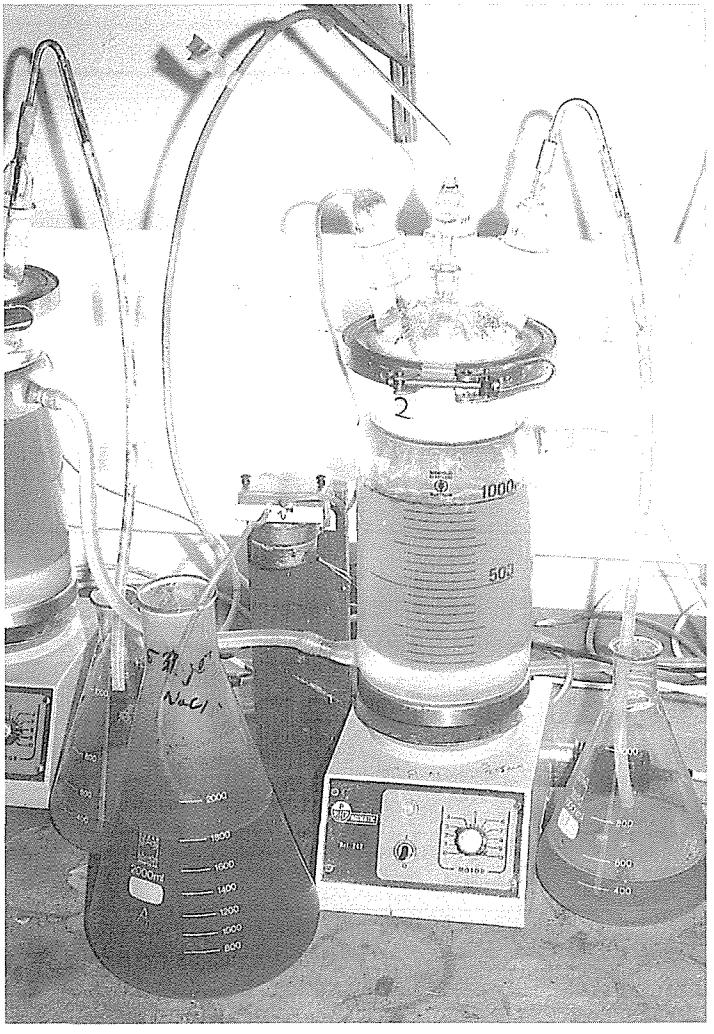
It was found that the in-lake annual mean orthophosphate P concentration steadily declined from 476 µg/ℓ in 1984/85 to 134 µg/ℓ in 1987/88. This trend has continued into 1988/89. The declining concentration coincided with the period during which the dam spilled (1987/88 and 1988/89) for the first time since 1981/82. However, this change in phosphate concentration was brought about within the impoundment rather than by a decline in the phosphate concentration in the inflowing water. A feature of the water quality during the 1988/89 summer was that phosphate P concentrations in the surface (0 to 5 m) water were as low as 5 µg/ℓ and that N:P ratios rose to over 25:1. Another phenomenon was the change in the species composition of the plankton which, until the end of 1987/88, remained similar to that of previous years. During the summer of 1988/89, *Microcystis aeruginosa*, which had been the dominant species in previous years, was almost entirely absent.

An important conclusion arising from this study was that the enforcement of the 1 mg/ℓ orthophosphate P standard is not complete. It appears that the recent reduction in in-lake phosphate concentrations and the disappearance of *Microcystis* are not due to the effluent phosphate standard and are likely to be permanent. Nevertheless, it has become clear that *Microcystis* occurrence is governed by phosphate availability and that the strict enforcement of the effluent standard should be continued. The prevention of stratification through aeration would also tend to drive nutrient availability and the N:P ratio in a direction unfavourable to *Microcystis*.

Based on these results the Department of Water Affairs has decided not to go ahead with the envisaged full-scale aeration/destratification of the dam. They have now requested the WRC to support further research in order to ascertain exactly what has caused the decline in *Microcystis* and the improvement of water quality. Based on the outcome of this investigation, which is currently being executed, the Department will decide whether or not to go ahead with the aeration/destratification experiment.

Research on the effective use of water by means of an algal-aquaculture system

It is estimated that South Africa will experience a protein fodder shortage of 400 000 t by the year 2000. In view of this, aquaculture, and in particular algal culture systems, presents a means by which the deficit may be partially supplemented. Such



The experiment in progress is testing the tolerance of Spirulina *to sodium chloride. Continuous culture flasks (1ℓ) are used.*

systems have the potential to produce a high biomass yield with a high protein content by making use of waste as a nutrient source. Over the past eighteen months the University of the Orange Free State developed an aquaculture system with a view to protein development.

The system consists of a culture of filamentous algae and invertebrates which are cultured in salt water with manure as the nutrient source. A simple experimental plant has already been operated for a year without any significant problems. Initial results indicate that the system has potential advantages for the production of protein (measured in dry mass protein per unit of water consumption), over that of crop production by means of irrigation. The system can be applied using waste water as well as salt water as is found in large parts of the country, and which cannot be used profitably for other purposes. The system also presents the possibility of supplementary yield from irrigation water if the water is first applied for aquaculture and thereafter for consumptive use by irrigation.

Although promising results have been obtained, the system is not yet completely viable in the present economic climate.

MARINE DISPOSAL

REPORT ON A COMPLETED PROJECT

Research on marine disposal practice in South Africa

The need to ensure that the marine environment maintains its capability of effectively assimilating domestic and industrial wastes, necessitates not only more efficient marine disposal systems, but also that these be operated as effectively as possible. In order to assist both the proprietors and designers of such systems in this regard, the Commission contracted the CSIR to compile a publication documenting the descriptive and technical details of known marine discharges around the South African coastline, and also to highlight the successes and failures of these.

In total 75 discharges were surveyed, of which 42 are only descriptively reported on as they discharge effluent either by pipeline to above the high-water level or into a river, estuary or open channel and, therefore, could not supply any useful information on the operation of marine outfall systems. Of the remaining 33 discharges, 12 are classified as offshore pipelines that discharge effluent beyond the surf zone and 21 are classified as surf-zone pipelines that discharge effluent into the surf zone.

Municipal discharge constitutes 44 per cent of the total discharge rate of 686 900 m^3/d, and varies from macerated raw sewage and septic tank overflow to almost fully treated sewage. The greatest variation in type and quality occurs in industrial effluents which account for 50 per cent of the total discharge rate. Pretreatment essentially comprises solids settling and screening prior to discharge, which is usually effected through long outfalls. The high organic content effluent from the fish processing industry constitutes about 6 per cent of the total discharge rate.

The emphasis in this report is on the offshore pipelines, of which most are located in Natal and the southern Cape. Although the offshore outfalls number only 12 they, nevertheless, account for 86 per cent of the total amount discharged. Most of the problems that were encountered with these are related to pipeline stability, settlement of solids in the pipeline, and discharge port blockages caused by improper design and operating practices. The general conclusion is that the 12 offshore pipelines perform satisfactorily. It is recommended that designers of new offshore outfalls take cognisance of the problems highlighted in the report, and that regular inspection and pipeline performance monitoring take place after commissioning.

Because of their simple construction and operation, surf-zone outfalls yielded relatively little meaningful information in a survey. In populated areas the discharge of effluent to the surf zone is restricted to minor discharges or to effluents that have undergone extensive pretreatment. It was concluded from the survey that there appears to be a tentative limit to the amount of effluent discharged to the surf zone, and above which the discharge is effected by an offshore pipeline. For industrial effluent this limit is about 3 000 to 4 000 m^3/d and for treated municipal sewage 15 000 to 20 000 m^3/d.

LIST OF RESEARCH PROJECTS

COMPLETED PROJECTS

- Evaluation of the impact of the phosphate standard on the water quality and trophic status of Hartbeespoort Dam (The CSIR - Division of Water Technology)
- Research on the effective use of water by means of an algal-aquaculture system (The University of the Orange Free State - Limnology Unit)
- Research on marine discharge practice in South Africa (The CSIR - Division for Earth, Marine and Atmospheric Science and Technology (EMATEK))

CURRENT PROJECTS

- Research on the inhibition of bacterial oxidation of pyrite and the concomitant acid mine drainage (The Chamber of Mines and the University of Stellenbosch - Department of Microbiology and Virology and the Institute for Polymer Science)
- Development of management-orientated models for eutrophication control (The CSIR - Division of Water Technology and the Department of Water Affairs)
- Hydrosalinity studies in the Eastern Cape (Rhodes University - Department of Geography)
- Research on an evaluation of the abilities of several salute and water transport models to predict the quantity and quality of water leaving the root zone (The University of Stellenbosch - De-

partment of Soil and Agricultural Water Science)

- Research on the evaluation of the design and use of irrigation systems in the Breë River with a view to the control of potential drainage losses (A firm of consulting engineers: Murray, Biesenbach and Badenhorst, Inc.)
- The development of phosphate export models for catchments (The CSIR - Division of Water Technology)
- Research on the quantification of the effects of land use on runoff quality in selected catchments in Natal (The CSIR - Division of Water Technology).
- Research on the culturability of faecal coli following exposure to seawater - a pilot study (The CSIR - Division of Earth, Marine and Atmospheric Science and Technology (EMATEK))
- The development of water quality monitoring strategies and procedures for water quality data interpretation (The CSIR - Division of Water Technology and the Department of Water Affairs)

NEW PROJECTS

- The evaluation of the four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions (The University of Natal - Department of Soil Science and Agrometeorology)
- Research on the harvesting of algal drift from Hartbeespoort Dam water for the reclamation of fine chemicals (The CSIR - Division of Water Technology)
- Research on the extension of the management-orientated models for eutrophication control (The CSIR - Division of Water Technology)
- Research on the management of phosphate concentrations and algae in Hartbeespoort Dam (The Department of Water Affairs and the CSIR - Division of Water Technology)

MUNICIPAL EFFLUENTS

DOMESTIC and industrial sectors use approximately 35 per cent of the total demand for water in South Africa, of which almost 80 per cent is used non-consumptively. Most of this water is returned to the environment after treatment to the required standard, and is available as such for reuse.

In order to maintain an acceptable water quality in a water environment which is under increasing pressure from pollution resulting from the continuous industrial development and demographic changes in South Africa, especially urbanisation, current purification processes have to be improved and new processes have to be developed constantly.

Research in the field of municipal effluents is aimed at the following aspects:

- combating pollution of the water environment;
- protecting public health; and
- producing effluents of adequate quality for direct or indirect reuse.

In order to achieve these main objectives, research on sewage purification, the treatment and disposal of sewage sludge and artificial wetlands is financed. During 1989 the Commission supported 13 projects in this field, of which two commenced, eight are current and three were completed.

SEWAGE PURIFICATION

Two projects were completed during the year, while two projects were initiated.

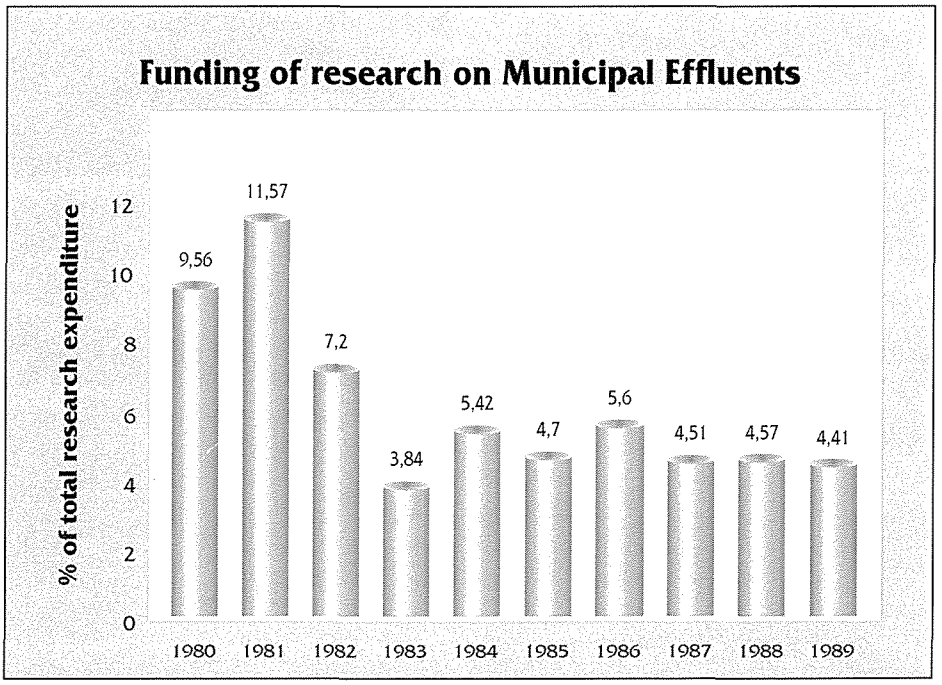
REPORT ON COMPLETED PROJECTS

Research on enhancement of biological phosphate removal from sewage by altering process feed composition

This project was undertaken by the Johannesburg City Council to improve biological phosphate removal by augmenting the concentration of readily biodegradable chemical oxygen demand (COD) which is naturally present in the influent sewage. This was achieved by the fermentation of primary sludge in the sedimentation tanks and subsequent recycle of sludge for elutriation of the soluble COD.

It was possible to explain at the molecular level why *Acinetobacter* spp. for instance have the ability to absorb substrate under one unfavourable situation (i.e. absence of oxygen) and use the stored substrate as an energy source under a second unfavourable situation (i.e. lack of external carbon) to absorb phosphate.

Further enhancement of phosphate removal was achieved by periodic air lancing of the fermenting sludge to prevent the conversion of fermentation products to methane. Primary sedimentation tanks specifically designed to incorporate the successful operational procedure developed during this contract are currently being constructed at three of the Council's activated sludge plants.



Funding of research on Municipal Effluents expressed as a percentage of total WRC research expenditure (1980 to 1989).

Research, development and full-scale evaluation of preventative and remedial methods for the control of activated sludge bulking

The objectives of this project were to:

- identify the filamentous organisms causing bulking in nutrient removal systems in South Africa;
- evaluate the effect of non-specific bulking control with chlorination on biological N and P removal; and
- evaluate specific bulking control procedures for long sludge age systems, in particular the role of aerobic, anoxic or anaerobic selectors for bulking control in nitrogen (N) and nutrient (N and P) removal systems.

In the survey, which covered 33 out of about 45 nutrient removal plants in South Africa, the six most frequently dominant filamentous organisms were found to be 0092, 0675, 0041, *Microthrix parvicella*, 0914 and 1951.

Chlorination was also found to be a viable method for sludge bulking control without significant reduction in biological N and P removal.

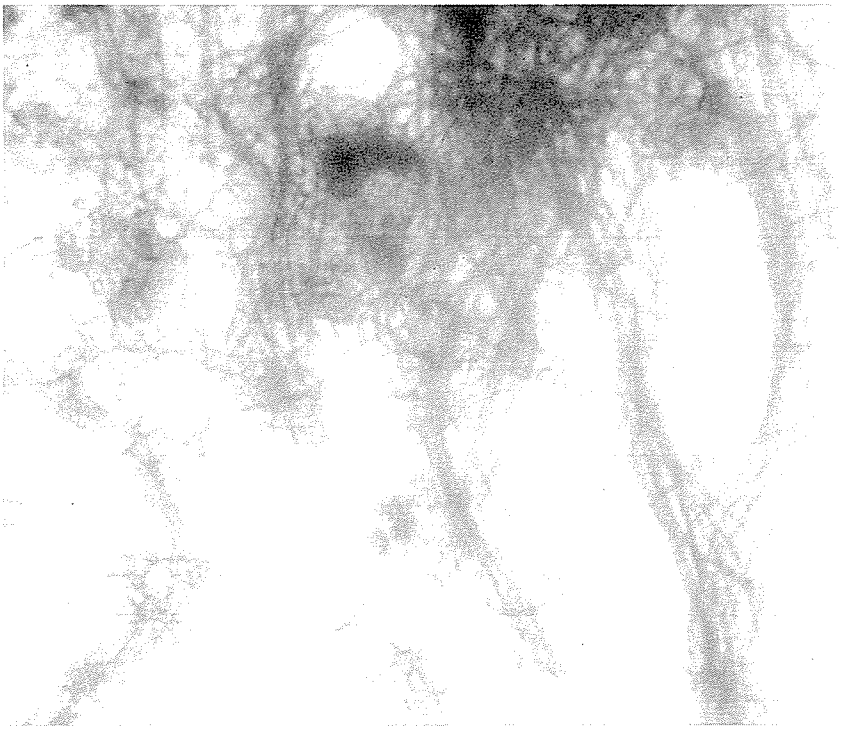
With regard to specific bulking control of low food/mass (F/M) filaments, the promoted method is to incorporate alternating feed-starve conditions such as intermittent (batch) feeding, multi-reactor or plug flow systems or completely mixed systems incorporating selector reactors.

