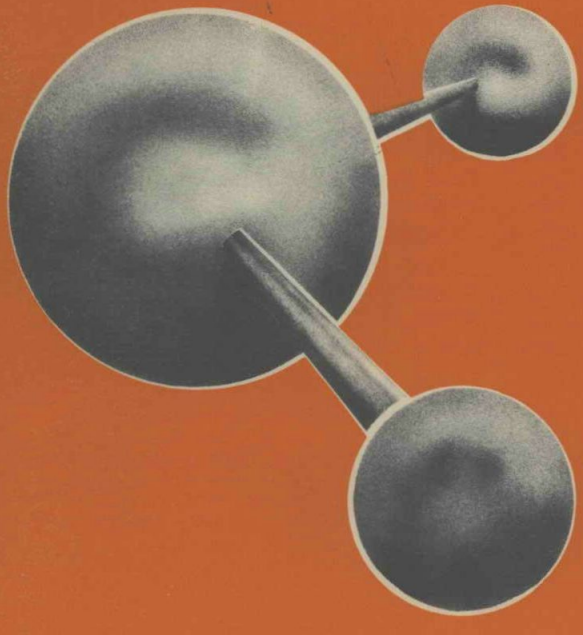

water research commission

ANNUAL REPORT

1 January 1980 to 31 December 1980

WATER RESEARCH COMMISSION

Annual Report

1 January 1980 to 31 December 1980

Water Research Commission
P O Box 824
Van der Stel Building
Pretorius Street
PRETORIA 0001

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WATERKOM
Telex: 3-0464
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THE OBJECTIVES OF THE WATER RESEARCH COMMISSION

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

(a) the occurrence, preservation, conservation, utilization, control, supply, distribution, purification, pollution or reclamation of water supplies and water;

(b) the use of water for —

(i) agricultural purposes;
(ii) industrial purposes; or
(iii) 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 purposes of such application".

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Water Research Commission
PO Box 824
PRETORIA
0001
30 June 1981

Dear Sir

We take pleasure in submitting to you, herewith, the report of the Water Research Commission. This report covers the period 1 January 1980 to 31 December 1980.

The balance sheet and statement of revenue and expenditure for the financial year 1 January 1980 to 31 December 1980, as certified by the Auditor-General, are furnished in Chapter 14 of this report.

Yours respectfully

MR Henzen
CHAIRMAN

JF Otto
VICE CHAIRMAN

Dr the Honourable CV van der Merwe, MP
Minister of Water Affairs, Forestry and
Environmental Conservation
PO Box 23
CAPE TOWN
8000

MEMBERS OF THE WATER RESEARCH COMMISSION FOR THE PERIOD ENDING 31 JULY 1980

DR MR HENZEN
Chairman: Chief Executive Officer

DR JP KRIEL
Vice-Chairman
Former Secretary for Water Affairs and now Consultant: Special Water Studies for the Department of Water Affairs, Forestry and Environmental Conservation

DR C vd M BRINK[+]
President of the Council for Scientific and Industrial Research

PROF GDB DE VILLIERS
Former Dean of the Faculty of Agriculture and former Vice Rector: University of the Orange Free State

PROF DC MIDGLEY
Director: Hydrological Research Unit
University of the Witwatersrand

MR EJ HALL
City Engineer Johannesburg

DR DW IMMELMAN
Director-General: Department of Agriculture and Fisheries

PROF DJ SCHOEMAN
Dean: Faculty of Engineering
University of Pretoria

DR N STUTTERHEIM
Chairman: Council of the University of the Witwatersrand
Chairman: Telephone Manufacturers of South Africa

MEMBERS OF THE WATER RESEARCH COMMISSION WITH EFFECT FROM 1 AUGUST 1980

DR MR HENZEN
Chairman: Chief Executive Officer

MR JF OTTO
Vice Chairman
Director-General: Department of Water Affairs, Forestry and Environmental Conservation

DR CF GARBERS
President: Council for Scientific and Industrial Research

MR LD HOBBS
Deputy Director-General: Department of Water Affairs, Forestry and Environmental Conservation
(Co-opted member from 1 August 1980 to 31 October 1980)

MR JG DU PLESSIS
Deputy Director-General: Department of Water Affairs, Forestry and Environmental Conservation
(Co-opted member from 1 November 1980)

MR EJ HALL

DR DW IMMELMAN

DR JP KRIEL

PROF DJ SCHOEMAN

DR N STUTTERHEIM

Chapter 1

The year in review

On 1 August 1980 the Water Research Commission was reconstituted for a three-year period of office and now consists of the following members: Dr MR Henzen (Chairman and Chief Executive Officer); Mr JF Otto (Vice-Chairman); Dr CF Garbers; Mr EJ Hall; Dr DW Immelman; Dr JP Kriel; Prof DJ Schoeman and Dr N Stutterheim. Mr JG du Plessis was co-opted as a member on 3 November 1980.

One of the serving members, Dr C vd M Brink, passed away on 3 May 1980. The late Dr Brink had been President of the CSIR at the time of his death and a valued member of the Commission since 1 August 1974. His extensive scientific knowledge and his broad experience and insight made his contribution to the activities of the Commission an invaluable one and the Commission was indeed privileged to have shared in his considered opinions and positive leadership. His death has left a deep sense of loss.

One of the founder members of the Commission, Prof DC Midgley, retired from the Commission on 31 July 1980 after serving for a period of 9 years. Prof Midgley, who is Director of the Hydrological Research Unit at the University of the Witwatersrand, played an extremely valuable role in the early years and later development of the Commission's activities. His important contributions will be remembered with great appreciation. Another member, Prof GDB de Villiers, former Dean of the Faculty of Agriculture and former Vice-principal of the University of the Orange Free State, retired after a three-year period of office. Sincere appreciation is also conveyed to Prof de Villiers for his commendable services.

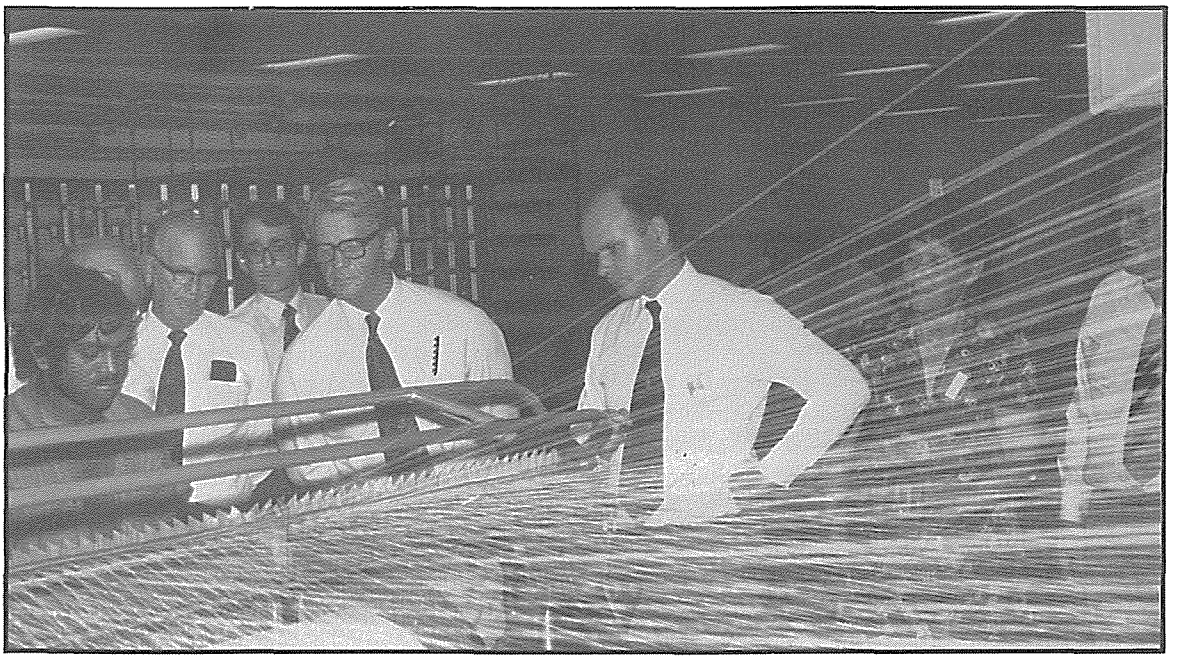
Commission members visit research projects

During the year under review the Commission met twice – in Bloemfontein on 17 April and in Durban on 13 November. The Commission had previously decided to meet in centres other than Pretoria to afford its members the opportunity of meeting with project leaders and to view some of the research locally. Communication between Commission members and project leaders can only lead to greater mutual understanding which will contribute to improved planning, coordination and execution of water research.

The first meeting of 1980 was held in Bloemfontein where the Commission currently sponsors eight research projects with the University of the Orange Free State. Through the years the Commission had made an important input to the development of centres of expertise at this University, particularly with regard to irrigation research in the Faculty of Agriculture; groundwater research in the Institute for Groundwater Studies; and flood damage studies in the Institute for Social and Economic Research. During the year under review the Commission also entered into an agreement with the University in terms of which the Institute for Environmental Sciences will do research on municipal sludge.

The visit to Durban afforded the Commission members the opportunity of discussing with researchers the research work being supported in Natal by the Commission. The Chemical Engineering Department of the University of Natal is currently involved in four research projects on water management and effluent treatment in the textile industry and in this regard a centre of expertise has already been firmly established there. Important research on surface hydrology has for some years been done by the University of Natal with financial support from the Commission and in this regard the Department of Agricultural Engineering is currently involved in three research projects and the Department of Civil Engineering in one. In terms of an agreement with the Commission, the University of Zululand's Geography Department is engaged in hydrological research in Zululand. During the year under review a contract has also been agreed with the City Council of Durban with respect to research into the disposal of municipal sludge to sea.