DISCUSSION OF NEW PROJECTS

Research on phosphate removal by means of electrochemically formed iron ions

This one-year project is being carried out by the University of Pretoria.

Existing biological processes are not efficient enough to ensure that effluents comply with the phosphate standard. Therefore most purification works also make use of chemical phosphate removal. This, however, results in increased salinity in the treated water which eventually leads to a build-up of dissolved salts in the water of certain catchment areas.



Microscopic appearance of two common low F/M filaments viz. 0092 and Microthrix parvicella *(400 x magnification).*

The electrolytic process only makes use of the metal ion, e.g. iron, to precipitate phosphates in sewage. The metal is oxidised to its ionic form by means of an electric current.

Different cell configurations were examined and the best results were obtained with the bipolar cell configuration. A pilot plant has been put into commission at Daspoort and studies are being carried out currently to determine where the elecrolytic cell can best be used in the biological process and whether the process is economically feasible in South Africa.

Research on the development and evaluation of specific control methods for ameliorating low food/mass (F/M) bulking

Over the past 5 years, research into activated sludge bulking has been investigated at the University of Cape Town under two successive contracts, each contributing substantially toward the recognition and understanding of the sludge bulking phenomenon. This three-year project aims to address activated sludge bulking by means of the following programme:

- establishment of the effect of sludge age in intermittent aeration systems on low F/M filament growth and nutrient removal capability;
- investigation of the influence of nitrates under conditions of incomplete nitrification;
- influence of the absence of influent biodegradable COD utilisation under anoxic conditions on low F/M filament growth; and
- influence of individual constituents in an artificial sewage on low F/M filament growth.

In some of the above-mentioned experiments the modified UCT nutrient removal system will also be compared with the Johannesburg nutrient removal system. It is intended that regular filament identifications be done to establish which of the low F/M filaments are influenced under the various conditions. With this in-depth research the aim is to modify the environmental conditions in an activated sludge plant so that floc-forming organisms can compete favourably for substrates and nutrients against the bulking filaments.

SEWAGE SLUDGE TREATMENT AND DISPOSAL

One project was finalised during the year.

REPORT ON A COMPLETED PROJECT

Research on chemical characterisation of South African municipal sewage sludge

The application of sewage sludge to agricultural land may be beneficial to crop production because the sludge contains significant amounts of the major nutrients nitrogen, phosphorus and potassium, as well as minor nutrients such as calcium, magnesium and certain trace elements. It is, however, essential that the sludges be adequately monitored for the presence of organic and inorganic chemical contaminants which could have adverse crop and food chain effects.

Twelve major inorganic chemical contaminants were identified as being commonly present in sewage sludge and suitable analytical methods were developed and tested for their determination, as well as for the determination of the nutrients previously mentioned.

Samples of air-dried sludge were collected from seventy-seven South African sewage works and analysed to determine their inorganic chemical contaminant and nutrient concentrations. The results obtained were used, with reference to limits laid down by various overseas countries, to prepare a set of suggested guidelines for the application of sewage sludge to agricultural land in this country.

It was recommended that a committee, composed of representatives from relevant organisations, be entrusted with the task of evaluating these and other suggested guidelines and preparing a set of mutually acceptable maximum limits for the concentrations of inorganic chemical contaminants in sewage sludges for application to agricultural land. This recommendation will be implemented in the near future.

LIST OF RESEARCH PROJECTS

COMPLETED PROJECTS

- Research on enhancement of biological phosphate removal from sewage by altering process feed composition (The City Council of Johannesburg)
- Research, development and full-scale evaluation of preventative and remedial methods for the control of activated sludge bulking (The University of Cape Town - Department of Civil Engineering)
- Research on the chemical characterisation of South African municipal sludges (The CSIR - Division of Water Technology)

CURRENT PROJECTS

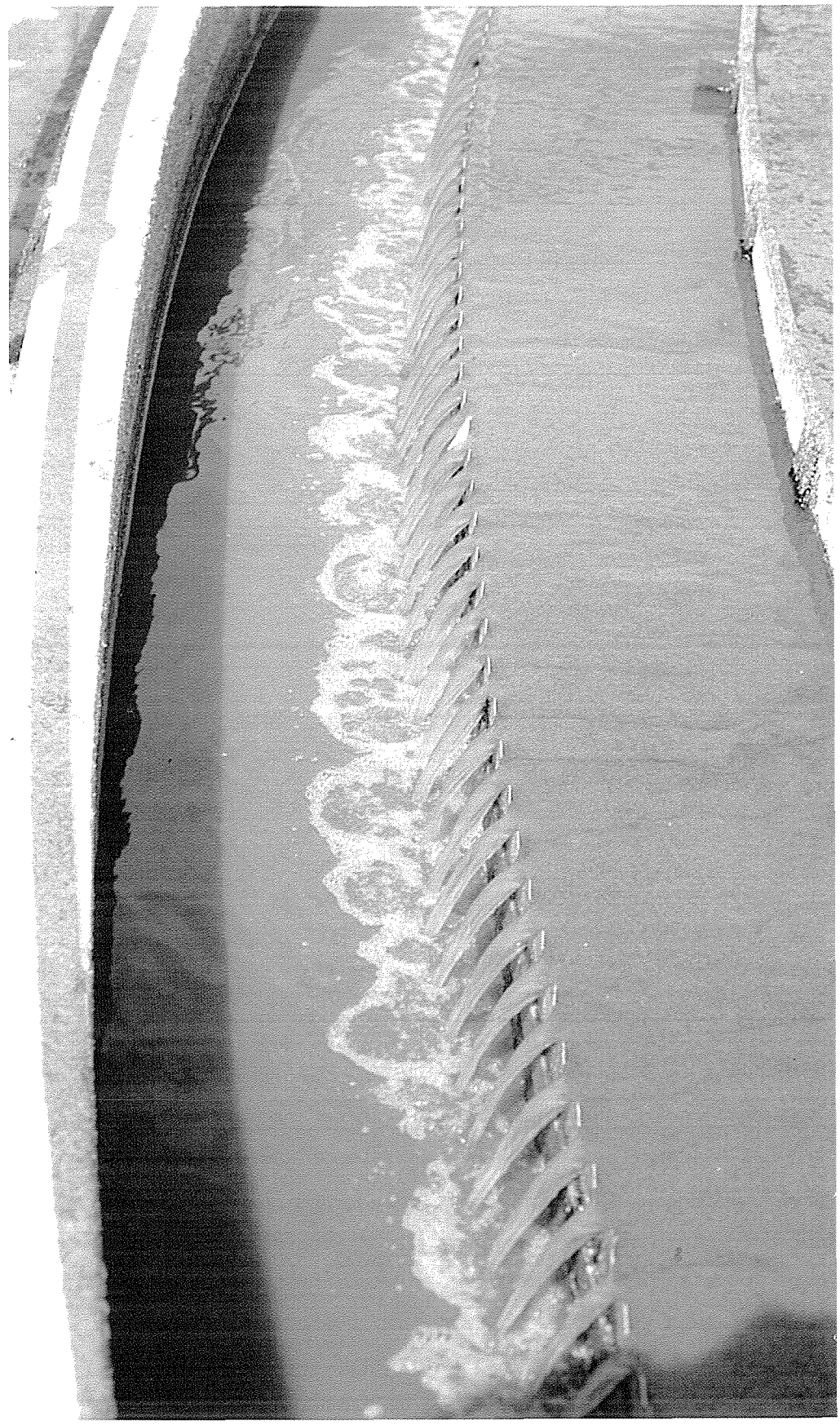
- Research on the preparation of engineering design guidelines for artificial wetlands for waste-water treatment (The CSIR - Division of Water Technology and Sviridov, De Waal and Associates Inc.)
- Performance evaluation of forced aeration composting of sewage sludge (The Municipality of Stellenbosch and the CSIR - Division of Water Technology).
- Research on phosphate crystallisation in activated sludge systems (The CSIR - Division of Water Technology)
- Research on electrochemically produced metal coagulants for the treatment of polluted water (The University of Pretoria - Department of Chemical Engineering)
- Research on the evaluation and optimisation of the process of dual diges-

tion of sewage sludge (The Town Council of Milnerton and the CSIR - Division of Water Technology)

- Research on chemical augmentation of biological phosphate removal (The City Council of Johannesburg)
- Research on phosphate fixation in waste waters by means of controlled struvite formation (The CSIR - Division of Water Technology)
- Consolidation of activated sludge and water chemistry research (The University of Cape Town - Department of Civil Engineering)

NEW PROJECTS

- Research on the development and evaluation of specific control methods for ameliorating low F/M bulking (The University of Cape Town - Department of Civil Engineering)
- Research on phosphate removal by means of electrochemically produced iron ions (The University of Pretoria - Department of Chemical Engineering)



A secondary clarifier in which excessive carry-over of activated sludge is taking place.

INDUSTRIAL WATER AND WASTE WATER

RESEARCH in the areas of industrial water and water economy at power stations is reported on in this Chapter.

INDUSTRIAL WATER

A study done by overseas consulting engineers in 1974 identified the most important problems caused by industrial effluents in South Africa, and recommendations were made with regard to short and long-term research on problems in a number of specific industries, as well as certain pollutants causing problems.

During the past thirteen years, attention has been focused specifically on the following industries: textiles, hides and skins, fish, fruit and vegetables and abattoirs. Water and waste-water management in the above-mentioned industries has been researched thoroughly with a view to decreasing the water intake per unit product, as well as developing economically acceptable treatment methods for complete or partial purification of effluents, with associated recovery of chemicals or energy where possible. The results of the research together with recommendations, are contained in guides for each of the above-mentioned industries.

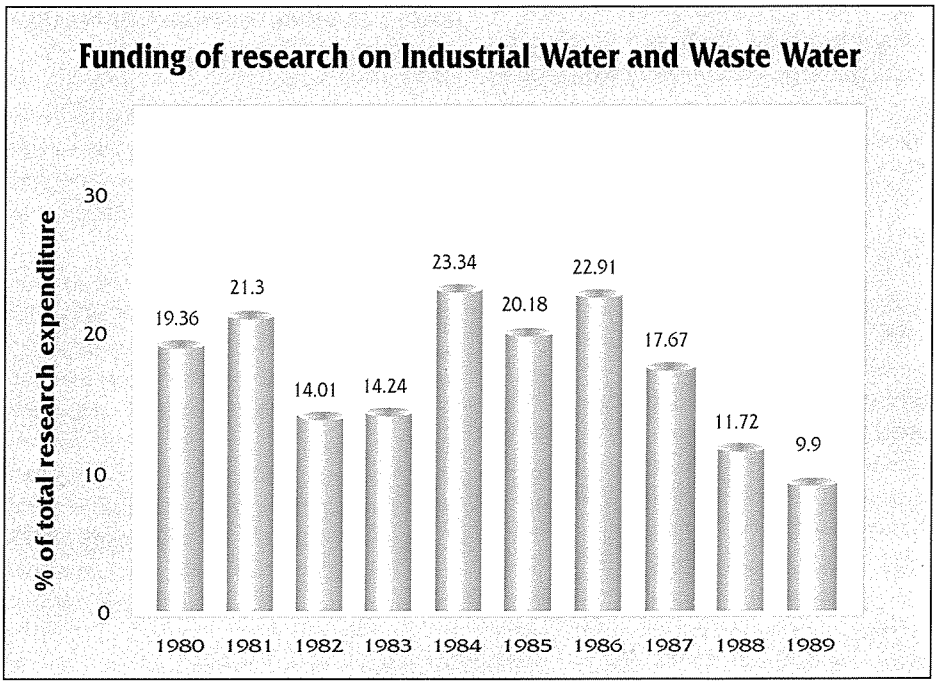
In addition to research on specific industries, a national survey of industrial water and waste water is being conducted to establish a data base containing information on water intake, raw materials, products, effluent quality and the amount of industrial waste from all types of industries using more than 150 m^3 water per day. Results from this survey are reported in the form of short information guides for each of 14 industries that had been identified as being either major water consumers or polluters of the environment. The following guides are to be released shortly: *Water and Waste-water Management in the Dairy Industry; Water and Waste-water Management in the Sorghum Malt and Beer Industry; Water and Waste-water Management in the Edible Oil Industry; Water and Waste-water Management in the Red Meat Industry* and *Water and Waste-water Management in the Laundry Industry.*

DISCUSSION OF NEW PROJECTS

Research on the dewatering of compressible filter cakes

Filter presses are generally used for dewatering sewage, water works and industrial sludges. To improve the filterability of the sludge, polyelectrolytes or other aids are added to render some sludges compressible. The specific resistance of the filter cakes and moisture content is a function of pressure. The lack of suitable methods to determine specific filter cake resistance as a function of pressure, necessitates time-consuming experiments in an operating plant. The problem with this approach is that full-scale plants do not usually have the necessary instrumentation to conduct systematic investigations. Such investigations are therefore seldom undertaken and

Funding of research on Industrial Water and Waste Water expressed as a percentage of total WRC research expenditure (1980 to 1989).



if they are, the investigation is expensive and often not conclusive enough to operate the plant experimentally.

This three-year project is being undertaken by the University of Natal to develop methods for the determination of specific filter cake resistance in order to predict the behaviour of a filter, to determine the effect and dosage of polyelectrolytes or other aids accurately and to calculate the required filter area reliably.

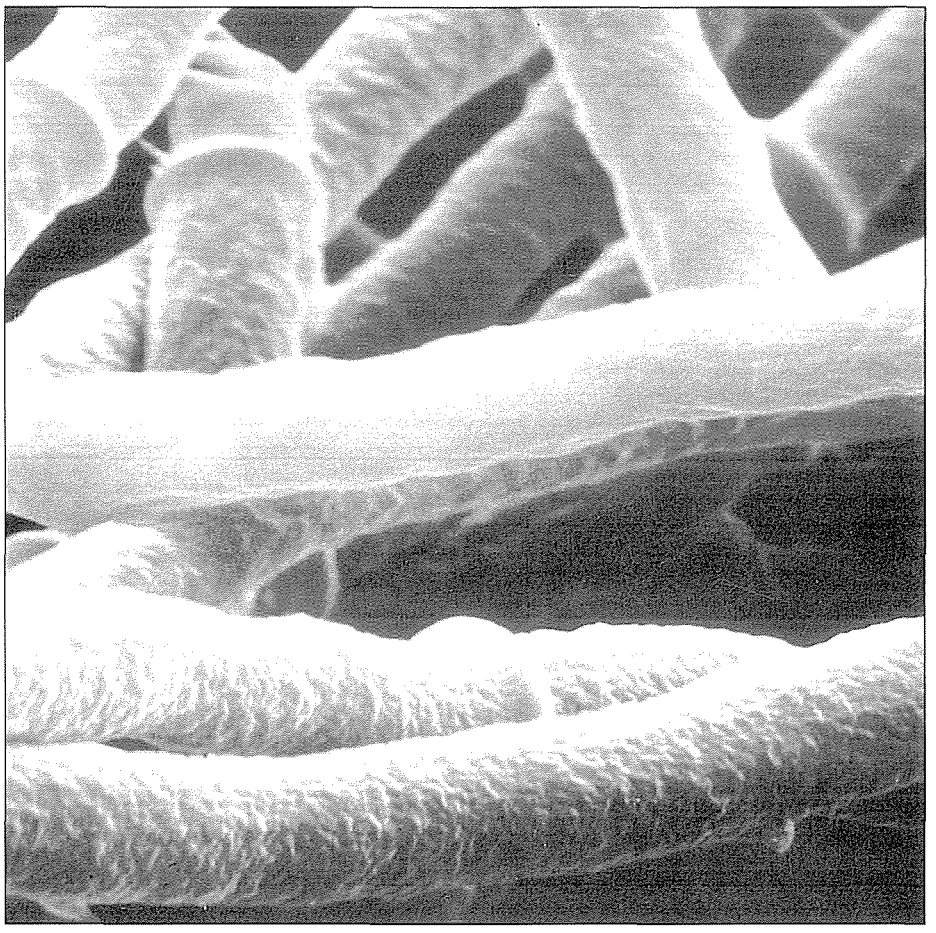
Research on biological techniques for the treatment of pulp bleaching effluent

Pulp effluents emanating from bleaching processes making use of chlorine and other bleaches, are the biggest contributors to environmental pollution caused by pulp factories. These effluents are high in organic and inorganic matter and include toxic compounds. These types of effluent are becoming increasingly unacceptable worldwide for discharge to sewage systems or to the environment because of their toxic content.

In South Africa the position is even more critical because no bleaching process effluents may be discharged by inland pulp factories after 1990. Although the problem is receiving attention worldwide, no technically and economically satisfactory technology has been developed to solve the problem. Desalination technology seems to be the most promising, but organic fouling of the membranes is a big impediment. At the moment various techniques are being investigated to remove the organic components, but apparently no attention is being given to biological methods.

A thorough investigation into biological methods to remove organic matter from bleaching process effluents before the application of desalination techniques can possibly be an important step towards the solution of the problem - especially for the two large inland plants at Springs and Ngodwana.

This two-year project conducted by Sappi Management Services, with WRC support, is aimed at investigating various biological treatment methods.



A monoculture of Geotrichum candidum.

Research on the biological treatment of industrial water with the simultaneous production of single-cell protein

The objective of this two-year project is to investigate further a unique process combination, developed by the University of Pretoria, up to the point where the process can be applied practically.

The process combination entails the selection of an aseptic monoculture of a filamentous fungus *Geotrichum candidum* by means of a crossflow microstrainer method. The fungus is a good source of single-cell protein (also called microprotein) as well as other fine chemicals, while it has great potential for the purification of several industrial effluents, such as lignines, which are difficult to break down. The crossflow microstrainer selects the fungus according to sieve mesh so that bacteria and other organisms pass through and are washed

from the system before they can multiply. Survival of other bacteria is also discouraged by decreasing the pH periodically. This research project has important application potential because of the resistance of the fungus to such chemical shocks, and its capability to handle difficult effluents, as well as the possibility to recover protein and fine chemicals from the fungus.

Research on abattoir solid waste: Development and implementation of a treatment system

Some 12 million animals are slaughtered annually at almost 300 abattoirs which results in approximately 80 000 t of kraal manure and 170 000 t of stomach contents. The Abattoir Corporation's share in this industry is of the order of 40 per cent and although the corporation processes a major part of it there are still about 27 000 t of manure which have to be disposed of uneconomically each year.

The most common methods of disposal are to apply the manure to land to use it as a soil conditioner, to dump it at disposal sites or even to discharge it to sewers. These methods are unsuitable and unacceptable especially from a hygiene point of view. Furthermore, disposal costs are increasing while the number of disposal sites are decreasing. More acceptable methods of disposal are thus urgently required of which composting looks promising.

This project will investigate various aspects of composting such as for example mixing with sewage sludge, aeration, stabilisation and plant design. The project will be carried out by the Abattoir Corporation over a period of one year.

WATER ECONOMY AT POWER STATIONS

In a coal-fired power station the conversion of thermal energy to electricity invariably involves the liberation of large quantities of waste heat. The conventional way of dissipating the waste heat to the environment is to use it to evaporate water in a wet-cooling tower. Although this wet-cooling technique is both efficient and cost-effective, its water consumption is high and, moreover, the associated progressive concentration of dissolved salts in the cooling tower water circuit can pose disposal problems.

An alternative approach is dry cooling, whereby the waste heat is directly dissipated to the atmosphere via an aircooled heat exchanger. The virtual elimination of water consumption means less dependency on water source proximity and thus greater freedom to site the power station at coal fields in relatively arid areas. A drawback is the reduced overall efficiency causing increased coal consumption, and it is thus necessary that dry-cooling systems be made to operate as efficiently as possible.

To comply with the water conservation endeavours of the Department of Water Affairs, Eskom is introducing dry cooling at three of its new power stations. Both the Matimba power station, near Ellisras, and the Kendal power station at Kendal, are nearing completion, while the construction of the Majuba plant near Volksrust will commence shortly. The nominal power output of each of these power stations will exceed 3 600 MW, so that dry cooling is to be effected on a scale never attempted before. To broaden the necessary information base the Commission, in collaboration with Eskom, undertook to support research on the optimisation of dry and dry-wet cooling under local conditions.

Since 1979, the Commission has been sponsoring research on the following:

- The effect of dry-cooling systems on the temperature of the surrounding environment.
- The effect of atmospheric conditions on the performance of dry-cooling towers.
- The potential of hot exit plume recirculation in dry-cooling systems.
- The development of computer techniques for the evaluation and optimisation of dry and dry-wet systems.

REPORT ON COMPLETED PROJECTS

Computer and laboratory optimisation studies on dry and dry-wet cooling

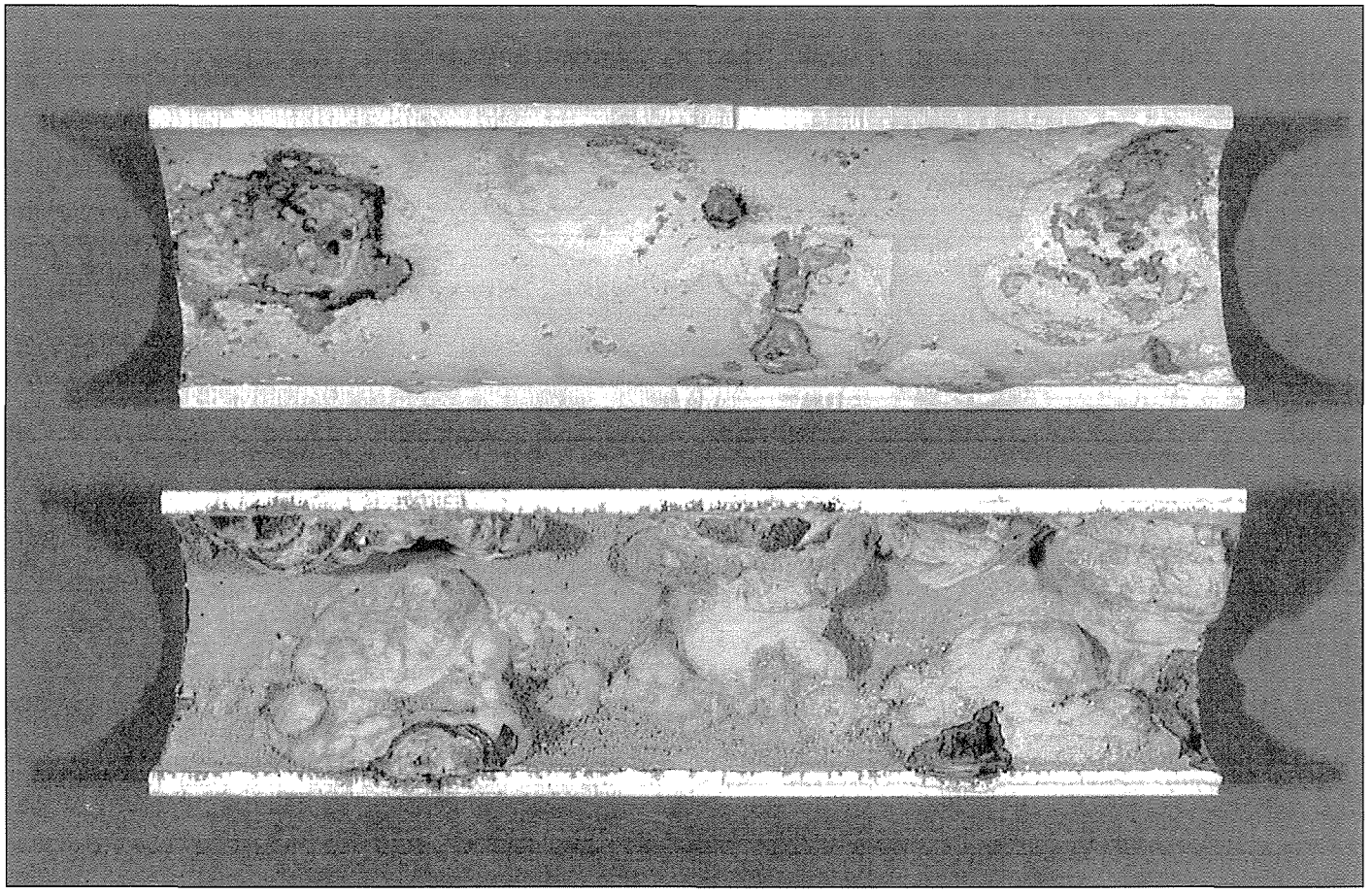
The study, conducted by Eskom and the University of Stellenbosch, was primarily devoted to the development of computer programs to predict the effect of both system parameters and climatic conditions on the performance of dry and wet-cooling systems at power stations. To develop the computer programs the fundamental characteristics of such cooling systems had to be clearly understood. Accordingly, extensive developmental mathematical and experimental modelling were done, and where possible, these were substantiated by supplementary tests conducted at power stations. The information so gathered was used to refine the computer models progressively.

The programs have been used by Eskom to check the performance of cooling towers at Kendal, Matimba and Duvha power stations, respectively. Good agreement between the computer predictions and the acceptance test results was obtained; in the case of Kendal the difference between the actual and the predicted outlet water temperature was only 0,06 ^{0}C. Because the operational fundamentals of dry cooling are now better understood the design of future cooling systems, for both the utility and the general industry, can be significantly improved.

Model studies on the minimisation of hot air recirculation at dry and dry-wet cooling systems

The water tunnel model studies, conducted by the CSIR, were aimed at establishing:

- Whether the partial recirculation of hot air ejected by a dry-cooling system, when situated adjacent to the boiler house, could be reduced by moving the cooling system away from the boiler house.



A typical example of biocorrosion in a water feed-pipe which shows pitting. The top photograph presents a section through the pipe after the removal of corrosion products.

- Whether the starving of the cooling system's fans, due to transverse winds, is affected by the gap size between the cooling system and the boiler house.
- Whether in a hybrid design, incorporating both dry and wet-cooling systems, a particular cooling system is adversely affected by the hot efflux from the other system located upwind to it. The inter-system sitings envisaged for Majuba power station were simulated in this phase of the study.

To assess the effect of gap size on hot air recirculation three gap settings were used. It was found that the smallest gap significantly reduced hot efflux recirculation, at all wind speeds in excess of 3 m/s, and that recirculation was only marginally decreased by further gap increases.

It was also found that gap size had but little detrimental effect on fan starvation and that the benefit of reduced efflux recirculation far outweighs the negative effects of fan starvation.

As regards inter-system interference, no evidence was found that a down-stream unit would entrain the hot efflux emanating from a cooling system sited upwind to it.

Model studies on air flow patterns in mechanical draught air cooling systems at power stations

Mathematical modelling of induced-draught air-cooling systems, developed by the University of Stellenbosch to predict the performance of such units, indicates that a significant portion of the hot efflux air can be re-entrained under certain wind conditions. Recycling of hot efflux air, through cooler performance impairment, adversely affects power station efficiency. The CSIR was therefore contracted to establish whether model studies conducted in their water tunnel were capable of validating the University's analytical approach, and if so, to investigate quantitatively the

potential means of reducing efflux air recycling.

In order to establish the credibility of water tunnel testing techniques a relatively inexpensive simplified model simulating uniform air flow over only the bank of heat exchangers was used. A streamlined ramp was installed upstream to the heat exchanger bank roughly to simulate the effect of the power station buildings which were omitted in this case. The simplified model revealed that there is a critical wind velocity above which the efflux plume is deflected downwards and the resulting vortex causes severe efflux recirculation, which is in keeping with the predictions of the analytical model.

Having established the credibility of the water tunnel techniques a representative model, incorporating all power station structures, was constructed and tested in order to establish more precisely the effect of both wind-speed and direction on the degree of re-entrainment of hot efflux air. Although it was found that the extent of efflux air re-entrainment is less severe than that registered for a simplified model, as much as 16 per cent of the efflux plume could still be re-entrained. In an attempt to reduce efflux plume recycling, the effect of the removal of the cladding between the boiler house and the heat exchanger bank was investigated. This modification drastically reduced efflux re-entrainment and was ascribed to the fact that air flow underneath the heat exchanger bank reduced the severity of the recirculation vortex.

As the introduction of a gap between the boiler house and heat exchanger bank could enhance air flow beneath the latter, the recommendation is that the potential benefits of such gaps be investigated in a follow-up project.

DISCUSSION OF NEW PROJECTS

Research on the interaction between the atmospheric boundary layer and the natural draught cooling towers at Kendal power station

The characteristics of the atmospheric boundary layer, such as temperature and wind velocity, significantly affect the performance of natural draught dry-cooling towers - hence the energy conversion efficiency of power stations incorporating such waste heat disposal systems. Details of the interaction between the atmospheric boundary layer and a dry-cooling system are important from a design point of view and, when coupled with information on the frequency and duration of specific atmospheric conditions they can also serve to validate the analytical models developed to predict the annual average performance of a power station.

Kendal, one of South Africa's largest power stations under construction, offers a unique opportunity for studying the phenomena on an unprecedented scale. The CSIR, in collaboration with Eskom, was thus contracted to relate the performance of the cooling towers at Kendal to the spatial temperature and wind velocity profiles existing adjacent to the cooling tower. To establish the effect of waste heat dissipation on the tower environment, similar profiles will also be determined at locations far afield. The three-year project aims to establish what part of the stable boundary layer is entrained into the cooling tower; to determine the region of influence of the cooling tower under stable conditions and hence optimum inter-tower spacing; and to provide experimental data for use in the validation of the analytical model developed by the University of Stellenbosch in the completed project *Computer and Laboratory Optimisation Studies on Dry and Dry-wet Cooling.*

Research on and evaluation of various factors affecting dry-wet cooling

The completed project entitled *Computer and Laboratory Optimisation Studies on Dry and Dry-wet Cooling,* which aimed at developing computer programs suitable for predicting the performance of such cooling systems under different climatic conditions, identified a number of aspects warranting further study.

The aim of this study, which is to be undertaken by the University of Stellenbosch in collaboration with Eskom, is to improve the understanding of the fundamentals relevant to dry and dry-wet cooling systems operating under local conditions, in order ultimately to effect refinement of the existing performance evaluating computer programs. The three-year project, involving both theoretical and experimental studies, will investigate aspects such as:

- steam flow, condensation, and instabilities in the condenser and dephlegmator;
- complex flow through fans subject to distorted inlet conditions;
- flow through heat exchangers and the effect thereon due to structures in close proximity;
- the effect of temperature inversions on the performance of cooling towers;
- water spray pre-cooling of cooling air; and
- the supplementary action of evaporative coolers.

The refinements to the computer programs will be validated by means of field tests conducted at Matimba and Kendal power stations.