During the visits by the Commission members to



In November 1980 members of the Water Research Commission visited a textile factory in Natal where the Commission is financing research on effluents in the textile industry. This picture was taken during the visit.

Bloemfontein and Durban, project leaders were given the opportunity of explaining their research efforts. In some cases it was possible to visit individual projects where ongoing research could be further explained through demonstrations.

These visits are considered to be of great value, not only for Commission members, but also for the respective project leaders and for this reason similar visits to other centres will be arranged in future to coincide as far as possible with Commission meetings.

Cooperation with government departments and statutory organizations

The Commission's responsibilities cover a wide range of scientific disciplines and problem areas and it therefore cooperates very closely with a variety of government departments and statutory organizations in order to coordinate and promote water research as effectively as possible. In this respect the Commission has close ties with government departments and statutory organizations such as the Department of Water Affairs, Forestry and Environmental Conservation; Department of Agriculture and Fisheries; Department of Health, Welfare and Pensions; Department of Transport (Weather Bureau); the CSIR (National Institute for Water Research, Centre for Scientific and Technical Information, SA Wool and Textile Research Institute, National Physical Research Laboratory and National Building Research Institute); the Leather Industries Research Institute; the Fishing Industries Research Institute; the SA Medical Research Council; the SA Institute for Medical Research; provincial administrations; universities; the SABS and the Chamber of Mines.

Apart from the financing of research projects at the majority of these organisations, cooperation is also effected via their representation on study groups, coordinating research and development committees (CRD committees) and steering committees established by the Commission. The establishment of study groups and CRD committees for specific high priority problem areas is regarded as one of the most important and successful strategies developed by the Commission for promoting the coordination of water research. A study group is appointed to investigate and report on a specific problem area, after which the group disbands. A CRD committee, on the other hand, continues to function in that it identifies problems within a specific field; compiles master plans for research and priority research programmes; coordinates research within the relevant field; evaluates progress; and decides on the publication and application of research results. The re-

quirements and research programmes of the organizations involved are taken into consideration by such CRD committees and study groups in executing the Commission's task of coordinating and promoting water research. It should also be mentioned that the Commission's cooperation with government departments has led to research work, which, because of a shortage of manpower or expertise could not be initiated or which could not proceed satisfactorily, being initiated or expedited. In the cases involved, the Commission contracted overseas specialists who were then seconded to the departments.

In the 1979 annual report of the Commission, a complete report on study groups and CRD committees developed by the Commission was presented.

Water research with respect to the agricultural, industrial and local authority sectors

The research sponsored by the Commission is aimed at promoting efficient water utilisation and making available sufficient water to the country as a whole. Although water research in respect of a specific sector will undoubtedly affect other sectors, it is expedient to divide the research in accordance with the sector to which it is of primary importance.

Excellent work is being done by the Department of Agriculture and Fisheries; the Department of Water Affairs, Forestry and Environmental Conservation and the Department of Cooperation and Development in the field of *agricultural uses* of water, and the Commission sees its task in promoting, stimulating and supporting the work of these organizations where possible. Research with regard to water consumption in the agricultural sector is being done in terms of research contracts with departments and universities.

The Commission's policy with regard to research on water consumption in *industry* is that research which is supported should be of national importance, i.e. to the advantage of the industry as a whole and not to a specific member of that industry only. In this respect the Commission has established contact with the respective national associations of each specific industry. Another advantage derived from dealing with national associations of industrial groups is that when research comes up with results that may be usefully and advantageously applied, the national association, by virtue of its constitutional authority, can influence its members to accept these improved techniques.

Research into water and wastewater management in industry covers a wide range and in each sector a CRD committee is responsible for guidance and control. The committee comprises representatives of the various national associations belonging to that group.

In the case of *local authorities* essential research on mutual problems is financed by the Commission and in the process the expertise and facilities of the larger cities are of great value. The Commission enjoys the cooperation of a number of municipalities who are willing to make important contributions to specific research work. Under the auspices of the Commission a Study Group has been established which comprises senior officials of six of the largest cities in the Republic. The Study Group considers various problems and makes recommendations for research relating to water and wastewater management and the question of solid wastes insofar as these may pollute water supplies. Some of these recommendations have resulted in the initiation of a number of research projects, reported elsewhere in this report.

Technology transfer and partnership research

One of the most important functions of the Commission is the promotion of technology transfer because the application of research results represents the final dividend in the Commission's investment in research.

As stressed in previous annual reports, the Commission is firmly convinced that technology transfer (TT) should be built into the planning and execution stages of research work. In order that this may be done, two important principles must be observed, *viz.* that research should firstly be directed at well-defined goals, and secondly, that operational organisations should be involved in the planning stages and execution of the research work as far as possible.

In order to identify research needs the Commission has established CRD committees and study groups through which direct liaison is possible with operational organisations which can benefit from the development and application of new knowledge and technology. These committees and study groups are also used for the identification of research needs in a coordinated manner and to formulate projects in an objective manner and on a priority basis which are specifically aimed at these needs.

The second principle, i.e. to involve operational organizations in the planning stages and execution of research work as far as possible, is achieved through partnership research. Partnership research means involving potential users of research results in the planning stages and in the execution of research work by contracting such organizations as partners in the research.

It has become evident that the Commission has a key role to play in its support of water research in respect of projects which could not previously be initiated because of the excessive financial burden for one organization to carry. With the establishment of the Commission and as a result of its structure and unique position, these projects could be launched through partnership research. In addition to the Commission and the potential user (e.g. local authority or industry), partner-

ship agreements normally involve a third party such as the CSIR or a university which is contracted by the Commission to provide a scientific input. The industry or local authority also contributes to the research and is willing to accept responsibility for the project because of the mutual trust created by the partnership principle. In this way the communication gap between research scientist and possible user is bridged.

Typical examples of the successful application of research results in practice are the construction of units for the treatment of textile and tannery effluents reported later in this chapter.

There are several other more conventional techniques that the Commission uses or is planning to use, especially where contract projects have reached the stage where useful information is being generated. In each case the TT techniques adopted must be tailored to suit the nature of the information gathered and of the user organizations to be reached. The most important of these techniques are the publication of technical manuals and other practically orientated publications; TT seminars; demonstrations and training; and dissemination of information.

Utilisation of overseas expertise and contact with overseas specialists

During the year under review the Commission contracted, as in the past, overseas specialists to come to the Republic to deliberate (against the background of their overseas experience and in the company of local consultants and experts from the various sectors and government departments) on specific problems in this country's water affairs and to make recommendations for research pertaining to these problems. These overseas specialists contribute to the atmosphere which is conducive to objective discussions with the various parties concerned, which is so very important for effective coordination of research.

Through the years the Commission has also established important ties and relationships with certain overseas specialists and organizations in the water field and has succeeded in opening doors for South African scientists. This has been achieved primarily by person contact through which a relationship based on mutual trust has developed. In addition, South Africa has been taking a leading role in certain fields of water research to which the Commission has made a significant contribution (e.g. in water reclamation) and as a result of this has established a favourable image overseas.

The Commission is continually expanding its overseas contacts by entering into agreements for the exchange of information, by taking up membership of appropriate overseas and international organisations and by subscribing to media and services which concentrate on important developments in research and technology.

The Commission initiates specifically oriented overseas visits (which include staff of other organizations) in order to obtain information relative to specific problem areas or research fields. This is an important strategy for the transfer of proven overseas technology and practices to South Africa and to obviate unnecessary duplication in the form of local investigations. These visits are generally related to study group activities and subjects covered by such study groups have been the management of impoundments for the control of eutrophication; dry cooling; groundwater research; and municipal sludge management.

New research agreements

During the year 16 new contracts were negotiated with organizations in terms of which research in various fields will be undertaken. The principle of partnership research has been incorporated in the majority of these agreements — i.e. the potential user (in these cases it has been the various city councils) of the results has been involved in the planning stages and execution of the research work as a partner.

In the field of *water reclamation* the City Council of Cape Town has accepted responsibility for the construction and operation of the prototype Cape Flats water reclamation plant and for monitoring the quality of the reclaimed water. The University of Cape Town is undertaking the epidemiological studies in order to obtain background information which will serve as basis for comparison if water reclamation should be practised in the area in future.

Research on the *removal of nutrients* from effluents has been extended by means of an agreement with the University of Cape Town for the optimisation of the modified activated sludge process for nutrient removal.

The Commission has for some time now, been aware of the problems associated with the *treatment and disposal of sludge* and the potential danger that it poses as a source of pollution of surface and groundwater due to various disposal practices. After thorough planning and several investigations in this respect, including the use of an overseas consultant and the recommendations of a fact-finding mission abroad, which involved local authorities, the Commission initiated seven projects in connection with the treatment and disposal of municipal sludges. These projects deal with the recovery of single cell protein from sludge (contract with the University of the Orange Free State); dewater-

ing of sludge and treatment of sludge liquors (contract with the City Council of Port Elizabeth); disposal of sludge to sea (contract with the City Council of Durban); pasteurization and thermophilic anaerobic digestion of sludge (contract with the City Council of Cape Town); autothermic aerobic digestion of sludge (contract with the City Council of Johannesburg); composting of sludge by means of forced aeration (contract with CSIR — NIWR); and sludge characterisation (contract with CSIR — NIWR).

As far as *industrial effluents* are concerned, three new agreements have been entered into. Two of these are in connection with water management and effluent treatment in the textile industry which are being investigated in terms of agreements with the University of Natal. The third project concerns the optimisation and evaluation of the full-scale treatment of spent wine residues and will be investigated by the NIWR of the CSIR and the Municipality of Stellenbosch.

In the field of *irrigation research* two new agreements have been negotiated: the University of Pretoria will research the water requirements of certain agronomic and vegetable crops and the University of the Orange Free State will research the effect of various time periods and intensities of internal plant moisture stress on photosynthesis, respiration and effective water use of some agronomic crops.

Research on *surface hydrology* has been further extended by an agreement with the University of Natal for an investigation of the continuous modelling of the flow in South African rivers.

Water Research Commission funds

Sections 12 and 13 of the Water Research Act provide for a Water Research Fund consisting of:

a) moneys appropriated by Parliament for the benefit of the fund;

b) rates and charges levied under section 11; and

c) donations, bequests or contributions which the Commission may receive from any other source.

In the past the Water Research Commission derived its income exclusively from rates and charges on water use.

Since the first announcement on rates and charges (Government Notice No 214 of 18 February 1972) these have remained unaltered *viz.* 0,2 c/m^3 of water supplied for urban, industrial or domestic use, and an amount varying between 20c and 40c/ha of land scheduled for irrigation.

Income for the past 5 years is as follows:

1976	1977	1978	1979	1980
R2 876 149	R3 040 428	R3 213 824	R3 517 750	R3 648 700 (estimated)

These figures show that income has increased by approximately 7% annually. If the inflation rate, which has constantly been more than 10%, is taken into consideration, it means that real income has decreased. Until the present time the Commission has been able to offset this situation in two ways. Firstly, by using the reserve which had accrued during the early years of the Commission before projects requiring expenditure came on line and also from the interest on investment of surplus funds with the Public Debt Commissioners. Secondly, through partnership research, as described earlier in this chapter, which has been used whenever possible.

Apart from the obvious advantages of partnership research with respect to technology transfer, as emphasised earlier, the input contributed by research partners through facilities, manpower and also finances represents a considerable saving for the Commission on direct research expenditure.

Reserve funds, however, have dwindled over the last few years, as the result of the application of funds for beneficial and, in some cases, urgent research work. In order to meet the increasing demand for water research the Commission has proposed an increase in the tariffs for rates and charges.

Staff

Senior staff of the Commission, apart from the Chairman: Chief Executive Officer, consists of two Chief Advisers, four Senior Advisers, three Advisers, one Assistant Adviser, a Secretary-Treasurer and an Accountant. From time to time the Commission appoints specialist consultants for the execution of specific tasks. Consultants recruited locally are contracted for periods varying from a few months to three years whilst overseas consultants are recruited for short periods of approximately 10 to 30 days. The Commission currently employs three local consultants.

One of the local consultants, who had been in the service of the Commission since 1972, Mr A Kinmont, passed away on 10 December 1980. The late Mr Kinmont was formerly City Engineer of Durban and a well-known and valued person who played a leading role in the Institution of Municipal Engineers and had the interests of municipal engineers at heart. At the Commission he made an outstanding contribution to the promotion of water research, especially with respect to local authorities and industry. His unrivalled dedication and capacity for work, coupled with a gentle and unassuming personality, will always remain an example to his friends and colleagues.

FOCUS ON CERTAIN ACTIVITIES

Reports on projects and other activities of the Commission are presented in the respective chapters. Certain activities and developments during the year, however, deserve special mention.

Waterlit now available world-wide

The computerised bibliographic data base, *Waterlit,* developed by the South African Water Information Centre (SAWIC), is now available world-wide. This important new development came about as the result of the Systems Development Corporation (SDC) in California, USA, one of the largest distributors of data bases in the world, providing a service on *Waterlit.* The agreement between the CSIR (which acts on behalf of SAWIC) and SDC was signed during the year. SDC will pay a fixed amount for the magnetic tapes containing *Waterlit* and in addition, SAWIC will receive royalties.

The South African Water Information Centre is operated as an independent unit by the CSIR on behalf of the Commission and provides several information services on water and related fields. The most important of the activities of SAWIC, however, is the development and maintenance of *Waterlit.* The standard and wide coverage of this data base are of such a high quality that SDC is prepared to provide a service based on it.

Apart from *Waterlit* there are only three other computerised data bases in the world which contain information on water exclusively. Only one of these, *viz. Aqualine* of the Water Research Centre in the United Kingdom, completed only recently, is distributed world-wide by a competitor to SDC.

The agreement stems from a visit to SDC in the USA by a Senior Adviser of the Commission and the Head of SAWIC in 1979.

The agreement with SDC will ensure wider publication of research and development work in the water field in South Africa and will provide additional contacts for South African water research scientists.

Textile factories are to apply research results for the treatment of effluents

As a result of research financed by the Commission, two textile factories are planning the erection of full-scale units for the treatment of effluents from the dyeing of wool/synthetic fibres and sizing/desizing respectively. Full-scale effluent treatment will not only effect savings in chemicals (as a result of reclamation), but will also drastically reduce water consumption and decrease the cost of effluent treatment. In both cases the savings are such that the capital investment in the relevant units will be amortised within a reasonably short period.

The Water Research Commission has for a considerable period of time been financing an extensive research programme on water management and treatment of effluents in the textile industry — a programme which is being undertaken by the Chemical Engineering Department of the University of Natal. During the year under review a further two agreements were entered into with the University for research into dyehouse effluents of cotton/synthetic fibre and into the effluents of wool scouring plants.

Investigations are carried out in the University's laboratories prior to pilot-scale studies by the firms themselves. In the case of the two textile factories involved, on-site investigations with pilot plants were conducted and the firms participated directly in the research. In both cases the firms made considerable contributions in the form of equipment, facilities and supervision.

Although this work has been done in cooperation with two specific companies, it has been undertaken in the interests of the South African textile industry as a whole. To this end two demonstration sessions of the pilot plants were held. The first was limited to representatives of interested government departments, statutory bodies and research organizations and the second open to all interested textile manufacturers in the country.

A technical manual based on these investigations is currently being prepared and upon completion will be available for general distribution.

Technology for treatment of tannery effluent applied on larger scale

A research agreement in connection with the treatment of tannery effluent, entered into on a partnership basis with a tannery in Pretoria, has been successfully completed and the tannery concerned has decided to erect a full-scale plant in order to treat all their effluents in accordance with the technology developed. The City Council of Pretoria and the Leather Industries Research Institute have also been involved in the execution of this investigation. Some time ago the latter organization was contracted by the Commission to undertake a research programme on management and effluent problems in the hides and skins, curing, fellmongering and tanning industries.

In the past, the tannery in question pumped its wastewater to evaporation ponds because it could not comply with the City Council of Pretoria's requirements for discharge of the wastewater to sewer. The use of evaporation ponds as disposal method has several disadvantages, for example the risk of pollution of the water environment by seepage or flooding and the generation of nuisance odour problems which are environmentally unacceptable.

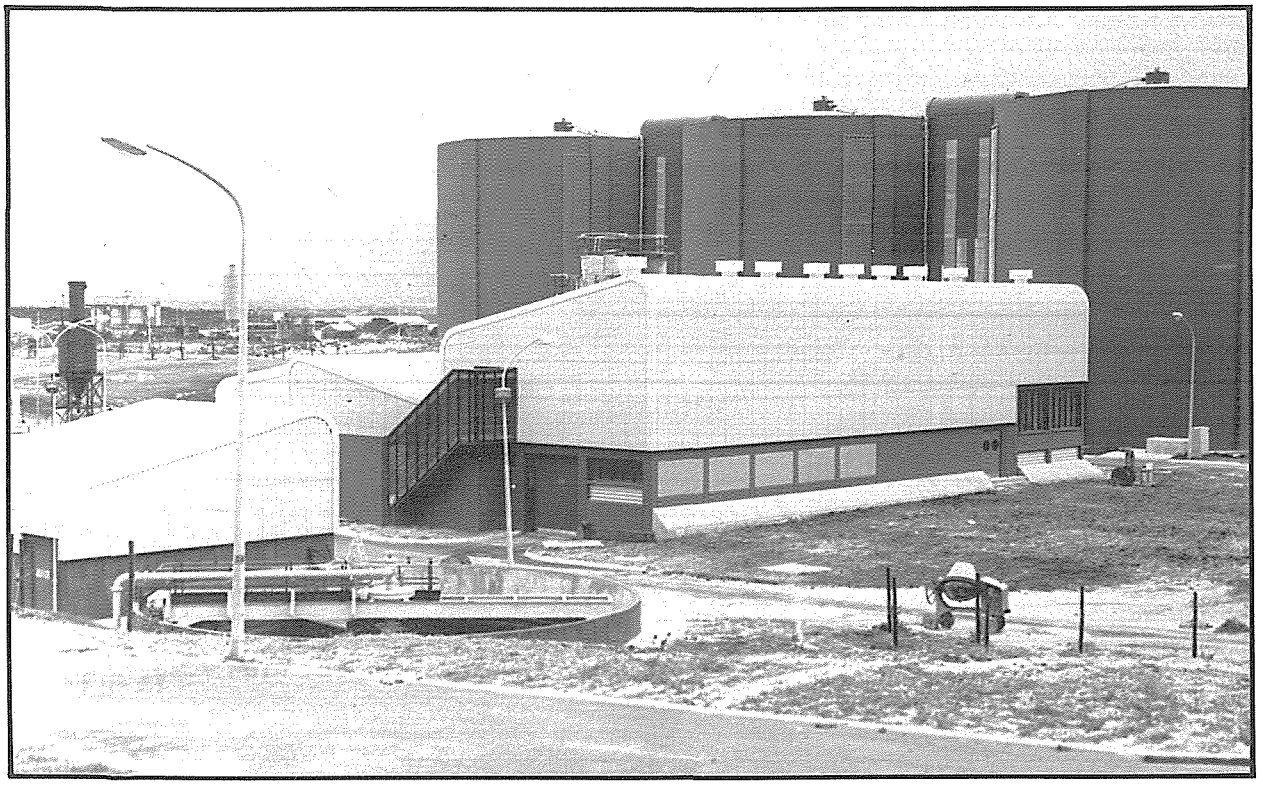
Studies on a pilot plant installed at the tannery on the use of air flotation with ferric chloride as coagulant led to a breakthrough in the treatment of mixed tannery effluent. The chemical oxygen demand, suspended organic solids and chrome content are reduced by 85%, 97% and 99% respectively. The treated effluent may be reused in certain sections of the factory and the effluent also meets the requirements for discharge to public sewer. By using a minimum of 80% green hides instead of salted hides, the problem of concentrations of inorganic salts in the effluent that are too high for discharge to sewer, can be overcome.