LIST OF RESEARCH PROJECTS

COMPLETED PROJECTS

- Computer and laboratory optimisation studies on dry and dry-wet cooling (Eskom and the University of Stellenbosch - Bureau of Mechanical Engineering)
- Model studies on air flow patterns in mechanical draught air cooling systems at power stations (Eskom and the CSIR - Division of Earth, Marine and Atmospheric Science and Technology (EMATEK))
- Model studies on the minimisation of hot air recirculation at dry and dry-wet cooling systems (Eskom and the CSIR - Division of Aeronautical Systems Technology).

CURRENT PROJECTS

- Research on thermal feedback caused by dry cooling at power generating stations (Eskom and the CSIR - Division of Earth, Marine and Atmospheric Science and Technology (EMATEK))
- A national industrial water and waste-water survey (NATSURV) (The Department of Water Affairs, and a firm of consulting engineers: Steffen, Robertson and Kirsten Inc.)
- Research into the treatment of wool scouring effluents (The University of Natal - Department of Chemical Engineering, a firm of consulting engineers: Steffen, Robertson and Kirsten Inc.; and Gubb and Inggs (Pty) Ltd)
- Research on chemical removal of sulphates (The University of Natal - Department of Chemical Engineering)
- Transfer of waste-water management technology to the meat processing industry (A firm of consulting engineers: Steffen, Robertson and Kirsten Inc. and the South African Abattoir Corporation)
- Research on the effect of biocorrosion in water systems (The CSIR - Division of Water Technology)
- Research on the removal of colloidal matter from gas stripliquor by coagulation and flocculation (The University of Pretoria - Department of Water Utilisation Engineering)
- Research on solids-liquid separation in biological systems (The University of Cape Town - Department of Chemical Engineering)
- Research on pelletisation in upflow anaerobic sludge bed (UASB) systems (The University of Cape Town - Department of Civil Engineering)

NEW PROJECTS

- Research on the interaction between the atmospheric boundary layer and the natural draught cooling towers at Kendal power station (Eskom and the CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- Research on and evaluation of various factors affecting dry-wet cooling (Eskom and the University of Stellenbosch - Bureau of Mechanical Engineering)
- Research on the biological treatment of industrial water with the simultaneous production of single cell protein (The University of Pretoria - Department of Chemical Engineering)
- Research on biological techniques for the treatment of pulp bleaching effluent (Sappi Management Services)
- Research on the dewatering of compressible filter cakes (The University of Natal - Department of Chemical Engineering)
- Research on abattoir solid waste: Development and implementation of a treatment system (The Abattoir Corporation)

DRINKING WATER

DRINKING water is essential for man and therefore its quality has to be such that it will not have a detrimental effect on his health. The user is entitled to water of a high quality which can be described in general as water which does not contain pathogenic organisms and which is aesthetically acceptable. It has to be clear and colourless and must have an acceptable odour and taste. Drinking water therefore has to comply with certain standards and consequently guidelines or standards for drinking-water quality exist world-wide as well as in South Africa.

The WRC undertakes various research activities relating to drinking water. The overall aim of the research is to gain knowledge of all aspects of drinking-water quality and to support the development of the technology necessary for water treatment, in order to ensure that water which does not pose a health risk and which complies with the necessary quality criteria is supplied to the consumer at a reasonable price.

A major responsibility rests on the water consumer. As there is considerable competition in South Africa for its limited water sources, water should be used sparingly and wastage should be eliminated. The WRC also supports a number of research projects in this regard.

The emphasis of this research falls on the following:

- development of the necessary water treatment technology;
- drinking-water quality and health aspects (which include the location and concentration of contaminants, the influence of water quality on man, and obtaining information which can contribute towards the establishment of quality criteria); and
- aspects relating to urban and rural water supply.

The WRC supported 23 projects in the above regard during the year, of which three were completed and four commenced.

WATER TREATMENT

REPORT ON A COMPLETED PROJECT

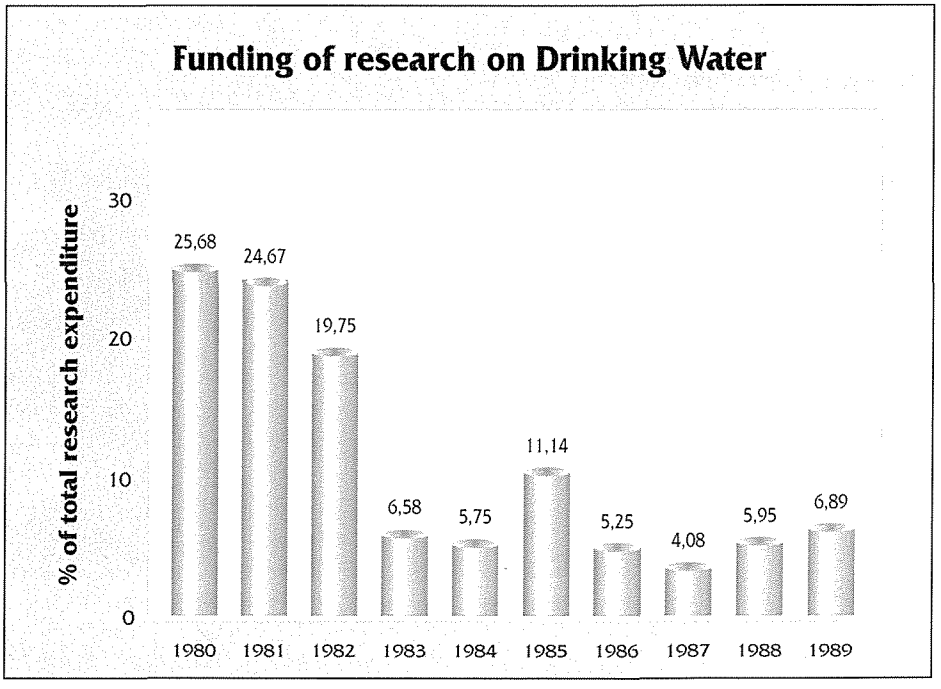
An exploratory study into the efficiency of drinking water treatment in South Africa

The objectives of this investigation, which was carried out by the University of Cape Town, were to identify problems and to rank the research needs in potable water treatment processes in South Africa. The investigation was effected via visits to major water supply authorities and treatment works.

The principal problems identified were the removal and control of algae; intermittent changes in raw water quality giving rise *inter alia* to tastes and odours; dewatering and disposal of inorganic sludges; corrosive and aggressive attack in reticulation systems; inadequacies and/or conservatism in design; and control and management problems related to water catchments.

The most important research needs to resolve these problems were identified as the development of measures for algal control and removal, development of economical treatment strategies to deal with intermittent problems related to changes in raw water quality and strategies for sludge

Funding of research on Drinking Water expressed as a percentage of total WRC research expenditure (1980 to 1989).



control and disposal. There is an urgent need for manuals of practice on water treatment processes applicable to South Africa.

DISCUSSION OF NEW PROJECTS

The evaluation of full-scale flotation-filtration and chlorine dioxide plants

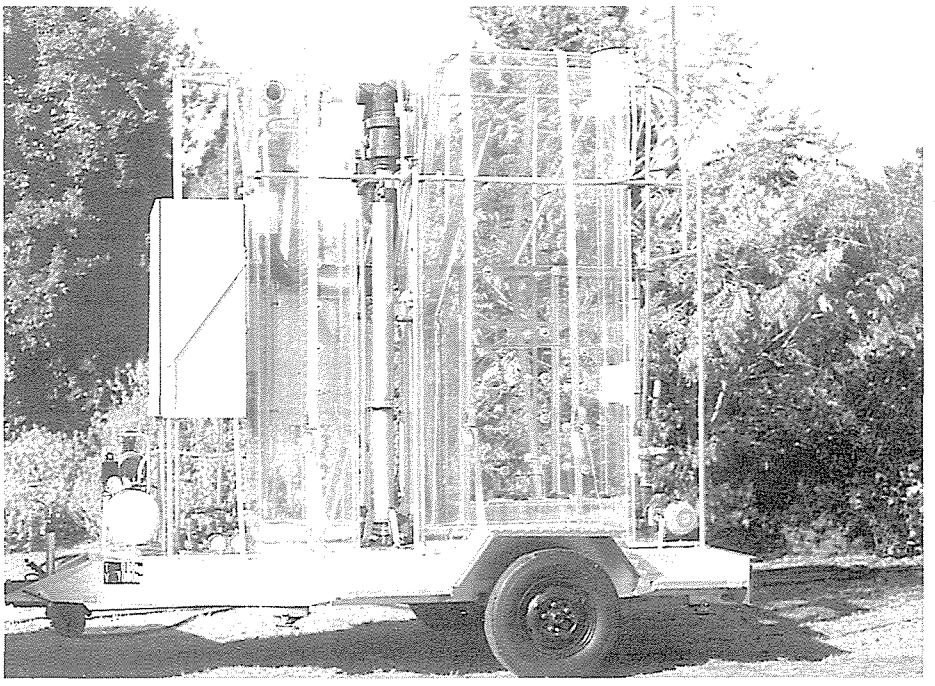
The incidence of algal growth in surface water sources creates considerable problems in the treatment of water sources for drinking-water purposes. The major problems centre on the efficient removal of algae, the formation of chlorinated compounds during disinfection with chlorine, as well as odours and tastes in the water.

All the above-mentioned problems are to a greater or lesser degree experienced by the OFS Gold Fields Water Board at its Balkfontein plant. In order to try to overcome these problems, the Board decided to adjust one of the modules of the plant in such a way that chlorine dioxide instead of chlorine could be used for oxidation and disinfection, as well as to modify one of the sand filters by fitting a flotation unit in its top. The operation of this full-scale unit can now be compared directly with the conventional units which are operated in parallel.

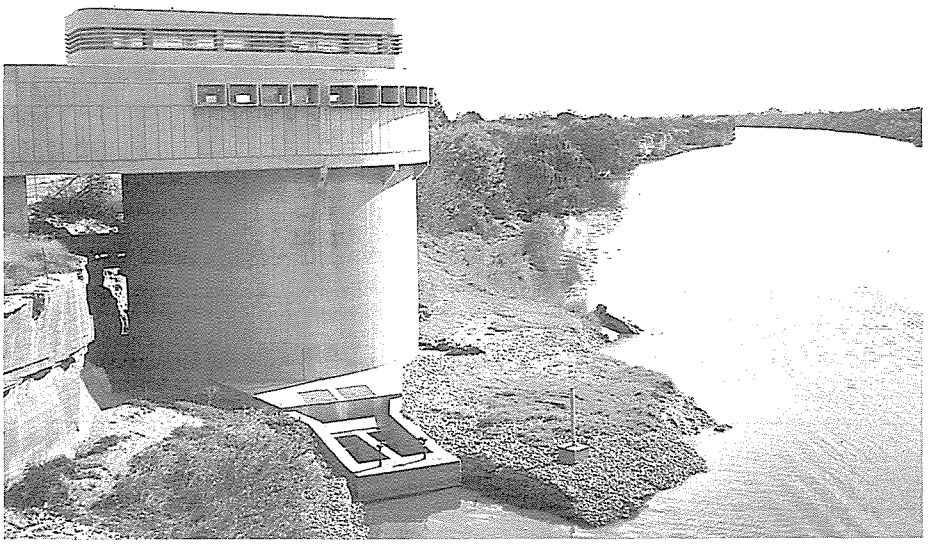
The contribution of the WRC to this two-year agreement with the OFS Gold Fields Water Board only relates to the incidence and identification of algae in the various stages of the process, as well as to other aspects of water quality. These investigations are being conducted by the University of the Orange Free State.

The development of a combination of sedimentation, flotation and sand filtration processes for water treatment

This two-year project will be carried out by the CSIR. The aim of the project is to obtain parameters for the design of a sedimentation/dissolved air flotation waterworks for the effective purification of enriched surface waters which can contain both light and heavy suspended matter at different times of the year. The Sedidaff pilot plant of the Division of Water Technology will be used for this purpose. This unit integrates co-current inclined plate presedimentation with dissolved air flotation and sand filtration in a unit.



The 24m³/d Sedidaff pilot plant of DWT.



The intake tower of the Balkfontein plant of the OFS Gold Fields Water Board.

DRINKING-WATER QUALITY AND HEALTH ASPECTS

During the year a CRD Committee for Water Quality and Health Aspects was established.

CRD COMMITTEE FOR WATER QUALITY AND HEALTH ASPECTS

The Committee representing a wide spectrum of interested organisations, will identify problems and research needs in the field of water quality and health aspects, draw up a master research plan, and make decisions regarding research priorities. These activities will assist in addressing research in this field more effectively on a priority basis.

REPORT ON COMPLETED PROJECTS

Research on the health implications of the intake of chemical contaminants by man

During 1985 the WRC reached an agreement with the University of Cape Town to support a Ph.D. study dealing with the toxicological effects of pesticides used in the RSA. The specific aspect supported by the WRC was a study of the health implications of the intake of certain contaminants in food, such as pesticides.

In the study the first aim was to determine the composition of the diet of Whites in the RSA. This information enabled the compilation of any imaginary diet. The study indicated that the diet consists of 11 major groups, *inter alia* fish, meat, dairy products, eggs, vegetables, fruit, drinks, soup, etc. The 11 major groups in turn consist of 142 different food items.

In order to make the study as representative as possible samples of the 142 items were purchased directly from retail traders in the RSA at 13 centres (7 cities and 6 rural towns). The samples were collected on the same day during the four seasons to determine seasonal distribution. A total of 5 538 samples were thus collected and sent to Cape Town for chemical analysis. Pesticide residues were determined, concentrating on the organo-chlorine and the organo-phosphate compounds.

Residues of only four pesticides were found, namely DDT, dieldrin, dichloran and an organophosphate, merkaptotion. Residues were found in eight of the eleven food groups. The concentrations were, however, still far lower than the world-accepted acceptable daily intake (ADI) and therefore compared favourably with overseas results.

The final conclusion was that chronic exposure to these residues in the RSA is negligible and this also confirms the success of the control measures instituted by the State for these substances in the RSA. Incidences of death can be attributed to exposure to toxic concentrations of those substances, which is normally the result of negligent handling.

During this study a model was developed which will make it possible to determine the extent of the exposure to a contaminant, if the composition of the diet is known. In the study a diet was established for Whites but not for Blacks or Asians. Nevertheless, the basic information is now available and can be utilised to calculate, for example, the contribution of drinking water.

An investigation into the occurrence and concentration of trihalomethanes and their precursors in South African drinking water

Trihalomethanes (THM) are halogenated organic compounds which result from the disinfection of water with chlorine. These compounds are of importance as they constitute a risk to the health of the user.

The project which was carried out by the CSIR, was aimed at quantifying the extent of the problem, which could also make a contribution should quality criteria for these compounds be developed. It was found that the average THM concentration in the drinking-water samples was 45 µg/ℓ and that only four of the forty samples collected throughout the country over a period of two years, contained in excess of 100 µg/ℓ. The criteria for THM differ from country to country and the incidence and concentration of THM in drinking water in South Africa compares very favourably with for example the criterium of 100 µg/ℓ set by the USA.

DISCUSSION OF A NEW PROJECT

Research on human viruses in water

The WRC entered into an agreement with the University of Pretoria during the year in terms of which it will carry out a project on human viruses in water over a period of three years.

Viruses play an important part in waterborne diseases - it is, however, difficult to determine the exact extent thereof. Methods used up to now for the determination of viruses, cannot be used to determine viruses which are mainly spread by water and can therefore only serve as indicators.

The main objective of the project is to develop new technology for the practical and reliable evaluation of the virological quality of water. It is also envisaged to develop less expensive and more practical methods for the culture of viruses in cell cultures. Attempts will also be made to increase the sensitivity of culture methods by making use of cell cultures not previously utilised for this purpose. The development of less expensive and more effective methods for the isolation of viruses from water will also receive attention. Lastly the new technology will be evaluated and applied in practice.

LIST OF RESEARCH PROJECTS

COMPLETED PROJECTS

- ❑ An exploratory study of the efficiency of drinking-water treatment in South

Africa (The University of Cape Town - Department of Civil Engineering)

- An investigation into the occurrence and concentration of trihalomethanes and their precursors in South African drinking water (The CSIR - Division of Water Technology)
- Research on the health implications of the intake of chemical contaminants by man (The University of Cape Town - Department of Zoology)

CURRENT PROJECTS

- Technological development of water reclamation on the basis of the Windhoek plant (The Municipality of Windhoek and the CSIR - Division of Water Technology)
- Research on dissolved air flotation for the treatment of eutrophied surface water for potable use (The CSIR - Division of Water Technology)
- The construction and operation of the Cape Flats prototype water reclamation plant and the surveillance of reclaimed water quality (The Municipality of Cape Town)
- A comparative study on chlorine dioxide and other oxidants in potable water treatment (The Western Transvaal Regional Water Company, the CSIR - Division of Water Technology; and Floccotan (Pty) Ltd)
- Research on a combined flotation-powdered carbon process for potable water treatment (The CSIR - Division of Water Technology)
- Research on the isolation and identification of mutagens in drinking water (The CSIR - Division of Water Technology)
- Research on the assessment of water quality problems due to microbial growth in drinking-water distribution systems (The CSIR - Division of Water Technology)
- Research on the effects of reduced water consumption on domestic sewer systems (CSIR - Division of Building Technology)
- Research on ground-water abstraction in residential areas (CSIR - Division of Building Technology)
- Research on the flow rate and pattern of water consumption and unaccounted-for water in urban areas (The University of Pretoria - Department of Civil Engineering and the City Council of Pretoria)
- Research into water loss analysis on municipal water distribution systems (Castle Brass Holdings (Pty) Ltd and the Johannesburg City Council)
- Research on the development and testing of data-logging equipment for the monitoring of water consumption patterns (CSIR - Division of Building Technology)
- Research on epidemiological surveillance of potential changes in drinking-water quality (The University of Cape Town - Department of Community Health)
- Research on the possible chronic health effects of consumption of reclaimed water on the consumers at Windhoek (The South African Institute of Medical Research)
- Research on the effects of varying water quality on the corrosion of different pipe materials in the PWV/Klerksdorp areas (The CSIR - Division of Materials Science and Technology)
- Research on the preparation of guidelines on cost-effectiveness of rural water supply and sanitation projects (The CSIR - Division of Water Technology)

NEW PROJECTS

- The evaluation of full-scale flotation-filtration and chlorine dioxide plants (The OFS Gold Fields Water Board)
- The development of a combination of sedimentation, flotation and sand filtration processes for water treatment (Sedidaff) (The CSIR - Division of Water Technology)
- Research on human viruses in water (The University of Pretoria - Department of Medical Virology)

TREATMENT TECHNOLOGY

ATER needs to be desalinated for two main reasons:

- To produce good quality drinking water from brackish or sea water. Various methods of desalination, such as distillation, reverse osmosis, ion exchange or electrodialysis, may be used to achieve this.
- To remove any dissolved salts from effluents to prevent the pollution of potable water sources and the general water environment. This may be achieved by distillation, electrodialysis, freeze desalination or chemical precipitation.

Reverse osmosis, which is a pressure-driven process, is being used increasingly for the production of potable water because it uses considerably less energy than distillation.

The technique of electrodialysis is used mainly for the desalination of effluents. It is an electrically-driven process which is capable of removing ionised materials from solution.

Over the past fifteen years the WRC has been supporting research into locally developed membranes used for reverse osmosis and ultrafiltration. This has led to the establishment of a local manufacturing industry for desalination equipment with concomitant savings in import duties.

The characteristics of municipal and industrial effluents may vary over a wide spectrum, hence the removal of dissolved salts from such effluents remains a very serious problem that needs urgent attention.

The Commission is currently engaged in several projects dealing with the desalination of various types of effluent emanating from mining operations and a variety of industrial activities.

SYMPOSIUM

During November 1989 the Commission organised the second symposium of the South African Membrane Separation Interest Group (SAMSIG) held at Wilderness to discuss research and development work on membranes. Aspects discussed included membrane fouling and suitable cleaning procedures, feed water pretreatment, membrane regeneration and replacement and a variety of case studies dealing with the application of membranes in the desalination of water in different industries.

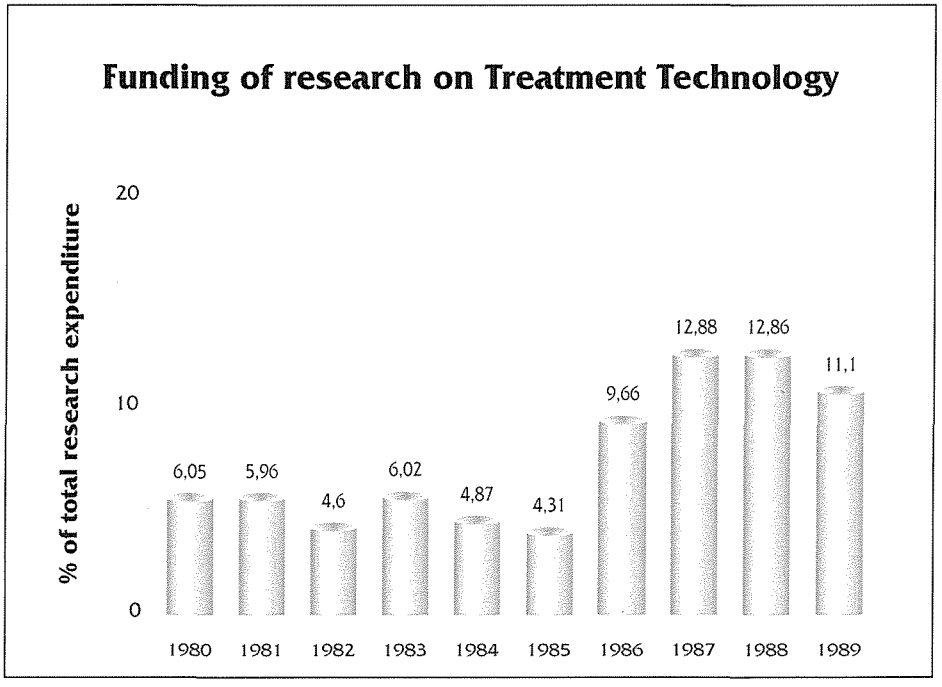
In this chapter two main areas of treatment and technology are addressed, viz. desalination and membrane development.

DESALINATION

DESALINATION OF MINE WATER

The daily underground water consumption by the gold mining industry is of the order of 4 000 Mℓ and this mine service water is used essentially for dust suppression, the watering down of working areas, water jetting and underground cooling. Drained service and saline fissure water collected underground form the major source of mine service water. Being of poor quality the collected water is usually treated prior to

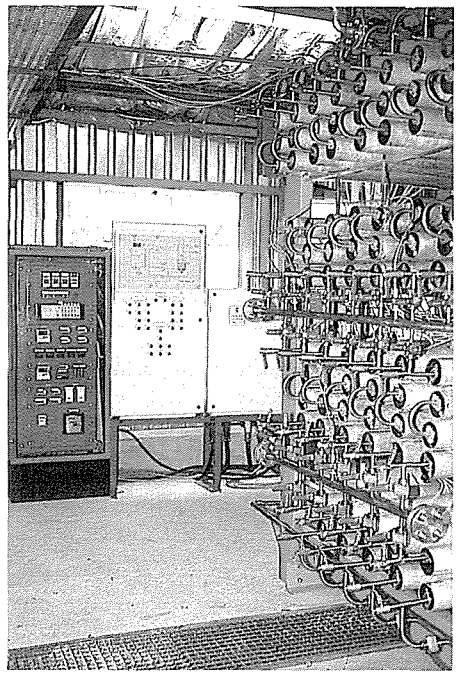
Funding of research on Treatment Technology expressed as a percentage of total WRC research expenditure (1980 to 1989).



being recirculated as service water. However, due to the harsh conditions prevailing underground the treated water is often still of relatively poor quality, and its use gives rise to problems such as erosion, corrosion, fouling and scale formation in equipment. The resulting cost to the gold mining industry is estimated to be around R300 million per year.

To limit the detrimental build-up of dissolved salts, mines are currently adding good quality potable water to the mine service water. The cost and limited availability of potable water, together with pressure from the public and authorities for better control of the quality and quantity of discharged water to the water environment, are causing the industry to step up the reuse of mine water wherever practically feasible. As this implies improved wastewater treatment, the Chamber of Mines, with WRC assistance, has embarked on an extensive programme to establish the techno-economics of suitable potential processes. The Chamber of Mines has decided that the following two treatment processes warrant investigation:

- the electrodialysis reversal process, suitable for water having a relatively low calcium sulphate content; and
- the slurry precipitation and recycle reverse osmosis or SPARRO process, capable of treating waters high in calcium sulphate content.



The slurry precipitation and recycle reverse osmosis (SPARRO) pilot plant.

REPORT ON A COMPLETED PROJECT

Pilot-plant studies on the desalination of underground mine water with electrodialysis reversal (EDR)

The Chamber of Mines erected a 1,6 ℓ/s EDR pilot plant at the Beatrix Gold Mining Company to establish the following:

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

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

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

MEMBRANE DEVELOPMENT

Different types of membranes have been developed by the University of Stellenbosch and the University of Natal with financial support by the WRC, for use in reverse osmosis, ultrafiltration, electrodialysis and crossflow microfiltration processes.

Research and developments on membranes at Stellenbosch have reached an advanced stage where specific applications of novel membranes are being investigated. For this purpose the WRC has instituted a subcommittee of the Steering Committee which deals with the development of membranes, specifically to handle the application of locally developed membranes to purify industrial effluents such as those emanating from Sasol, Eskom, the paper and pulp industry and the mining industry. The study in connection with the mining industry is being conducted in collaboration with the Chamber of Mines Research Organisation.

DISCUSSION OF NEW PROJECTS

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

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

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

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

The development of low-cost ultrafiltration systems

This project has been initiated in terms of a one-year agreement between the WRC and Bintech (Pty) Ltd.

The development of low-cost, tubular ultrafiltration modules is aimed at reducing the cost contribution of membranes to the capital cost of ultrafiltration systems. This is achieved by eliminating the usual support structure of tubular membranes by means of a reduction in the tube diameter so that the tubes are self-supporting. Such unsupported tubular modules can bring about a 65 per cent reduction in the cost of ultrafiltration systems. The operating cost of the system may also be reduced since less energy is required to attain identical tube flow velocities in the smaller diameter tubes.

This novel tubular ultrafiltration system is able to produce good quality pure water from sources such as dams, boreholes and rivers at a cost comparable to that of cartridge filtration. The system also finds application in the anaerobic digestion-ultrafiltration (ADUF) process which involves a combination of anaerobic digestion and ultrafiltration as a means of biomass separation.

Evaluation of membrane technology for electroplating effluent treatment

This project will be carried out by the CSIR over a period of two years. The annual water consumption of the electroplating industry is in excess of 9 x $10^6 m^3$, or approximately 1 per cent of the water consumed by all industries in the RSA. Of the water used by the electroplating industry approximately 80 per cent is later discharged as effluent containing a wide variety of heavy metals such as nickel, copper, zinc, cadmium, chromium and silver. These heavy metals may adversely affect biological treatment processes and soils treated

A mobile ultrafiltration unit.

with sewage sludges or destroy flora and fauna in surface water sources, or increase the total dissolved solids of the water environment. Expensive metals and water may be recovered from electroplating effluents by means of desalination techniques making use of suitable membranes.

LIST OF RESEARCH PROJECTS

COMPLETED PROJECT

- Pilot-plant studies on the desalination of underground mine water with electrodialysis reversal (EDR) (The Chamber of Mines Research Organisation)

CURRENT PROJECTS

- Research on the feasibility of reverse osmosis for water reclamation on large scale (The Municipality of Port Elizabeth, the CSIR - Division of Water Technology, and Bintech (Pty) Ltd)
- The development of low-cost ultrafiltration modules (Bintech (Pty) Ltd)
- Research on membrane development and fabrication for reverse osmosis and ultrafiltration (The University of Stellenbosch - Institute for Polymer Science)
- The development of fixed and dynamic membrane systems for the treatment of brackish water and effluents (The University of Stellenbosch - Institute for Polymer Science)
- Research on the development of polymers for the formation of dynamic membranes and the evaluation thereof for the treatment of industrial effluents (The University of Natal - Department of Chemical Engineering; the University of Stellenbosch, and the CSIR - Division of Water Technology)
- Research on design criteria for cross-flow microfiltration (The University of Natal - Department of Chemical Engineering)
- Research on the treatment of inorganic brines (The University of Natal - Department of Chemical Engineering)
- Research on the concentration of industrial effluents with sealed-cell electrodialysis (The CSIR - Division of Water Technology)
- The development of seeded reverse osmosis technology (The Chamber of Mines, Iscor, and Bintech (Pty) Ltd)

NEW PROJECTS

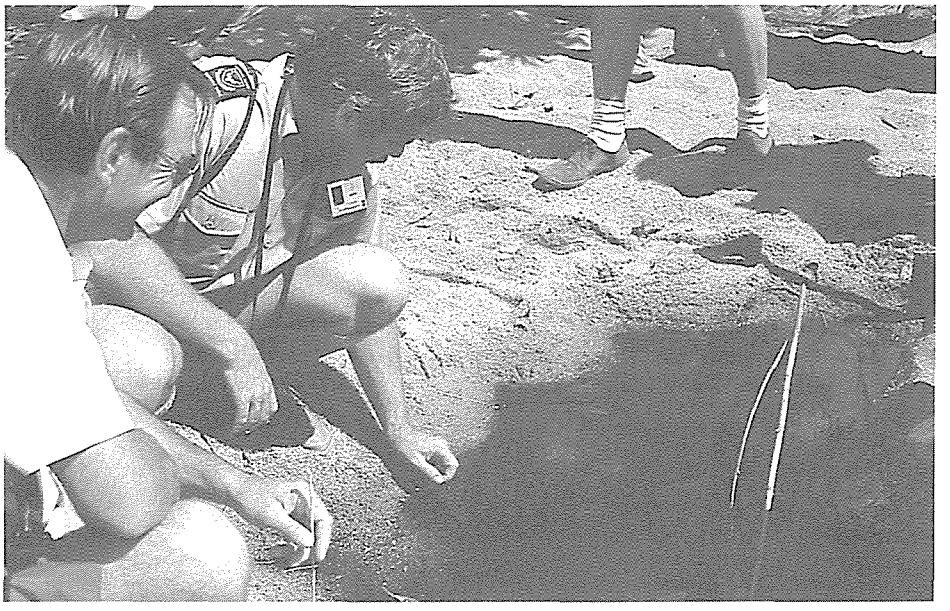
- The development of low-cost ultrafiltration systems (Bintech (Pty) Ltd)
- Evaluation of membrane technology for electroplating effluent treatment (The CSIR - Division of Water Technology)
- Technical support for the application of dynamic membrane plants for the treatment of industrial effluents (The University of Natal - Department of Chemical Engineering)

CONSERVATION OF ECOSYSTEMS

THE WRC has, since its inception, either directly or indirectly, contributed towards the ecological aspects of water research. In recent years pressure has steadily mounted for more direct and pertinent funding in the research sphere of water quantity and quality requirements to maintain the ecology. Furthermore, during the year under review, the WRC was invited to participate in the Kruger National Park Rivers Research Programme.

This research programme has its origin in the fact that water resources of some of the perennial rivers draining eastwards through the Kruger National Park (KNP) into Mozambique are barely adequate to meet existing demands. Of concern at present is the issue of allocating water in a rational manner to the numerous economic user sectors within these catchments. The KNP, one of the world's foremost conservation areas and an important contributor to the country's tourist industry, is recognised as one of these user sectors to which water must be allocated. However, water resource managers have recognised that South African knowledge and expertise in assessing minimum flow requirements of river systems is at present far too limited for concrete decisions to be made on water allocations to the KNP rivers as demands for water increase.