In order to ensure the successful large scale application of the technology developed, an action committee consisting of representatives of the tannery, the City Council of Pretoria, the Department of Water Affairs, Forestry and Environmental Conservation, and the Commission has been established. This Committee will ensure that the recommendations in the final project report will be applied in practice. Based on the final report, a manual dealing with the treatment of tannery effluent will be published.

Comprehensive research programme on the treatment and disposal of sewage sludge

Research on the treatment and disposal of sewage sludge has entered an important phase, with the Commission having negotiated seven new agreements. Four of these agreements are with city councils, *viz.* Johannesburg, Cape Town, Port Elizabeth and Durban, and the agreements are typical examples of partnership research where the potential user of the results is directly involved in the research and makes an important contribution to the work. Two of the remaining three con-

The Water Research Commission supports an extensive programme of national research in the field of sewage sludge treatment and disposal. The building in the foreground houses a sludge pasteurisation plant and is part of the Cape Flats Sewage Treatment Works where research in this field will be carried out. Sludge digestion facilities may be seen in the background.



tracts are with the CSIR (through the NIWR) and one with the University of the Orange Free State.

Sewage sludge is derived from the treatment of domestic and industrial wastewater and constitutes a potential source of pollution of surface and groundwater in view of various existing disposal practices. Local authorities play an extremely important role in the prevention of pollution and spend large amounts of money annually in the treatment of wastewater to ensure that it will comply with the requirements for discharge to rivers and streams. Sewage sludge treatment demands sophisticated and costly technology in much the same way as wastewater treatment. Health restrictions and the potential water pollution hazard impose serious limitations on sludge disposal practices of local authorities. These restrictions are expected to become more serious as stricter standards are imposed.

The Commission has for some considerable time been aware of the national importance of this problem and initiated the necessary groundwork which led to the adoption of the extensive research programme. In planning the research the Commission commissioned the services of a specialist consultant and then sent a fact-finding mission abroad. The report of the consultant and the fact finding mission were studied by a Committee established by the Commission, *viz.* the Research Review Committee for Local Authorities and the CRD committee for Solid and Toxic Wastes, and a Master Plan of research was compiled. The Master Plan consists of four sections, *viz.* sludge processing and treatment, sludge disposal, health aspects and the beneficial utilisation of sludge. The relevant research projects stem from this Master Plan.

New measure for limiting water pollution

During the year under review an important step in the prevention of water pollution was taken by the Minister when it was announced in the Government Gazette that the phosphate content of wastewater was to be limited. In terms of an amendment to the standards for industrial wastewater and effluent discharges, the orthophosphate content of treated effluent and wastewater must now be less than 1 mg/l (as P) before discharge in certain critical catchments. This step will contribute significantly in limiting one of the most well-known symptoms of pollution of the water environment, i.e. eutrophication, which is caused by the enrichment of water with plant nutrients such as phosphate. When enrichment reaches a certain order of magnitude, it causes excessive growth of algae and nuisance aquatic plants.

Since its inception the Commission has afforded high priority to research into the development of economical techniques for the removal of nutrients from wastewater. Because the introduction of the standard for phosphate has for some time been regarded as desirable, the Commission has been supporting projects aimed at the development of technology for the removal of phosphate from effluents. Two of the original agreements with the CSIR (through the NIWR) and the University of Cape Town in connection with biological removal of plant nutrients by means of a modified activated sludge process have terminated. In terms of agreements with the Commission, two further research projects are now being undertaken by the same organizations. This research relates to the evaluation and optimisation of the full-scale application of both biological and chemical nutrient removal from municipal wastewater at sewage works in Johannesburg and Pretoria. Towards the end of the year an agreement was negotiated with the University of Pretoria for research on biochemical processes which effect phosphate and nitrogen removal in the modified activated sludge process.

Technology for the removal of nutrients from wastewater is largely available but is being developed still further. Naturally it is of paramount importance that the technology which is developed should be successfully applied and for this reason technical guides and design manuals are being prepared. In 1979 the Commission, in cooperation with various organizations, also arranged a seminar on the removal of nutrients from municipal effluents. The proceedings of this seminar have been published and are available.

Fight against water pollution in the PWVS complex enters a new phase

The research project on water pollution in the Pretoria-Witwatersrand-Vereeniging-Sasolburg complex (PWVS complex) that has been supported by the Commission since 1975 and terminated at the end of 1980 will be taken over and continued by the Directorate of Water Affairs of the Department of Water Affairs, Forestry and Environmental Conservation. The Department, which has been closely associated with this project and therefore has a clear insight into the activities, has decided that the project and the results are of sufficient value for the Department to assume responsibility for the project from January 1981 onwards.

The PWVS complex is characterised by a high demand for water and also by the fact that treated sewage and industrial effluents, as well as stormwater runoff are being discharged at an increasing rate to the Barrage, from which most of the water for domestic and industrial consumption is taken. During the past few years there has been a marked deterioration in the Barrage water quality and in the Vaal River further downstream. Research on pollution control and water reuse has been supported by the Commission and undertaken by a firm of consultants, appointed as project managers, in cooperation with the Hydrological Research Unit of the University of the Witwatersrand. Mathematical models

have been developed for the daily variation in the mineral salts in the system and an attempt has been made to find a practical solution to the problems of increased mineral salt content.

Complementary to this work, the Commission has launched an investigation into the cost implications to the individual water consumer and the industrialist of a water with increased mineral content. If these costs can be determined, it will assist in the development of a strategy for combating or decreasing further trends in mineralization.

The Department has an important responsibility with respect to water supply and in cooperation with the Rand Water Board (with respect to the latter's area of supply) will utilise the results of the project, especially the mathematical models, to the best advantage in the supply of a water of suitable quality from the Vaal River.

Groundwater resources in the Cape Flats to be developed

A Committee for the development of groundwater resources in the Cape Flats was established during the year under review, with representatives of the City Council of Cape Town, the Department of Water Affairs, Forestry and Environmental Conservation and the Commission. The establishment of this committee is the result of earlier investigations which indicated that the storage of groundwater in the sand deposits of the Cape Flats could be a useful auxiliary source of water for Cape Town. The initial task of this committee will be to study the final reports of the two relevant Commission projects which have been concluded and to use that information as a basis for future planning.

One of the projects referred to was undertaken by the University of Stellenbosch under contract to the Commission. The study involved an investigation of the feasibility of storing water from the Eerste River and from its most important tributary, the Kuils River, in the sand deposits adjacent to the False Bay coast. The final conclusion drawn from the investigation was that this is physically possible. Information gathered on the surface hydrology, geohydrology and water quality in the area concerned may be used to determine the economic feasibility of such a scheme.

The other project was undertaken on contract to the Commission by the CSIR (through the NIWR) and dealt with the geohydrology of the sand deposits of the Cape Flats. The aim of this investigation was to determine the potential storage possibility of the sand deposits and to obtain an indication of the amount of natural groundwater which may be extracted and utilised on a

The feasibility of storing water from the Eerste and Kuils Rivers in the sand deposits of the Cape Flats has been investigated. The information gleaned from this research will be used to determine the economic viability of this scheme. The picture shows the Kuils River after it has burst its banks.

continuous basis from the sand deposits. To this end a simulation model has been developed which may be advantageously used in future planning. The geohydrology of the aquifer system as well as its water potential were also determined.

Water reclamation on Cape Flats progressing

A prototype water reclamation plant is to be erected on the Cape Flats by the City Council of Cape Town in terms of an agreement with the Commission. The City Council, contracted as a partner in the agreement with the Commission, will contribute on an equal basis towards the cost for the operation of the plant and will pay for the operating expenses of the plant.

Since 1973 the Commission has been supporting research on water reclamation in the Cape Peninsula with a view to the augmentation of expected shortfalls in water supplies. The two existing contracts with the CSIR (through the NIWR) and the City Council of Cape Town in connection with water reclamation in the Cape Peninsula were terminated and the research reached the stage that a decision was made to erect a prototype reclamation plant as a precursor to full-scale reclamation should this be implemented at a later stage. The emphasis on this project will be to demonstrate water reclamation in practice by means of the prototype plant. It is planned that the plant will be operated as a demonstration unit for at least a year after optimisation of its performance. Monitoring of all aspects of water quality will still remain a fundamental part of the project as well as quality control in the drainage area.

Because of the possible utilization of reclaimed water as a complementary water supply source in the Cape Peninsula, it is considered essential that the consumer be fully and correctly informed and consequently extensive public relations programmes and dissemination of information to the public are being planned. These programmes are being planned by the City Council of Cape Town in cooperation with the Commission and the Departments of Water Affairs, Forestry and Environmental Conservation and of Health, Welfare and Pensions and will be carried out by these organizations.