In March 1987 the Department of Water Affairs convened a workshop at which the water requirements of the KNP were discussed. The workshop concluded that relationships between water availability and ecosystem quality and functioning were almost completely lacking. It was therefore motivated that a co-operative multidisciplinary research programme should be initiated urgently. A small group of specialists subsequently met to compile a document which would incorporate the philosophy, goals and objectives of such a programme.



Dr Andrew Deacon, freshwater ecologist of the Kruger National Park, pointing out some interesting aspects of a small pool of water in the Sand River to Dr Peter Reid (WRC).

This document was submitted to the executives of certain Government and statutory agencies (the WRC, Department of Water Affairs, Department of Environment Affairs, National Parks Board and the CSIR) who unanimously supported the concept of initiating a full-scale research programme to assess the water requirements of the KNP.

The aim of the programme is to develop the means to predict the impact on KNP river systems of changing flow regimes and water quality as the basis of a protocol for managing the allocation of water for ecological purposes.

The objectives of the programme are to:

- define and evaluate scientific information pertinent to the allocation of water to the KNP;
- develop the appropriate expertise for managing water allocation for ecological purposes;
- develop and maintain the necessary inter-institutional co-operation and communication;

- define and initiate research in priority areas;
- secure and make recommendations on funding requirements; and
- ensure the appropriate documentation of research findings.

The programme is co-ordinated by a committee of executives of the Foundation for Research Development, the Department of Water Affairs, the Department of Environment Affairs, the National Parks Board and the WRC. It is managed by a working group of specialists. The working group will be concerned with planning the programme, implementing management actions and co-ordinating activities.

Thus far thirteen main fields of research have been identified as priority areas requiring attention. It is envisaged that some of the required research will commence in 1990. Dr PCM Reid, a research manager at the WRC, has been appointed programme manager.

With the above in mind 1989 saw, for the first time, a WRC call for research proposals, for the post-1989 period, in the specific sphere of the ecological aspects of water research. The response was overwhelming and should funding of some of these projects be approved for the post-1989 period, exciting, interesting and high-priority research will be undertaken. Furthermore, in anticipation of possible WRC funding of some of these projects, various meetings and workshops were held during 1989, with research ecologists, in order that priorities could be identified and possible research proposals finalised on a co-ordinated basis.

SOCIO-ECONOMIC STUDIES ON THE EFFECTS OF WATER RESTRICTIONS

THE imposition of water restrictions during periods of drought is a common practice world-wide. In the Republic of South Africa (RSA) it is also an important measure which is applied when it becomes clear that available water supplies, at the normal rate of consumption, will not meet the demand over a realistic period. As such situations occur almost regularly, it is a prerequisite that the operation and extent of the restrictions will be of such a nature that unacceptable economic losses or the undesirable lowering of the quality of life will not be incurred.

When the water restrictions were imposed in large parts of the RSA between 1983 and 1987 the position was, however, that little information was available on the exact socio-economic and financial consequences of water restrictions. The restrictions during the said period therefore provided the ideal opportunity for extending the state of knowledge in this field. Hence research agreements were concluded with three research organisations in terms of which the consequences of the restrictions for the period March 1983 to March 1985 in the following water supply systems would be investigated:

- Ngagane River Government Water Scheme, Natal
- Mgeni catchment area, Natal
- Vaal River system, excluding tributaries of the Vaal River
- Riet River Government Water Scheme, OFS
- Vaalharts Government Water Scheme, Cape Province.

In the *1987* and *1988 WRC Annual Reports* an account has been given already on the sections of the investigation which were carried out by the Bureau for Market Research of the University of South Africa and the Institute for Social and Economic Research of the University of the Orange Free State. The report by the third research organisation, the Centre for Applied Social Studies of the University of Natal, was submitted during 1989. For various reasons the investigation was conducted sectorally and not geographically, and the sectors which were investigated comprised local authorities, selected industries, and trade organisations, as well as other private organisations.

As indicated earlier the three above-mentioned projects investigated the effects up to March 1985, and as the remaining water restrictions were only lifted in September 1987, a period of approximately 30 months remained for which the consequences of the water restrictions had not been determined. In 1989 therefore a further agreement was reached with the University of the Orange Free State to investigate this period as well. This should tentatively conclude the research on this aspect.

REPORT ON A COMPLETED PROJECT

The socio-economic consequences of water restrictions on industries and local governments

This research project which was conducted by the Centre for Applied Social Studies of the University of Natal had the following objectives:

- to determine the extent and quantitative effects of the water restrictions, as experienced by local governments, trade and industry;
- to investigate the financial, technical and social problems resulting from water restrictions on local authorities, trade and industry, as well as the wider implications of these problems;
- to compare the different techniques which had been implemented to reduce water consumption; and
- to gather and report comments and suggestions by local authorities, trade and industry in connection with water restrictions and the enforcement thereof.

The research approach which was followed in this project differed markedly from that followed by the other two research organisations, in that a qualitative instead of a strictly quantitative approach was followed. Local authorities which had not recorded the effects and consequences of water restrictions to the same extent; their willingness to co-operate; their personnel available to assist in the investigation; as well as a wide variety of technical complexities prompted this research approach.

The investigation revealed that, in general terms, consensus could not always be reached on the value of water restrictions as a water economy measure. Some theories and observations voiced by local authorities were contradictory. It was, however, clearly evident that it is imperative for all future water restriction measures to be co-ordinated well and from a central point. Such co-ordination has to take place

after thorough consultation and with due allowance for the autonomy of the local authorities concerned. Strategies have to be spelt out clearly and feedback must be accurate and trustworthy at all times.

DISCUSSION OF A NEW PROJECT

The determination of the socio-economic and financial implications of water restrictions since 1983 up to its annulment in 1987

In the research which was concluded in the completed projects as stated above, a full account had been given already of the consequences of the water restrictions which had been in force in Natal. In the other areas included in this investigation the period March 1985 to September 1987 had, however, not been included in the previous investigation. This follow-up research project, which will be conducted over a period of eighteen months by the Department of Agricultural Economics of the UOFS, therefore has the overall objective to determine the **total** socio-economic and financial implications of water restrictions for the Vaal River System, the Riet River Government Water Scheme and the Vaalharts Government Water Scheme. This being the point of departure, the sub-objectives are:

- to give a qualified and/or descriptive explanation of the total nature and extent of the palpable and non-palpable implications of water restrictions; and
- to determine the relationship between the nature and extent of water restrictions and the consequences thereof for the different sectors.

It is envisaged that the information which is being gathered during this final investigation will be of great value in the planning and/or upgrading of water supply systems. This will ensure that the enforcement of water restrictions in the future will take place in such a way that the quality of life will not be affected unacceptably.

LIST OF RESEARCH PROJECTS

COMPLETED PROJECT

- Research on the socio-economic effects of water restrictions on industries and local governments (The University of Natal - Centre for Applied Social Studies)

NEW PROJECT

- The determination of the socio-economic and financial implications of water restrictions since 1983 up to its annulment in 1987 (The University of the Orange Free State - Department of Agricultural Economy)

RESEARCH SUPPORT SERVICES

THE HYDROLOGICAL INFORMATION SYSTEM (HIS)

The development of the Hydrological Information System (HIS) by the Department of Water Affairs is receiving assistance from the WRC on two main aspects:

- system development on the mainframe (software development); and
- capture of historic data collected before 1980.

By the end of 1989 all water level measurements taken in South African rivers between 1910 and 1989 had been digitised. The completion of the necessary discharge tables to relate water level to flow also progressed satisfactorily. This is a milestone in the project that could have been achieved only with a major increase in productivity of the data-capturing team.

At the same time the accessibility of the data bank has been made more user-friendly for both direct and indirect access users. As the HIS becomes more complete and more well-known, a steady increase in user demand is expected. It is therefore envisaged that system development will continue in the future, well beyond the end of the present agreement between the Department of Water Affairs and the WRC.

Regarding the National Ground-water Data Base, which forms an integral part of the HIS, compatibility between the mainframe and the PC-based HYDROCOM has been achieved as far as both off-loading and uploading of data are concerned. The same kind of data exchange is planned for the other data banks in the HIS, namely: streamflow, reservoir data, evaporation and water quality. Considerable progress has been made with the integration of these separate data banks.

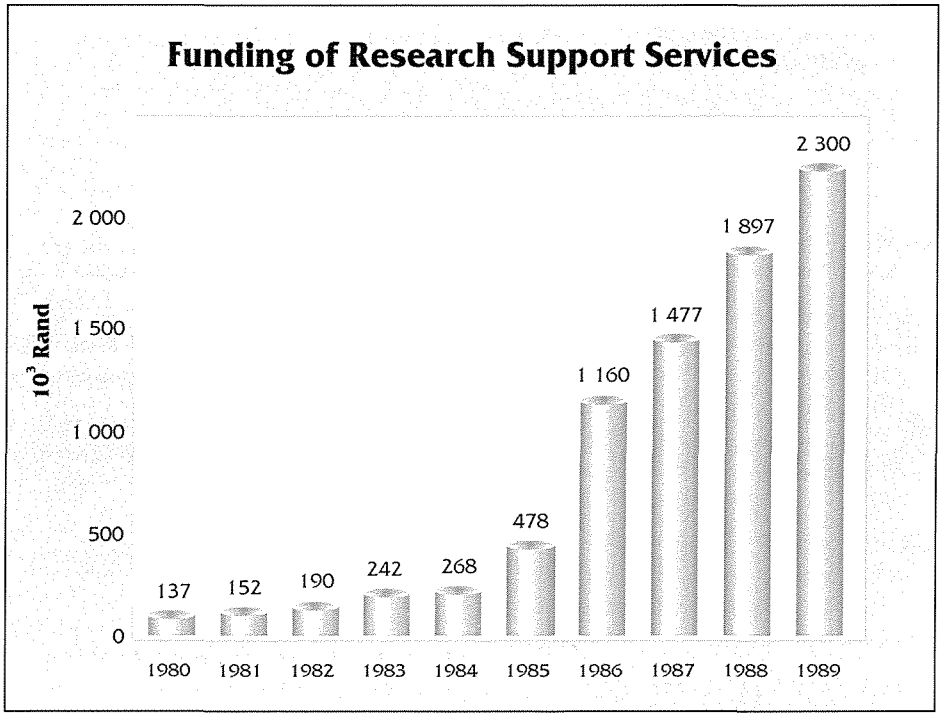
THE COMPUTING CENTRE FOR WATER RESEARCH (CCWR)

In 1986, the WRC in collaboration with ISM (Pty) Ltd (then still IBM (SA)(Pty) Ltd) and the University of Natal, established the Computing Centre for Water Research (CCWR) which is a numeric information system. The mission of the CCWR is:

"To support water research in South Africa by providing a national, computer-based information system which will:

- enhance the transfer of data and results;
- provide a facility for multi-disciplinary research; and
- provide alternative computer facilities."

Funding of Research Support Services by the WRC for 1980 to 1989.



The objectives of the CCWR are:

- The provision of a national facility for:
- the enhanced transfer of data and other information between supply organisations and researchers;
- the development of appropriate data products and the provision of these to researchers;
- the provision of appropriate software for water research purposes; and
- the enhanced transfer of research results between researchers and end-user organisations.
- The provision of a facility whereby multi-disciplinary, multi-organisational research can be undertaken by people in different organisations throughout the country.
- The provision of enhanced and/or alternative computing and computer graphics capabilities for water researchers throughout South Africa.

The CCWR is accessible to scientists at all research institutions in the country through one or more of the following routes:

- UNINET which is a joint computing network among certain research councils, universities and other organisations. Users at these institutions have access from terminals which are connected to their local networks and also to UNINET.
- CSIRNET which is an asynchronous countrywide network of the CSIR. A number of institutions have been connected to this network for some time.
- Dial-in access through network ports at several major centres is also available.
- The CCWR has developed a link to GOVNET and hence to the mainframe of the Department of Water Affairs and the Department of Agriculture and Water Supply. The CCWR is therefore able to serve researchers with data from the above organisations.

During 1989 the CCWR had 79 registered users from 16 different institutions and a total of 34 departments within those organisations. The extent of the communication of information, messages and ideas between users is reflected by the transfer of 15 224 files between users since the inception of the CCWR.

THE SOUTH AFRICAN WATER INFORMATION CENTRE (SAWIC)

SAWIC is funded by the WRC and operated by the Division of Information Services of the CSIR. SAWIC provides services on a national basis to all users who require information on water-related topics.

SAWIC operates a computerised bibliographic data base WATERLIT, which has been developed by themselves. WATERLIT presently contains over 155 000 references which are added to at a rate of about 11 500 items per year. Items are selected from 471 scientific and technical journals, as well as reports, theses, books and conference proceedings.

In the course of the year an average of 143 retrospective information searches was carried out monthly on WATERLIT. Some of these retrospective searches were done by the Department of Water Affairs, other divisions and regional offices of the CSIR, university libraries and the JLB Smith Institute of Ichthyology.

Approximately 370 clients are making use of the SDI (selective dissemination of information) services in which they are informed monthly of publications in their specific field of interest.

SAWIC has continued its association with the JLB Smith Institute of Ichthyology in Grahamstown and computerised support for the FISHLIT data base is provided by SAWIC. FISHLIT contains over 15 000 references on fish and at present about 130 SDI profiles are run on a monthly basis. SAWIC has free access to FISHLIT.

The 1989 edition of the *Bibliography of African Limnology South of the Sahara* was compiled by SAWIC for the Limnological Society of South Africa. The *Bibliography on Large Dams 1985 - 1988* was produced covers all information on large dams in South Africa.

Costs for SAWIC services were introduced in April 1989. These range from R25 to R75 for a retrospective information search and R50 to R100 per annum for the monthly SDI service. Clients involved in research at academic institutions are exempt from these costs.

The publication of *Selected Journals on Water* has ceased due to insufficient interest.

Table 1 contains information on the users of WATERLIT for 1988 and 1989, and

Table 2 contains information on the most frequently requested topics for 1989.

TABLE 1

Types of organisations making use of the WATERLIT retrospective search service for 1989

Categories	% of total amount
Private sector	27,8
Educational institutions	34,7
Government and semi-state organisations	15,1
The CSIR	16,6
Miscellaneous	5,8

TABLE 2

Summary of subject topics most frequently used for profile and retrospective searches (1 July 1988 to 30 June 1989)		
Topics	**% of total**	
	Searches	**Profiles**
Estuaries, liminology, aquatic weed control and freshwater fish	5,7	20,9
Hydrology and hydraulics engineering	8,7	13,3
Dams, water supply, water distribution and quality control	9,7	5,9
Water treatment and desalination	11,8	3,7
Industrial water, waste water and effluents, industrial wastes, solid wastes and composting	29,7	20,9
Aquaculture and marine culture	12,7	12,8
Pollution and marine pollution	4,7	4,3

TRANSFER OF INFORMATION AND TECHNOLOGY

THE promotion of information and technology transfer is one of the most important objectives of the Commission. This is very clearly defined in the Water Research Act, namely to "accumulate, assimilate and disseminate knowledge in regard to the results of such research and the application thereof, and promote development work for the purpose of such application".

For the promotion of its programme of information and technology transfer, the Commission has developed a number of activities. Although some of these activities are directed at the transfer of information, the emphasis falls mainly on technology transfer, i.e. the application of research results, since this will always represent the final dividend of the research investment.

PARTNERSHIP RESEARCH

Partnership research is regarded as a very effective method of enhancing technology transfer. The partnership principle is incorporated, as far as possible, in research projects, and means that the end user of the results participates in the planning and execution of the research.

PUBLICATIONS

The Commission's publications cater for three levels, viz. pure scientific, popular scientific and practical scientific.

WATER SA

Water SA is the Commission's scientific journal which contains original research articles and review articles on all aspects of water science, technology and engineering. The journal appears quarterly and the first edition was launched in April 1975.

Water SA has a strict refereeing system whereby all articles submitted for publication are first referred to referees, whereafter a decision is taken on publication.

Water SA has an extensive local as well as overseas readership. It also enjoys worldwide coverage in the sense that it is covered by more than 20 international abstracting services who publish and distribute summaries of articles which appear in *Water SA*.