During the year under review, the Commission entered into an agreement with the University of Cape Town in connection with epidemiological studies related to possible reclamation and reuse of reclaimed water in the Cape Peninsula. The investigation is aimed at the collection of epidemiological data on water consumers and which may serve as a basis for comparison with future epidemiological data should the reuse of water become reality. A comparative study of this nature is regarded as final assurance that the use of reclaimed water will not detrimentally affect consumers.

Membranes for desalination now manufactured locally

Membranes for the desalination of water by means of reverse osmosis are to be manufactured by a local firm. During the year under review the Commission entered into an agreement with the firm in terms of which the Commission will make available to the firm the required expertise for the manufacture of tubular membranes of cellulose acetate.

The Commission has been supporting desalination research for some time now in order to obtain the optimal use and reuse of saline waters and effluents. In its support of this research, the Commission concentrates on desalination techniques such as reverse osmosis, ultrafiltration and ion exchange for the desalination of water containing high concentrations of dissolved salts.

Considerable emphasis has been placed on reverse osmosis as a desalination technique and promising results have been obtained. One of the projects in this respect deals with the development of membrane support systems and modules for reverse osmosis units. This project is being undertaken in terms of an agreement with the CSIR (through the NIWR). The knowledge and expertise for the manufacture of membranes, developed during this project, will now be utilised by the firm.

The firm itself has contributed significantly in this field in the development of a module which is considerably cheaper than its imported counterpart. In terms of the agreement with the Commission the firm will actively strive to manufacture and market the reverse osmosis membranes and modules and the Commission will receive royalties. The Commission has also reserved the right to review the agreement after a period of time in view of progress made in manufacturing and marketing of the membranes.

Irrigation research

It is calculated that the agricultural sector is currently responsible for approximately 75% of the annual water consumption in the Republic and it is therefore in everybody's interest that irrigation water should be used as effectively as possible. Estimates show that as a result of the ever increasing water demand associated with the development of industries, mining, and towns, only 45% of the total water consumption by the end of the century will be used for agriculture (although it is expected that the agricultural use of water will be increased). This means that the agricultural sector will have to compete strongly for its rightful share of available water in future. It is, therefore, of the utmost importance that the available water supplies should be used judiciously. The Commission of Enquiry into Water Matters express-

ed the opinion in 1970 that a saving of 25% should be aimed for in the use of water for irrigation purposes. This aim can only be realised if irrigation is practised on a more scientific basis, if improved irrigation methods are used and wastage eliminated. In this way, total yield from irrigation could still increase for many years.

In view of the above, the Commission has, since 1975, been supporting irrigation research of national importance and which will directly benefit the irrigation farmer. The Commission has launched ten irrigation research projects of which two have been completed and one initiated during the year. In promoting this research the Commission makes use of expertise which exists at universities or which has been developed there as a result of the Commission's support. The Commission cooperates very closely with the Department of Water Affairs, Forestry and Environmental Conservation and the Department of Agriculture and Fisheries and overseas specialists have already been recruited and seconded to the latter Department to augment available manpower.

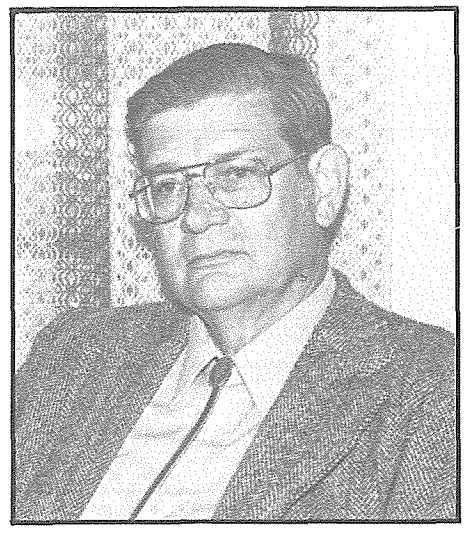
In supporting irrigation research the Commission lays great emphasis on those projects which will exert the greatest influence with respect to optimal water utilisation. The most important of these is related to water requirements of crops, and, stemming from this, scientific scheduling of irrigation.

For the application of research results in practice, the Commission publishes and distributes final project reports to the respective organizations and persons involved, amongst others to the Department of Agriculture and Fisheries, in order to promote the transfer of technology through its extension officers, and to the Department of Water Affairs, Forestry and Environmental Conservation, for improved planning and administration of irrigation schemes. Other methods such as the use of agricultural magazines and radio will also be employed to bridge the gap between results and their application.

The influence of agricultural land use on hydrology

During the year under review, specific attention has been paid to the effect of agricultural land use and catchment management on the water resources of South Africa. This aspect is seen by the Coordinating Committee for Hydrological Research (CCHR) as having a high priority in hydrological research and a workshop on this topic was arranged.

Agricultural land use, whether for agricultural or afforestation purposes, plays an important role in the runoff of a catchment. This involves not only the volume of water reaching rivers, but also the quality of the water. The CCHR arranged the workshop in order to clarify research priorities in this multidisciplinary field. The workshop was attended by a large number of representatives from universities, government departments, statutory and other organizations as well as by an overseas consultant. The consultant is Prof John Hewlett of the School of Forest Resources of the University of Georgia and his visit was made possible by the Commission. Prof Hewlett made an important contribution to the workshop in that he was not only able to share the knowledge acquired in various countries, but could also apply this knowledge and make important recommendations in the light of his visits to various regions of the Republic. The resolutions and discussions of the workshop are now being coordinated and processed by the CCHR.



Prof John Hewlett, forest hydrologist from the USA who visited the Republic as a consultant to the Water Research Commission.

For several years now the Commission has been supporting hydrological research as is reported elsewhere in this report. As far as the coordination of hydrological research is concerned, the Commission and the former Department of Water Affairs, held joint discussions on the matter and in 1977 decided to establish a Coordinating Committee for Hydrological Research. This Committee is responsible for the overall coordination of research regarding the hydrological cycle in South Africa. The CCHR is operated by the Directorate of Water Affairs of the Department of Water Affairs, Forestry and Environmental Conservation.

Chapter 2

Water reclamation

Water reclamation is still regarded as an important supplementary source of water supply and the Commission supports several research activities in this regard. During the year under review research progressed well and the organizations concerned are, to an increasing extent, prepared to increase their inputs into research on water reclamation.

Important progress has been made with the research which the Commission has been supporting in the Cape Peninsula since 1973. As mentioned in Chapter 1, the two existing contracts with the CSIR (through the NIWR) and the City Council of Cape Town have been terminated and it was decided to erect a prototype reclamation plant, should full-scale reclamation be instituted. The accent in this research project will be on the use of the prototype plant for demonstrating water reclamation in practice. It is envisaged that the plant, after optimisation of its performance, will be operated for a period of at least one year as a demonstration unit. Monitoring of all aspects of water quality will remain a fundamental part of the project, as well as quality control in the drainage area. In addition, the City Council of Cape Town, in cooperation with the Commission and the Department of Water Affairs, Forestry and Environmental Conservation and the Department of Health, Social Welfare and Pensions, will develop programmes for public relations and the dissemination of information to the public should reclaimed water be utilized as a supplementary water supply source in the Cape area.

As mentioned in Chapter 1, the Commission entered into an agreement with the University of Cape Town during the year under review in connection with epidemiological studies with respect to the reclamation and use of reclaimed water in the Cape Peninsula. The investigation is aimed at the collection of epidemiological data which may serve as a basis for comparison with future epidemiological data should the reuse of water become reality. A comparative study of this nature is regarded as the final assurance that the use of reclaimed water will not detrimentally affect consumers.

Microbiological monitoring of the reclaimed water of the Windhoek plant was continued during the year, and, as in the past, the water produced was of an excellent quality. The Windhoek Reclamation Plant produced reclaimed water for the major part of the year since it was necessary to supplement conventional supplies. Monitoring and investigations into active carbon adsorption and the removal of residual organic substances have been continued.

During the year the City Council of Pretoria successfully operated the Stander Water Reclamation Plant at Daspoort. The aim of this project, on the one hand, was to illustrate that a local authority is capable of operating a water reclamation plant as part of its normal routine and operating practice, and, on the strength of its findings, cost-benefit studies of production and possible use of reclaimed water will be done. Another important aspect of this research project is the development and execution of a programme for catchment quality control. Owing to staff shortages, however, these activities could not be pursued for the greater part

of the year; a situation which was rectified towards the end of the year.

The agreement with the City Council of Cape Town and the CSIR in connection with the reclamation of water at Athlone Works was completed towards the end of the year and final reports are currently being compiled. At this stage a follow-up project is not being considered because the sewage works is currently being modified and extended and possible continuation will only be considered when work is completed.

RESEARCH PROJECTS

Reclamation of water at the Athlone Sewage Works, Cape Town

(Existing project: Contract with the Municipality of Cape Town and the CSIR — National Institute for Water Research)

This project was completed at the end of the year. The aim of the project was to investigate the reclamation of wastewater discharged to the Athlone Sewage Works in Cape Town, with a view to its reuse by certain industries. The wastewater is characterised by a high percentage of industrial effluent.

The reclamation plant consists of a series of physico-chemical treatment processes with a biological process which is an integral part of the process configuration. The plant was operated for a period of approximately 3 months with ferric chloride as primary coagulant. Due to the fact that the alkalinity of the water is very low, certain problems were encountered which were absent when lime was used as coagulant. The problems were overcome by altering the process configuration in such a manner that chemical precipitation was preceded by the biological purification stage.

Investigations were also carried out in connection with the use of the reclaimed water in laundries. Investigations with full-scale washing machines yielded satisfactory results, but it would seem to be desirable to soften the reclaimed water before using it for this purpose.

The City Council of Cape Town is currently extending and modifying the Athlone Sewage Works and the decision was taken, therefore, not to launch a follow-up project on water reclamation at the plant at this stage. A decision will be taken after all alterations have been completed.

Research on water reclamation and pollution control: Operation of the Stander Water Reclamation Plant by the City Council of Pretoria, the implementation of surveillance programmes relevant to health aspects and the application of catchment quality control

(Existing project: Contract with the City Council of Pretoria and the CSIR — National Institute for Water Research)

At the end of 1979 the City Council of Pretoria assumed responsibility for operating the Stander Water Reclamation Plant and it was, in fact, operated continuously for a period of approximately eight months.

This formed part of some of the objectives of the project, *viz.* to illustrate that a local authority is capable of operating a water reclamation plant as part of its normal duties. In addition, and on the strength of its findings, cost-benefit studies of production and the possible use of reclaimed water will be done.

A monitoring programme on the reclaimed water is also being carried out by the CSIR and the SA Institute for Medical Research (SAIMR) to determine its suitability for human consumption. Investigations have proved that the quality of reclaimed water during periods of continuous operation met the requirements for this purpose. One aspect, however, has been identified for which there is a degree of uncertainty. This is the formation and removal of volatile chlorinated hydrocarbon compounds and especially their implication for the frequency with which active carbon should be regenerated and for the economics of the process as a whole.

A further aspect which forms part of the project is the establishment and execution of a programme of catchment control. The objective is not only to identify substances which may occur in the reclaimed water and which may be toxic, but also to provide for their removal. This investigation commenced during 1980 but owing to the fact that suitable staff could not be recruited progress has been minimal.

Technological development of water reclamation on the basis of the Windhoek plant

(Existing project: Contract with the Municipality of Windhoek and the CSIR — National Institute for Water Research)

The Windhoek Water Reclamation Plant has for different periods in the past, and again in the year under re-

view, played an important role in the water supply of the city. This was done by integrating the reclaimed water with the conventional supply in the distribution system.

The modification of the plant, previously decided on, was completed towards the end of 1979 and the production of reclaimed water again resumed during February 1980. The modifications comprised the replacement of the high lime process, ammonia stripping and recarbonation by alum clarification and interstage chlorination. These modifications were necessary because the new activated sludge sewage purification works, constructed in 1979, had produced a very high quality effluent and there was no need for ammonia stripping. Furthermore, the high lime process was successfully replaced by a process of alum clarification and interstage chlorination which is a much simpler and more economical alternative.

The quality of the water is closely monitored as part of the quality surveillance programme. One aspect which is under close scrutiny is the formation and removal of volatile halogenated hydrocarbons (VHH) during the reclamation process. The most important role of activated carbon in the removal of these compounds and their precursors was again confirmed. Another important aspect in preventing formation of VHH is the strict control of interstage chlorination.

The quality of the reclaimed water during the year once again conformed to all standards set for reclaimed water for potable use.

Microbiological quality and health aspects of drinking water

(Existing project: Contract with the South African Institute for Medical Research)

In terms of this contract the microbiological quality and health aspects of drinking water are investigated and reclaimed water from the Windhoek Water Reclamation Plant and from the Stander Water Reclamation Plant at Daspoort, Pretoria, is monitored. During the year under review the investigation concentrated mainly on the reclaimed water from the Windhoek Plant.

As in previous years the water produced at the Windhoek Water Reclamation Plant was monitored for microbiological quality by the South African Institute for Medical Research (in terms of a contract with the Commission) in collaboration with the Windhoek Municipality, the Department of Water Affairs, Forestry and Environmental Conservation and the National Institute for Water Research. The water was again shown to be of excellent quality.

The plant had been modified and the production of reclaimed water was again resumed in February 1980 and the water integrated with the conventional supply system. This was after an interval of 22 months during which only conventional water was consumed by the people of Windhoek. Epidemiological studies which had continued uninterrupted throughout the year failed to show any adverse effects on the incidence of gastro-enteritis since consumption of reclaimed water was resumed.

Epidemiological studies pertaining to the reclamation and reuse of purified sewage effluent in the Cape Peninsula

(New project: Contract with the University of Cape Town — Department of Community Health)

In various countries, including the United States of America and South West Africa-Namibia, surveillance programmes have been developed which are directed at the determination of the status of health of communities receiving reclaimed water. All of these studies were retrospective studies. A prospective survey of health patterns in an urban community and their possible changes with time is planned in view of the possible utilization of reclaimed water as a supplementary source of water supply in the Cape Town area. Observed health patterns will be correlated against a variety of epidemiological parameters in order to develop an integrated health data base for the greater Cape Town area. This will allow observation of any changes which may occur in the health status of the community should reclaimed water be utilized as a supplementary source of water supply.

The construction and operation of the Cape Flats Prototype Water Reclamation Plant and the surveillance of reclaimed water quality

(New project: Contract with the City Council of Cape Town)

This agreement came into effect in January 1980 and is scheduled for a duration of 5 years. The project stems from previous research on water reclamation at the Cape Flats where oxidation pond effluent was reclaimed for infiltration and abstraction studies by the NIWR of the CSIR. During 1979/80 a new activated sludge sewage purification plant, designed for biological nutrient removal, was commissioned at the Cape Flats site where the construction of the 4,5 Ml/d prototype reclamation plant is currently nearing completion.

The main objective of this reclamation project is to demonstrate on a prototype scale the technical and eco-

nomical feasibility of reclaiming water for unrestricted reuse.

Some of the process units for this prototype plant were previously constructed as part of the interim reclamation plant. Construction of all the other required units is currently under way and is scheduled for completion towards the end of 1982. After that the plant will be commissioned, its performance optimised and then continuously operated as a demonstration plant for a period of at least one year.

During this period an investigation will be conducted as to the most economical and beneficial route for reuse of the reclaimed water.

Research on the development and application of aspects of equilibrium chemistry and precipitation kinetics to water stability problems encountered in water reclamation

(Existing project: Contract with the University of Cape Town — Department of Civil Engineering)

Research sponsored by the Commission has indicated that problems with water stability, either scale formation or corrosion, may be experienced when sewage effluents are reclaimed for potable reuse. The ultimate aim of this project is, therefore, to develop a guide for the stabilisation of reclaimed waters. This guide will be aimed primarily at plant operators, chemists and designers.

During the year research has centred principally on two aspects *viz.* the formulation of simple graphical methods for estimating chemical dosages to stabilise reclaimed waters and, secondly, an investigation of the corrosive behaviour of reclaimed waters on metal pipes and fittings.

Considerable effort went into developing a suitable theoretical basis for the compilation of conditioning diagrams. A breakthrough was made in this field, in that a method was developed for accurately estimating single ion activities in aqueous systems with salt concentrations of up to approximately ten times that of sea water. Accurate estimates of single ion activities are an essential prerequisite to the development of simple graphical conditioning diagrams.

Water quality criteria for inhibition of corrosion of metal pipes carrying treated and untreated waters derived from natural sources as well as from reclaimed water, are still not well understood. Consequently, in order to formulate hypotheses linking water quality to corrosion rates and corrosion pacification, the corrosive effects of synthetic waters on cast iron specimens are being investigated in terms of the parameters pH, buffer capacity, cálcium carbonate saturation state and salinity, simulating reclaimed waters. Subsequently reclaimed waters produced by operational full-scale plants will be studied with the objective of delineating stabilisation procedures to minimize both corrosion and precipitation.

Chapter 3

Groundwater

In order to rationalize the groundwater research programme in South Africa, a specialist consultant to the Commission presented a situation statement on matters relating to groundwater which included a programme of investigation, research and development aimed at the optimal utilization of the available groundwater resources. The report was formulated to provide recommendations that accommodate the requirements of the Department of Water Affairs, Forestry and Environmental Conservation. These recommendations are to be integrated with the findings of an overseas delegation comprising representatives of the Commission, the Division of Geohydrology of the Department of Water Affairs, Forestry and Environmental Conservation and the Institute for Groundwater Studies at the University of the Orange Free State. The delegation visited various centres in Israel, the Netherlands, the United Kingdom and the United States of America with the specific objective of assessing the latest trends and techniques in the field of groundwater research. In order to meet the immediate objective of adequate quantification of the most important groundwater resources, it is evident that much emphasis will have to be laid on building up expertise in groundwater modelling skills, the use of tracers and environmental isotopes and research leading to an improved knowledge of the movement of moisture in the unsaturated zone.