SA WATERBULLETIN

SA Waterbulletin is a bilingual bi-monthly periodical. Within the broad spectrum of water research it aims to:

- furnish information on water and water research in a popular scientific manner to the different interest groups in the water field;
- promote the transfer of technology by announcing the availability of reports, manuals, guides etc. which emanate from water research;
- promote communication between the Water Research Commission and authorities and individuals, such as researchers, engineers, technicians, government departments, local authorities and the industrial and agricultural sectors; and
- convey social news and matters of interest (e.g. about conferences and personalities) to the water research community.

MANUALS, GUIDELINES AND REPORTS

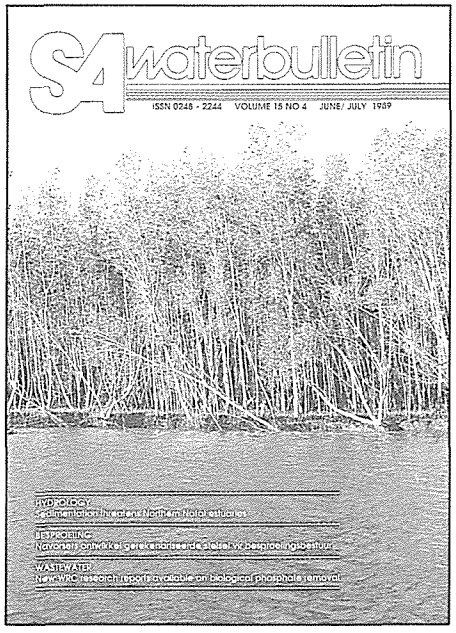
At the conclusion of a project, and also while research is still under way, results are evaluated in respect of possible use and application and depending on the nature of the results a decision is taken on publication, dissemination and application thereof. More information on these publications appears in the relevant chapters in the **Annexure**.

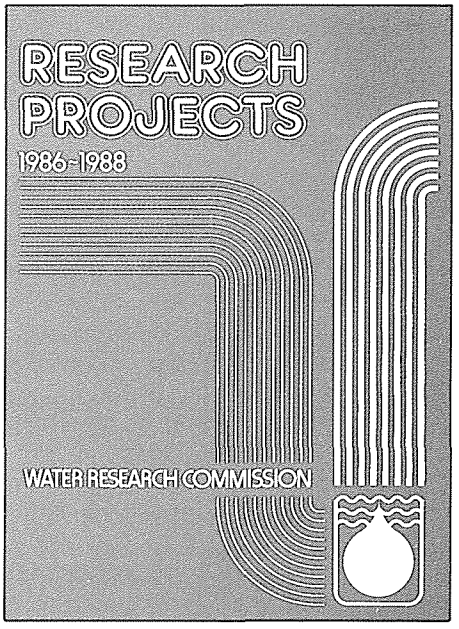
LIST OF COMMISSION PUBLICATIONS

The **Annexure** to this annual report contains a list of publications (articles, papers and published reports) which appeared during 1989 and which emanated from research supported wholly or in part by the Commission.

CONFERENCES, SEMINARS, WORKSHOPS AND DEMONSTRATIONS

From time to time the Commission, on its own or in co-operation with other organisations, arranges such meetings. These afford ideal opportunities for promoting personal contact between research scientists or between research scientists and the users of research results. In this way the transfer of information and technology is greatly enhanced. More information on meetings held during the year is contained in the individual chapters.





MASS MEDIA

In this regard the accent falls on information transfer, and press releases, radio and television are used to this end.

UTILISATION OF OVERSEAS EXPERTISE

It is in the national interest that overseas expertise and knowledge be used where these are not available locally, and the Commission has developed various methods to achieve this. Overseas specialists, for example, are engaged as consultants and the Commission from time to time sends personnel and other experts overseas in order to obtain information on a particular problem area. More information in this regard appears in the individual chapters.

COMMERCIALISATION

In future the WRC will focus increasingly on a further aspect of technology transfer, which is in progress already, viz. the commercialisation of research results by e.g. the private sector. The patenting of research results and the sale of publications and computer programs would be classified as such. In this way the WRC earns royalties, locally as well as abroad.

FINANCIAL STATEMENTS

THE Statement of Income and Expenditure and the Balance Sheet have been drawn up in terms of section 14(2) of the Water Research Act, 1971 (Act No. 34 of 1971), as amended and certified by the Auditor-General and cover the period 1 January 1988 to 31 December 1988.

The Commission derives its income from rates and charges on water usage and on scheduled irrigation land. The tariffs for the 1989 financial year were 1,05c/m^3 for water supplied for urban, industrial or domestic use, and 115c/ha of land scheduled for irrigation.

STATEMENT 1

BALANCE SHEET AS AT 31 DECEMBER 1988

1987	Liabilities		1988
R		R	R
	Accumulated funds -		
	Balance at 31/12/87	17 740 959,06	
17 740 959	*Plus*: Income over expenditure, 1988	9 873 628,49	27 614 587,55
	Current liabilities		
	Sundry creditors -		
	Revenue paid in advance	5 044,46	
	Project advances	284 079,73	
5 432	Bank overdraft	-	289 124,19
R17 746 391			R27 903 711,74

1987	Assets		1988	
R		R	R	R
	*Capital assets -			
5 000	Land (Cost)		5 000,00	
	Motor vehicles	164 645,84		
23 950	*Less*: Depreciation	16 565,63	148 080,21	
	Office equipment	262 628,35		
237 735	*Less*: Depreciation	17 458,78	245 169,57	
	Office furniture	133 675,18		
31 287	*Less:* Depreciation	2 962,34	130 712,84	528 962,62
9 226 922	Loans			15 518 514,21
	Investments -			
	Cash investment	4 655 517,55		
	Plus: Accrued interest	111 884,27	4 767 401,82	
5 036 757	Unlisted shares		755 938,74	5 523 340,56
	Current assets-			
	Sundry debtors -			
875 896	Outstanding revenue		6 259 239,58	
2 220 776	Project advances		-	
-	Subsistence and transport advances	3 150,00		
87 618	Motor financing	52 255,70		
300	Deposits	600,00	56 005,70	
150	Cash on hand		150,00	
-	Cash in bank		17 499,07	6 332 894,35
R17 746 391				R27 903 711,74

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

Pretoria, 26 July 1989

(Signed) PE ODENDAAL
Executive Director

The accounts of the Water Research Commission have been audited in terms of sections 5 and 18(2) of the Auditor-General Act, No. 52 of 1989, read with section 14(1) of the Water Research Act, No. 34 of 1971, and in my opinion the annual financial statements are a fair representation of the financial position of the Commission as at 31 December 1988 and the result of its operations for the year then ended.

15 November 1989

(Signed) RP WRONSLEY
Auditor-General

STATEMENT 2

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31 DECEMBER 1988

1987	Expenditure	1988
R		R
1 848 060	Salaries and allowances	2 009 481,93
48 232	Subsistence	53 825,37
10 404	Motor transport	6 588,38
195 949	General transport	197 295,06
1 700	Commission members' allowances	5 678,66
11 413	Postal and telegraph services	17 317,16
43 751	Telephone services	40 030,23
39 140	Printing and stationary	42 834,77
17 114	Advertisement	36 275,00
258 482	Publications and information	314 100,80
14 105	Technology and information transfer	16 764,71
37 824	Lease and maintenance of office equipment	47 158,45
10 213	Entertainment	13 228,27
71 065	Office rental	164 362,34
1 089	Maintenance of and alterations to offices	8 720,00
9 413	Electricity	15 077,54
33	Maintenance and lease of furniture	3 712,22
1 154	Typing and translation services	10 015,63
18 536	Insurance and licenses	18 100,93
159 043	Collection fees	188 330,28
3 846	Audit fees	3 378,08
128 640	Legal costs	67 077,96
24 330	Registrations and subscriptions	33 740,52
15 277	Miscellaneous petty expenses	36 916,27
-	Interest on loan	110 941,23
17 830	Depreciation	36 986,75
7 246 077	Research projects and research support services (St 3)	10 810 065,89 *
221 503	Contracting of researchers and expertise	257 231,59
105 000	Research and other grants	107 000,00
110 336	Specialist and consultation services	124 014,08
5 304 580	Income over expenditure	9 873 628,49
R15 974 139		R24 669 878,59

1987	Income	1988	
R		R	R
	Rates		
198 818	Government irrigation schemes with canal systems		249 469,65
290 204	Irrigation board schemes		220 653,88
	Charges		
12 116 530	Metered water from Government schemes		18 555 775,01
3 000 455	Municipalities		5 161 370,48
9 530	Interest on rates and charges in arrear		28 495,47
	Interest on investments -		
	Received	218 759,93	
270 641	Accrued	111 884,27	330 644,20
87 961	Sundry income		123 469,90
R15 974 139			R24 669 878,59

* Only includes expenditure for which audited statements are received.

STATEMENT 3

STATEMENT OF EXPENDITURE AND ADVANCES OUTSTANDING IN RESPECT OF RESEARCH PROJECTS AND RESEARCH SUPPORT SERVICES AS AT 31 DECEMBER 1988

Project	Expenditure		Total advances outstanding as at 31/12/88
	1988	Total to 31/12/88	
	R	R	R
1. RESEARCH PROJECTS			
Technological development of water reclamation on the basis of the Windhoek plant	1 670,44	812 635,99	1 812,62
Research on detailed geohydrological investigations in the Poesjenels River catchment in the Breede River valley, with special reference to mineralisation	10 420,24	233 935,37	(13 221,81) *
Water management and effluent treatment in the textile industry: Treatment of scouring and bleaching effluent	7 769,31	741 619,56	-
Research on an investigation into the use of physical/chemical techniques for water and waste-water management in the meat processing industry	60 100,00	560 700,00	-
Research on the inhibition of bacterial oxidation of pyrite and the concomitant acid mine drainage	18 598,57	170 769,55	478,45
Research on enhancement of biological phosphate removal from sewage by altering process feed composition	40 398,66	262 033,83	(1 398,66) *
Hydrological research in catchments of the Eastern and Southern Cape	136 220,72	604 648,51	5 331,49
Research on the use of the soil/root conductance index and stress ratio as inputs for the determination of irrigation requirements of selected soil/plant/atmosphere systems	1 857,29	272 273,89	5 039,35
A national industrial water and waste-water survey	1 029 415,00	2 900 603,12	36 885,00
Research on biological excess phosphate removal	141 964,32	568 207,73	-
An investigation into rainfall recharge to ground-water	120 206,02	576 804,82	1 062,69
Research on correction factors for the evaporimeter coefficients used in the irrigation scheduling of wheat	29 941,53	232 454,48	(241,53) *
Research on the practical scheduling of irrigation in the northern Transvaal	-	227 156,41	(22 796,29) *
Research on the quantification and limitation of water losses associated with centre pivot irrigation systems	49 532,14	219 252,63	(1 477,75) *
Applied hydrological process and modelling studies for the determination of water and sediment yield	239 852,84	975 052,43	14 947,57
Research on thermal feedback caused by dry cooling at power generating stations	48 000,00	203 928,00	-
Research into the treatment of wool scouring effluents	320 284,00	1 078 257,22	(30 737,22) *
The technical performance evaluation of a full-scale industrial waste-water treatment plant: Textile dyehouse effluent treatment by hyperfiltration	-	44 162,72	2 412,28
Research on and development and full-scale evaluation of preventative and remedial methods for the control of activated sludge bulking	87 042,60	200 244,99	(20 124,68) *
Research on improving irrigation management based on soil water monitoring and detailed knowledge of profile available water capacities	138 399,16	287 099,33	4 041,10
Research on the sosio-economic effects of water restrictions on industries and local governments	-	98 234,63	4 223,03
Research on socio-economic domestic losses as a result of restrictions on water consumption	11 620,00	109 854,63	-
Research on the exploitation potential of Karoo aquifers	180 994,73	729 749,13	22,27
The development of management-orientated models for eutrophication control	36 873,46	219 331,46	23 277,54
Modelling of the ground-water quality in the Atlantis aquifer	288 170,89	696 347,68	(370,89) *
The development of a computer program to simulate water flow in distribution canals	52 897,97	141 481,04	4 810,94
Research on the possible chronic health effects of consumption of reclaimed water on the consumer at Windhoek	19 580,00	57 809,67	(21 558,00) *
Research on chemical characterisation of South African municipal sludges	26 075,26	62 629,26	924,74
Research on the evaluation of the impact of the phosphate standard on the water quality and trophic status of Hartbeespoort Dam	83 243,65	233 536,65	363,35
Research on the effective use of water by means of an algal-aqua culture system	3 228,05	25 672,16	(83,05) *
Research on the effects of urbanisation on catchment water balance	377 320,42	539 669,16	45 378,70
A pilot study of the irrigated areas served by the Breë River (Robertson) irrigation canal	15 000,00	209 953,27	-
Research on drip irrigation of tomatoes	180 995,00	383 057,13	17 278,57

STATEMENT 3 (CONTINUED)

Project	Expenditure		Total advances outstanding as at 31/12/88
	1988	Total tot 31/12/88	
	R	R	R
Research on epidemiological surveillance of potential changes in drinking-water quality	222 021,40	319 513,08	(69 031,07) *
Research on the development of polymers for the formation of dynamic membranes and the evaluation thereof for the treatment of industrial effluents	136 687,38	523 190,79	3 129,21
Research on the evaluation and optimisation of the process of dual digestion of sewage sludge	124 643,65	284 899,69	950,31
Computer and laboratory optimisation studies on dry and dry-wet cooling	266 309,12	783 105,81	7 690,88
Research on the feasibility of reverse osmosis for water reclamation on large scale	19 394,00	536 000,00	-
The development of a portable toxicity detector for water	6 631,25	24 503,25	15 496,75
An investigation into the occurrence and concentration of trihalomethanes and their precursors in South African drinking water	4 697,12	38 529,12	5 902,88
Hydrosalinity studies in the eastern Cape	176 815,53	539 209,72	32 750,28
The evaluation of the abilities of several solute and water transport models to predict the quantity and quality of water leaving the root zone	56 189,47	165 102,12	10 197,88
Development of phosphate export models for catchments	4 010,71	12 386,71	22 113,29
The development of methods to assess the impact of agricultural practices on water resources in southern Africa	223 314,38	346 063,10	24 736,90
Research on the effects of reduced water consumption on domestic sewer systems	39 148,31	60 913,27	3 526,73
Research on the development of a stochastic daily climate model for South African conditions	90 824,48	90 824,48	(31 477,30) *
Research on the treatment of inorganic brines and concentrates	194 735,10	302 259,93	65 140,07
Research on dissolved air flotation for the treatment of eutrophied surface water for potable use	50 147,26	102 018,26	(3 638,26) *
Research on chemical removal of sulphates	42 670,88	75 601,94	(2 001,94) *
Development of water quality monitoring strategies and procedures for water quality data interpretation	44 270,93	93 807,93	44 492,07
Research on the isolation and identification of mutagens in drinking water	15 209,54	52 217,54	14 432,46
Research into water consumption rates and patterns and unaccounted-for water in urban areas	33 770,45	33 770,45	2 034,55
Research on the development of an adjustable low pressure flow-rate control valve for flood irrigation	37 942,16	37 942,16	7 577,16
Research on the development of criteria for sprinkler irrigation systems to combat surface sealing of soils	51 222,44	72 221,40	46 678,60
An investigation into methods of developing operational rules for individual irrigation systems	153 177,49	284 360,58	6 922,51
Research on the electrochemical produced metal coagulants for the treatment of polluted water	7 637,79	7 637,79	-
Research on ground-water abstraction in residential areas	74 294,00	101 195,10	(11 195,10) *
Research on the use of electromagnetic exploration techniques for the development of ground-water resources	86 692,57	86 692,57	(7 692,57) *
Research on marine disposal practice in South Africa	22 750,00	39 997,60	-
Research on the culturability of faecal coli following exposure to sea-water - a pilot study	5 000,00	5 000,00	-
Research on phosphate crystallisation in activated sludge systems	70 923,58	86 486,58	6 576,42
Research on the evaluation and development of techniques for the determination of geohydrological parameters by use of geo-electrical methods	23 291,42	34 435,42	1 379,58
An exploratory study into the efficiency of drinking-water treatment in South Africa	21 368,28	21 368,28	(14 596,53) *
Research on economic evaluation of alternative irrigation scheduling strategies for wheat in the irrigated area of the Orange Free State	52 590,61	79 735,21	1 501,79
The development of fixed and dynamic membrane systems for the treatment of brackish water and effluents	552 571,93	552 571,93	(287 071,93) *
Forced aeration composting performance evaluation	33 000,00	33 000,00	-
Research on geohydrological investigation and evaluation of the Zululand coastal aquifer	105 605,30	105 605,30	(17 605,30) *
Research on the reconstruction of the climatic history of the last 2000 years in the summer rainfall regions of southern Africa	43 037,00	43 037,00	(1 427,00) *
Research on precipitation and airflow in cumulus clouds	74 975,11	74 975,11	24,89
Research on the development of techniques for the evaluation and effective management of surface and ground-water contamination in the Orange Free State Gold Fields	238 833,40	238 833,40	61 645,59
Research on the enhancement of the national ground-water data base facilities	100 087,49	100 087,49	(87,49) *