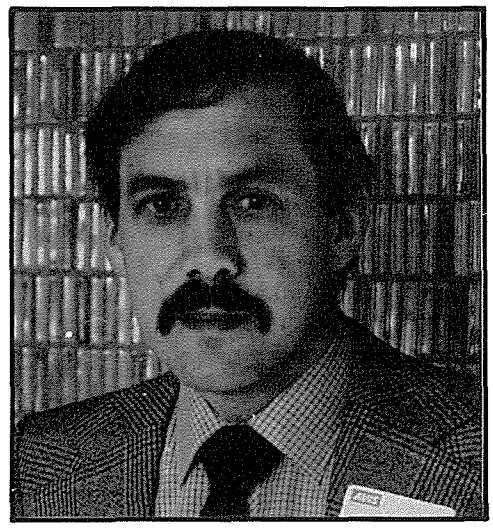
Investigations of the sand deposits of the Cape Flats, financially supported by the Commission, have indicated that groundwater in the sands could play an important role as a local source of water for Cape Town. As has been said in Chapter 1, a "Working Committee for the Development of the Groundwater Resources of the Cape Flats" was formed with representatives of Cape Town Municipality, the Department of Water Affairs, Forestry and Environmental Conservation and the Water Research Commission. The initial task of the Committee will be to study the final reports of two Commission projects which have recently terminated and have direct relevance to the activities of the Committee. One of the projects was carried out by the National Institute for Water Research of the CSIR and concerns the geohydrology of the sand deposits in the Cape Flats. A digital simulation model was used in this study to evaluate the design and predicted consequences of various configurations of extraction well fields and pumpage rates. As a result of the model studies, two alternative well fields have been suggested for exploitation of the groundwater resources in the sand deposits. The second report provides the results of the research emanating from the project on the utilization of the water from the Eerste River by means of storage in sand beds or other methods, which was carried out by the Department of Civil Engineering at the University of Stellenbosch. The research has shown that infiltration of water from the Eerste River and its tributary, the Kuils River, into the sand beds and then subsequent recovery of the water by extraction wells is a feasible proposition. These two reports will provide valuable information for the Committee and will form the basis of further investigations of the feasibility of developing these potential additional sources of water supply for Cape Town.

The Commission brought a groundwater consultant, Mr DB Oakes of the Water Research Centre in England to the Republic with the purpose of providing the Department of Water Affairs, Forestry and Environmental Conservation with advice on numerical modelling of stream/aquifer systems in the Breë, Hex and Crocodile River catchments. During his visit Mr Oakes also presented a paper at the Groundwater Symposium held in Pretoria from 7 to 9 July. The symposium was organised by the Groundwater Division of the

Geological Society of South Africa in collaboration with the Division of Hydraulic and Water Engineering of the SA Institution of Civil Engineers and the organisers have produced extended abstracts of the 36 papers that were read.

The Doornberg fault zone project which was carried out by the National Physical Research Laboratory of the CSIR in conjunction with the Institute for Groundwater Studies of the University of the Orange Free State, has been completed and the results show that the joints from which large quantities of water flowed into the Orange-Fish Tunnel during 1969 are probably not linked to the Doornberg fault zone. In addition, no evidence was found that the fault zone, at depth, is an important aquifer. The report on this project contains a wealth of geophysical, chemical, geohydrological and geological data that have greatly advanced knowledge of the groundwater resources in the vicinity of Venterstad, De Aar, Prieska, Beaufort West and Kenhardt.

This chapter also contains a report on the research in connection with the project concerning the exploitation potential of groundwater resources in the Southern Free State and Northern Cape which is nearing completion. It is anticipated that this project will constitute the major focus of attention in groundwater research during the coming year.



Mr DB Oakes, a groundwater specialist from the United Kingdom who was brought to the Republic by the Commission to advise on numerical modelling of stream/aquifer systems.

RESEARCH PROJECTS

Utilization of water from the Eerste River by means of storage in sand beds or other methods

(Existing project: Contract with the University of Stellenbosch — Department of Civil Engineering)

The aim of this project has been to determine the feasibility of storing water, which is not being utilised in any other scheme, from the Eerste River and the Kuils River, in the sand deposits in the eastern part of the Cape Flats. This water, which would otherwise flow to sea, would then be utilized by storing and subsequent abstraction from the sand deposits. The project has been completed and the final report compiled. As mentioned in Chapter 1, the report is now being studied by a committee which is studying the development of groundwater sources in the Cape Flats with a view to the possible institution of a scheme for the storage and abstraction of water.

The annual volume of water available for storage in the sand deposits by the year 2000 has been estimated, as well as the annual variation in the volume of available water. The storage capacity and permeability of the sand have also been investigated. In addition the concentration and composition of dissolved salts in the groundwater and river water have been determined with the aim of estimating the salt content of the water which may be made available through such a scheme. This information is necessary to determine the treatment required to render the water suitable for human consumption.

Methods for the planning, design and operation of such a scheme have been suggested and a method has been suggested to enable a satisfactory balance between the withdrawal of river water and the abstraction of groundwater. This will enable cost estimates to be carried out and selection of the most economical scheme. The limited experience gained during the research project into the abstraction of groundwater from the sand deposits could be useful in the design of a full-scale abstraction system.

The results have indicated the volume of water which will be available annually i.e. 38 million m^3 of which 22,5 million m^3 will be obtained from the Eerste River and 15,5 million m^3 from the Kuils River.

Development and evaluation of techniques for determining the exploitation potential of groundwater resources in the Southern Free State and Northern Cape

(Existing project: Contract with the University of the Orange Free State — Institute for Groundwater Studies)

The development of techniques for the evaluation of groundwater resources in South Africa has been one of the main objectives of the current research programme conducted by the Institute for Groundwater Studies in terms of an agreement with the Water Research Commission. In this project the emphasis is on techniques for determining the exploitation potential of groundwater resources in the Southern Free State and Northern Cape.

One of the main reasons why groundwater resources in South Africa have often been ignored as a continuous source in the past, is the complexity of the system and the lack of methods to evaluate and administer the system, as in the case of a surface supply source.

During the year the Institute made important breakthroughs in this respect, in that mathematical techniques were adapted and refined to such an extent that the accuracy of the groundwater models has been improved considerably. As a result of this, complex groundwater systems may now be administered and investigated to the same extent as surface water resources by means of these models. Models have reached such an advanced stage that the movement and extent of dispersion of a contaminant in the groundwater system may be predicted. In areas where pollution of groundwater resources is a possibility, these models may be used to good advantage to prevent any detrimental effect.

During the year research was stimulated by the donation by a company of an aircraft to the Institute. The only condition to this donation is that the aircraft should only be used for geohydrological research.

This aircraft has been donated by a company to the Institute of Groundwater Studies of the University of the OFS for the promotion of geohydrological research.

Development and evaluation of techniques for determining the exploitation potential of groundwater resources along the Doornberg fault zone

(Existing project: Contract with the University of the Orange Free State — Institute for Groundwater Studies, and the CSIR — National Physical Research Laboratory)

This project commenced in 1975 stemming from the large quantities of groundwater found in the Orange-Fish Tunnel during excavations in 1969. The groundwater has been associated with a zone which can be traced in a westerly direction to the so-called Doornberg fault zone near Prieska and it is suspected that the formation of the joints could be linked to this fault zone. Against this background it was decided that the exploitation potential of groundwater resources in this Doornberg fault zone should be investigated and as a result, the development of techniques for this purpose were investigated.

The project was completed at the end of the year and during the year under review the emphasis was on the compilation of the final report. This final report will consist of the following sections:

Part 1 — Introduction and summary

Part 2 (a) — Venterstad vicinity — geophysical studies

(b) — Venterstad vicinity — geological and geohydrological studies

(c) — Venterstad vicinity — natural isotopes

Part 3 (a) — De Aar and Prieska vicinity — geophysical studies and geohydrological investigation of the Prieska area

(b) — Prieska vicinity — geological studies

Part 4 — Kenhardt vicinity — geophysical and geohydrological studies

In addition to these four parts the Natural Isotopes Division of the National Physical Research Laboratory also compiled a report on the occurrence of natural isotopes in the groundwater of the Beaufort West vicinity. Since this work is indirectly related to the Doornberg fault zone project, this report will be included in the final report.

Briefly it may be stated that the cause of the waterbearing joint zone in the Orange-Fish Tunnel and its relationship to the Doornberg fault zone has not been finally determined. However, the zone in which the Doornberg fault zone occurs under a cover of Karoo formations, has been better defined by means of geophysical techniques. Apart from an area close to the Orange-Fish Tunnel, there are no large linearly structured groundwater occurrences which relate to the tectonic period in which the Doornberg fault zone came into being. The detailed geological mapping has been of great value to a better understanding of the tectonic history of the area especially around Prieska. Chemical analyses of groundwater samples as well as the study of the occurrence of various isotopes in these samples yielded informative results and were important in determining recharge areas.

A wealth of geophysical, chemical, geological and geohydrological information has been collected and processed during the project and has considerably enhanced knowledge of this area of the Karoo and the North Western Cape. It will also be of inestimable value in further and related research undertaken in this area in future.

Chapter 4

The water environment

Through the rapid growth in population and the concomitant urban, industrial and agricultural development, the quality of surface water supplies will unavoidably deteriorate. This, in turn, will adversely affect man's utilization of the water environment. For this reason the Commission has, for several years, been sponsoring research on issues relating to the water management.

One of the best-known symptoms of pollution in the water environment is that of *eutrophication,* i.e. the enrichment of water with plant nutrients (mainly nitrogen compounds and phosphates) to such an extent that the excessive growth of algae and nuisance aquatic plants such as hyacinths, occur in impoundments. This leads to several restrictions in the utilization of the water.

In dealing with the eutrophication problem it is necessary to adopt two methods of approach. Firstly, an attempt must be made to eliminate plant nutrients at their point of origin as far as possible. As indicated in Chapter 1, a first step in containing eutrophication has been taken by the authorities by limiting the concentration for phosphates discharged via wastewaters or effluents to certain critical areas. Several projects supported by the Commission are aimed at developing and improving techniques for the removal of plant nutrients from effluents, details of which are given in Chapter 5.

The second and complementary approach in dealing with eutrophication is to develop management strategies for the water environment in order to ameliorate the impact of eutrophication. With regard to this approach, the Commission supported a long term project at the National Institute for Water Research (NIWR), aimed at investigating the occurrence of eutrophication in South Africa and the development of guidelines for its control. In this regard two publications have been published jointly by the Commission and the NIWR, *viz.* "Guidelines for the Control of Eutrophication in South Africa" and "The Limnology of Selected Impoundments in South Africa".