STATEMENT 3 (CONTINUED)

Project	Expenditure		Total advances outstanding as at 31/12/88
	1988	Total to 31/12/88	
	R	R	R
Research on maximising irrigation project efficiency in different soil-climate-irrigation situations	96 462,64	96 462,64	(21 366,64) *
Research on the storage and utilisation of rain water in soil for the stabilisation of plant production in semi-arid regions	151 994,39	151 994,39	(28 569,39) *
Research on the factors affecting the water use efficiency of irrigated crops, with special reference to the physiological responses of these crops	212 793,84	212 793,84	(55 568,84) *
Research on the estimation and evaluation of moisture stress in crops by means of remote control aerial surveillance	-	-	59 000,00
Development of a manual to be used with the IDES computer programs for the design of irrigation systems	64 000,00	64 000,00	(4 000,00) *
Research on the preparation of guidelines on cost-effectiveness of rural water supply and sanitation projects	43 085,32	43 085,32	17 414,68
Research on the preparation of engineering design guidelines for artificial wetlands for waste-water treatment	14 000,00	14 000,00	(14 000,00) *
An investigation of the hydrological response to third world settlements in peri-urban areas of Natal/KwaZulu	18 873,00	18 873,00	(2 839,00) *
The development of a systems model for the Mgeni catchment	22 915,11	22 915,11	7 084,89
Hydrological modelling studies in the eastern Cape	39 344,94	39 344,94	14 855,06
The development of a model to simulate flow in alluvial rivers	47 345,91	47 345,91	-
Research on the quantification of the effects of land use of runoff quality in selected catchments in Natal	56 690,10	56 690,10	16 309,90
Research on the design criteria for crossflow microfiltration	170 412,07	170 412,07	28 587,93
Research on the removal of gas stripliquor by coagualation and flocculation	13 756,63	13 756,63	5 893,37
Research on solids-liquid separation in biological systems	22 516,36	22 516,36	(17 016,36) *
The development of low-cost ultrafiltration modules	60 000,00	60 000,00	-
Research on a combined flotation-powdered carbon process for potable water treatment	21 814,86	21 814,86	46 185,14
The development of seeded reverse osmosis technology	100 000,00	100 000,00	-
Research on the concentration of industrial effluents with sealed-cell electrodialysis	42 404,56	42 404,56	(804,56) *
A comparative study on chlorine dioxide and other oxidants in potable water treatment	21 521,35	21 521,35	40 478,65
Research on pelletisation in upflow anaerobic sludge bed (UASB) systems	30 272,70	30 272,70	(11 272,70) *
Research on phosphate fixation in waste waters by means of controlled struvite formation	31 233,51	31 233,51	32 766,49
Consolidation of activated sludge and water chemistry research	39 983,80	39 983,80	(19 983,80) *
Research on the assessment of water quality problems due to microbial growth in drinking-water distribution systems	31 549,91	31 549,91	18 450,09
Research on the effect of biocorrosion in water systems	28 740,53	28 740,53	21 259,47
Research on the effects of varying water quality on the corrosion of different pipe materials in the PWV/Klerksdorp areas	89 399,10	89 399,10	(54 399,10) *
Research on the development and testing of data logging equipment for the monitoring of water consumption patterns	17 287,47	17 287,47	17 712,53
Research on the evaluation of the design and use of irrigation systems in the Breë River with a view to the control of potential drainage losses	64 463,12	64 463,12	-
Research on the water use efficiency of certain irrigated temperate pasture species	91 349,39	91 349,39	950,61
Model studies on the minimisation of dry and dry-wet cooling systems	84 592,83	84 592,83	(84 592,83) *
TOTAL	8 992 967,24	22 797 070,00	7 891,71
2. RESEARCH SUPPORT SERVICES			
South African Water Information Centre	428 849,44	1 349 836,81	(289 617,33) *
The establishment of a National Hydrological Information System	1 139 770,28	2 878 408,12	-
The establishment of a Computing Centre for Water Research	248 478,93	539 222,51	(2 354,11) *
TOTAL	1 817 098,65	4 767 467,44	(291 971,44) *
GRAND TOTAL	10 810 065,89	27 564 537,44	(284 079,73) *

* Excess expenditure over advances for projects.

STATEMENT 4

BUDGET 1990

	R	R
ESTIMATED INCOME		
Rates and charges in terms of section 11 of the Water Act		26 199 000
Loan		1 000 000
Interest on investment		350 000
Erf Sewe-Nul-Ses Rietfontein (Pty) Ltd		745 000
Sundry income		-
TOTAL ESTIMATED INCOME		R28 294 000
ESTIMATED EXPENDITURE		
Administrative expenses:		
Salaries and allowances	3 368 000	
Subsistence and travelling expenses	537 000	
Postal, telegraph and telephone	93 000	
Printing, stationary, advertisements and publications	641 000	
General expenditure	1 352 200	5 991 200
Research expenses:		
Research projects		
Research on the inhibition of bacterial oxidation of pyrite and the concomitant acid mine drainage	1 300	
Research on thermal feedback caused by dry cooling at power generating stations	82 800	
Research on improving irrigation management based on soil water monitoring and detailed knowledge of profile available water capacities	7 000	
Research on the effects of urbanisation on catchment water balance	310 000	
Research on drip irrigation of tomatoes	142 000	
Hydrosalinity studies in the eastern Cape	239 000	
Research on the evaluation of the abilities of several solute and water transport models to predict the quantity and quality of water leaving the root zone	61 000	
Development of phosphate export models for catchments	131 800	
The development of methods to assess the impact of agricultural practices on water resources in southern Africa	293 200	
Research on the effects of reduced water consumption on domestic sewer systems	6 677	
Research on the development of a stochastic daily climate model for South African conditions	4 500	
Development of water quality monitoring strategies and procedures for water quality data interpretation	96 000	
Research into flow rates and patterns of water consumption as well as unaccounted-for water in urban areas	40 000	
Research on the development of criteria for sprinkler irrigation systems to combat surface sealing of soils	98 500	
An investigation into methods of developing operational rules for individual irrigation systems	3 000	
Research on ground-water abstraction in residential areas	9 000	
Research on the use of electromagnetic exploration techniques for the development of ground-water resources	26 900	
Research on economic evaluation of alternative irrigation scheduling strategies for wheat in the irrigated area of the Orange Free State region	112 500	
The development of fixed and dynamic membrane systems for the treatment of brackish water and effluents	638 328	
Research on geohydrological investigation and evaluation of the Zululand coastal aquifer	310 000	
Research on the reconstruction of the climatic history of the last 2000 years in the summer rainfall regions of southern Africa	30 000	
Research on precipitation and airflow in cumulus clouds	211 200	
Research on the development of techniques for the evaluation and effective management of surface and ground-water contamination in the Orange Free State Gold Fields	282 000	
Research on the enhancement of the national ground-water data base facilities	180 912	
Research on maximising irrigation project efficiency in different soil-climate-irrigation situations	191 100	
Research on the storage and utilisation of rain water in soil for the stabilisation of plant production in semi- arid regions	152 500	
Research on the factors affecting the water use efficiency of irrigated crops, with special reference to the physiological responses of these crops	293 000	
Research on the estimation and evaporation of moisture stress in crops by means of remote control aerial surveillance	64 000	
Research on the preparation of guidelines on cost-effectiveness of rural water supply and sanitation projects	74 500	
An investigation of the hydrological response to third world settlements in peri-urban areas of Natal/KwaZulu	12 500	
The development of a systems model for the Mgeni catchment	139 600	
Hydrological modelling studies in the eastern Cape	294 000	
The development of a model to simulate flow in alluvial rivers	108 500	
Research on the quantification of the effects of land use on runoff quality in selected catchments in Natal	106 400	
Research on the design criteria for crossflow microfiltration	418 000	
Transfer of waste-water treatment management technology to the meat processing industry	54 000	

STATEMENT 4 (CONTINUED)

	R	R
Research on the filtration of compressible cakes	50 000	
The development of seeded reverse osmosis technology	200 000	
Research on the concentration of industrial effluents with sealed-cell electrodialysis	47 000	
A comparative study on chlorine dioxide and other oxidants in potable water treatment	95 000	
Research on chemical augmentation of biological phosphate removal	21 000	
Research on pelletisation in upflow anaerobic sludge bed (UASB) systems	108 000	
Research on phosphate fixation in waste waters by means of controlled struvite formation	60 000	
Consolidation of activated sludge and water chemistry research	64 400	
Research on the assessment of water quality problems due to microbial growth in drinking-water distribution systems	141 000	
Research on the effect of biocorrosion in water systems	50 000	
Research on the effects of varying water quality on the corrosion of different pipe materials in the PWV/ Klerksdorp areas	135 500	
The evaluation of the design and use of irrigation systems in the Breë River with a view to the control of potential drainage losses	113 400	
Research on water use efficiency of certain irrigated temperate pasture species	62 700	
Research on the effect of water quality chemical composition on the corrosivity in mild steel pipelines	50 000	
Research on the relationship between climate and crop factors	57 500	
Research on soil-plant-water relations in the upper reaches of plant available soil water	85 000	
Research on moisture sensors to facilitate water management	111 000	
Research on the biological treatment of industrial water with the simultaneous production of single cell protein	25 500	
Research on human viruses in water	127 500	
Research on the extension of the management orientated models for eutrophication control	80 000	
Research on the evaluation and development of geophysical techniques for characterising the extent and degree of ground-water pollution	227 000	
Research on a preliminary survey of pesticide levels in ground water from a selected area of intensive agriculture in the western Cape	21 500	
Research on the evaluation of the four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions	53 900	
Research on hydrological systems model development	477 000	
A comparative study of two and three-dimensional ground-water models	183 000	
An investigation into the oscillation method for the determination of aquifer transmissivity	30 000	
An investigation of the potential use of NOAA satellite remotely sensed data for identification of regional-scale fracture zones for ground-water supply purposes in southern Africa	11 000	
Technical support for the application of dynamic membrane plants for the treatment of industrial effluents	237 000	
The investigation into the evaluation of membrane technology for electroplating effluent treatment	22 000	
Research on biological techniques for the treatment of pulp bleaching effluent	20 000	
Research on the prediction of South African summer rainfall variability from ocean surface temperatures	112 000	
Research on relationships between lightning and precipitation	81 000	
The evaluation of full-scale flotation, ultrafiltration and chlorine dioxide plants	40 500	
Research on the effect of water quality on the effectiveness of chlorine dioxide in drinking-water treatment	40 000	
The development of a combination of sedimentation, flotation and sand filtration processes for water treatment (SEDIDAFF)	15 000	
Research on the interaction between the atmospheric boundary layer and the natural draught cooling towers at Kendal power station	50 000	
Research on and evaluation of various factors affecting dry-wet cooling	284 400	
Research on development and evaluation of specific control methods for ameliorating low F/M bulking	68 000	
Determination of the sosio-economical and financial implications of the water restrictions in force from 1983 up to its annulment in 1987	35 000	
Research on the management of phosphate concentrations and algae in Hartbeespoort Dam	94 500	
Research on flood and furrow irrigation: A critical evaluation of design procedures and the computerisation of the most suitable procedures	128 000	
A regional investigation into ground-water quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam subcatchment	403 000	
Expected projects	8 523 900	
	18 068 217	
Contracting of researchers and expertise	525 000	
Research and other grants	50 000	
Specialist and consultation services	500 000	
Loan (Company for Research on Atmospheric Water Supply)	-	
Research support services	2 653 988	21 797 205
TOTAL ESTIMATED EXPENDITURE		27 788 405
Expected investment balance		505 595
		R28 294 000

STATEMENT 5

STATEMENT OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 31 DECEMBER 1989

RECEIPTS	1989	
	R	R
Balance on 1 January 1989 -		
Investment at Corporation for Public		
Deposits	4 655 517,55	
Cash on hand	150,00	
Cash in bank	16 595,47	4 672 263,02
Rates -		
Government irrigation schemes with canal systems		226 202,36
Irrigation board schemes		179 665,92
Charges -		
Metered water from Government schemes		17 062 490,94
Municipalities		4 831 925,82
Interest on rates and charges in arrear		25 628,10
Interest on investments		603 199,46
Sundry income		75 231,88
Subsistence and transport advances recovered		104 124,97
		R27 780 732,47

PAYMENTS	1989	
	R	R
Salaries and allowances		3 046 401,61
Motor transport		11 912,86
Subsistence		96 058,81
Subsistence and transport advances		93 921,17
General transport		208 083,28
Commission members' allowances		7 670,00
Postal and telegraph services		17 295,86
Telephone services		58 558,22
Printing and stationary		72 632,91
Advertisements		19 913,95
Publications and information		333 206,57
Technology and information transfer		36 508,18
Office equipment: Purchases		54 352,95
Office equipment: Computer software		3 540,43
Lease and maintenance of office equipment		72 940,76
Entertainment		17 761,03
Office rental		492 498,30
Electricity		48 399,30
Office furniture		29 650,55
Maintenance and lease of furniture		1 695,36
Typing, translation and services rendered		3 100,97
Insurance and licenses		27 631,72
Collection fees		223 259,14
Audit fees		9 750,66
Legal costs		77 868,03
Registrations and subscriptions		33 160,11
Miscellaneous petty expenses		33 120,67
Project advances		11 565 454,80
Research projects		573,08
Contracting of researchers and expertise		345 695,23
Research and other grants		100 000,00
Specialist and consultation services		486 988,04
Loans		2 246 382,21
Research support services		1 321 148,52
Balance as at 31 December 1989 -		
Investment at Corporation for Public Deposits	6 158 717,01	
Cash on hand	150,00	
Cash in bank	424 730,18	6 583 597,19
		R27 780 732,47

ANNEXURE

PUBLICATIONS EMANATING FROM RESEARCH FINANCED WHOLLY OR PARTIALLY BY THE COMMISSION

This **Appendix** contains a list of publications released in 1989. Requests for publications should be directed, as far as possible, to the authors.

PUBLICATIONS FOR 1989
ARTICLES AND PAPERS

❑ Adam, BF and Bruintjes, RT (1989) In-cloud droplet cooling and contact nucleation. Paper presented at the 6th Annual Conference of the SA Society for Atmospheric Sciences, Pretoria. 26-27 October.

❑ Barnard, JL and Nicholls, HA (1989) Case studies in N and P removal. Paper presented at the Seminar on Nutrient Removal, Magaliesburg.

❑ Beater, AB (1989) The applicability of two simple single event rainfall-runoff models to catchments with different climate and physiography. Unpublished M.Sc. Thesis, Rhodes University, Grahamstown.

❑ Bloem, G (1989) Evaluasie van besproeiingstelselontwerpe met behulp van die IDES rekenaarprogramme. Handelinge van die 21ste Nasionale SAILI, Simposium, Brits. 111-118.

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