During 1980 the NIWR has also undertaken (in terms of an agreement between the Commission and the CSIR) a short-term exploratory project in connection with the establishment of an adequate scientific basis for the management of eutrophication in South African impoundments. Details of this project appear later in this chapter.

In order to assess the current state-of-art concerning the management and control of eutrophication, a study group comprising representatives of the Department of Water Affairs, Forestry and Environmental Conservation, the CSIR and the Commission was sent overseas under the aegis of the Commission. The group has come forward with new perspectives on in-dam eutrophication management and control techniques, as well as the role mathematical modelling can play in this field. Their recommendations will give direction to future research, and will be of considerable value to the Department in its current management and control of eutrophication.

Another project sponsored by the Commission which is directly related to the water environment and is dealt with in this chapter, concerns *pollution control*

and water reuse in the Pretoria-Witwatersrand-Vereeniging-Sasolburg (PWVS) complex. This area is characterized by a high demand for water and by the fact that treated sewage and industrial effluents are to an increasing extent finding their way, together with stormwater runoff to the Barrage, which is an important link in water supply. The research has led, *inter alia,* to the development and testing of an extensive mathematical model for the daily variation of mineral salts in the area. The Commission has also initiated a separate investigation into the cost implications of increased mineralization to householders and industrialists.

A third research project covered in this chapter is aimed at multipurpose utilization of the water environment and is in connection with the *production of fish in a raceway system.* The system being investigated entails linking a fish production system to an irrigation scheme by producing fish in the supply canal leading to the farmer's storage impoundment. This research is done by the Department of Nature Conservation of the Transvaal Provincial Administration with partial financial support from the Commission.

Research on the water environment is also indirectly sponsored by the Commission by way of an annual block grant to the *Committee for Inland Water Ecosystems (CIWE)* of the National Programme for Environmental Sciences of the CSIR. This Committee in accordance with a formal agreement with the CSIR, acts as a Co-ordinating Research and Development Committee for the Commission in the field of inland water ecosystems.

RESEARCH PROJECTS

Water pollution and reclamation of effluents in the Pretoria-Witwatersrand-Vereeniging-Sasolburg complex

(Existing project: Contract with a firm of consulting engineers in collaboration with various local bodies)

The Pretoria-Witwatersrand-Vereeniging-Sasolburg (PWVS) complex is characterized by a high demand for water and by the fact that treated sewage and industrial effluents to an increasing extent, together with stormwater runoff, are finding their way to the Vaal River Barrage, which is an important link in water supply. This is a matter of major concern to authorities in the region and research is focused on all aspects affecting the pollution of the catchments in this area.

The project commenced in 1975 and was completed at the end of 1980. The main emphasis has been the development of a suite of mathematical models which, given a selected hydrological sequence, would be capable of correlation for various time horizons the volume of water which could be made available from the storage dams in the Vaal River system with the concentration of the total dissolved solids (TDS) in the water. The models were also to be capable of predicting the TDS at various points in the Barrage and in the main tributaries draining the Witwatersrand area. Given this information, the mineral quality of the water to be supplied to consumers in the PWVS complex can be assessed without difficulty.

The project was carried out in close collaboration with the Hydrological Research Unit (HRU) of the University of the Witwatersrand, the Rand Water Board and the Department of Water Affairs, Forestry and Environmental Conservation.

In order to calibrate the mathematical models it was necessary to institute an extensive programme to collect and assemble data relating to existing sources of pollution and to establish, on the various rivers which drain the Witwatersrand, a network of stations at which the daily flow and pollution load are monitored.

It has now been demonstrated that the mathematical models, the development and calibration of which are complete, are capable of predicting with reasonable accuracy in view of the future water consumption in the Vaal System, the TDS of the water stored in the dams and in the Vaal Barrage and at the monitoring points on the tributaries. Work on the final documentation of the models was commenced during the last quarter of 1980.

Parallel with the development of the mathematical models, a desk study was carried out to determine the order of magnitude of the increased cost to water consumer and industrialist which results from increasing TDS in the water supplied to the PWVS region. This study has now been completed and indicates that increasing TDS imposes a considerable financial burden on the community as a whole and that considerable capital expenditure on the improvement of water quality is warranted.

The research phase of this project is at an end and the mathematical models, the data that has been as-

sembled and the experience gained during the past five years are to be used by the Department of Water Affairs, Forestry and Environmental Conservation, in consultation with the Rand Water Board, to test options for improving water quality in the PWVS region and to develop a water management plan.

Research relating to the management and utilization of eutrophied impoundments in South Africa

(New project: Contract with the CSIR — National Institute for Water Research)

Towards the end of 1979 the Commission entered into a contract with the CSIR whereby the NIWR would conduct a short-term investigation on eutrophication in the Hartbeespoort Dam. This investigation was launched to establish the research needs for the creation of an adequate scientific basis for the management of eutrophication in South African impoundments.

During the year three tasks were undertaken, *viz.* synthesis of existing information of the limnology of the Hartbeespoort Dam, a literature review of modelling techniques which have a bearing on nutrient cycles in impoundments, and the development of an initial elementary model for nutrient cycles in the dam.

The synthesis of existing information on the Hartbeespoort Dam revealed that the earliest limnological data for the dam was collected in 1926. Since that time, a wide range of intermittent studies have been completed. The available data mainly concentrates on physical-chemical aspects of the dam's limnology. Some data are available on the phytoplankton and zooplankton populations, but fish have largely been ignored. Process rates, both biological and chemical, have not been measured. The available literature allows only a general assessment and description of the limnological status of the impoundment. The synthesis demonstrated that sufficient data are not available for modelling dynamic processes which take place in the Hartbeespoort Dam ecosystem.

Modelling techniques were reviewed under two major categories, i.e. simple phosphorus load/lake response models and more complex ecological models. The state-of-the-art in eutrophication modelling has been established and served as a basis for the development of a first elementary ecological model for the Hartbeespoort Dam. The model was used to simulate phosphorus flows through the various subcomponents of the dam ecosystem, i.e. dissolved phosphorus in the water, undissolved phosphorus flows through the various subcomponents of the dam ecosystem, i.e. dissolved phosphorus in the water, undissolved phosphorus in the sediment, as well as phosphorus in the phytoplankton (algae), zooplankton, and fish. Simulated results were reasonable, but many areas for improvement have been identified.

It was concluded that a well co-ordinated multidisciplinary study is necessary to obtain the data required for a scientific basis for the management of eutrophication in South African impoundments. It was further demonstrated that simulation modelling offers a powerful tool in the co-ordination and planning of research on assessing the usefulness and consequences of various management strategies for eutrophication.

Research on intensive freshwater fish production using the raceway system

(Existing project: Contract with the Transvaal Provincial Administration — Department of Nature Conservation)

The raceway system at the Lowveld Fisheries Research Station, at Marble Hall, Eastern Transvaal, makes use of flowing water from the Loskop Irrigation Scheme and the water is afterwards used for irrigation. Although the surface area and water losses are more than in the case of common irrigation canal systems, evaporation losses from large water surfaces in fish production dams are eliminated. The water is therefore used not only for the production of fish but also for the irrigation of crops.

During the year fish populations in various sections of the production unit were reduced in comparison with the previous year and certain of the segments were mechanically aerated. This was done so as to ensure that oxygen would not be the limiting factor in the experiment as in the past. One of the raceway sections was reduced to half its original size in order to obtain a stronger flow of water. The experimental work conducted during the past season lasted for 163 days.

In comparison with the previous season, aeration of the water in the raceway canal improved the survival of the fish, the growth of fish and consequently the daily production of fish meats. The indication here is that insufficient dissolved oxygen limits fish production. Additionally aeration of the water resulted in an increase in the mean individual growth rate of the fish from 2,8 g to 4,4 g per day. The average daily production of fish meat in the raceway system also increased from 0,033 kg $m^{-3}d^{-1}$ to 0,047 kg $m^{-3}d^{-1}$. In the case of the section which was reduced in size, a biomass of 14,1 kg/m^3 (similar to that in the other section) was maintained, which amounted to almost double the biomass per

volume unit of the other sections in the raceway system. This was, however, achieved at the expense of growth rate. In practice this would mean that fish would have to be kept in the smaller canal for a longer period before being marketed. The mean survival rate of fish in the raceway system was 86% whilst a food ratio of 2,09 kg food to 1 kg fish was realised.

For a short period of time the flow of water through the system was doubled to 56 l/s (2 cusec) in order to determine the effect of an increased water flow in the canal. The increased flow undoubtedly improved water quality as well as fish growth which presents the possibility of increasing the production potential of carp in the raceway system.

Chapter 5

Treatment of municipal wastewater

Local authorities play a key role in the optimization of water utilization in the Republic and they have a primary interest in and responsibility for the prevention of pollution by domestic and industrial wastes, including effluents, solid and toxic wastes, and sludges. In order to assist local authorities in this important responsibility, the Commission has for many years closely collaborated with them and initiated and sponsored several activities and research projects which are not only of direct importance to this sector, but also to the country as a whole. On the one hand, the Commission is financing essential research in specific problem areas, and on the other hand, utilising the expertise and facilities available at local authorities of the larger cities. In this regard most of the research projects are being carried out in terms of contracts based on the partnership principle i.e. the local authorities are directly involved in the research and make valuable contributions by means of facilities, man-power, etc.

A major part of the water research financed by the Commission directly concerns local authorities as can be seen from the projects reported on in the various chapters of this annual report. In this chapter projects dealing with municipal wastewater are discussed and they can be classified into two categories viz. removal of substances, which could cause pollution and/or eutrophication from wastewater and treatment and disposal of sewage sludge.

As stated in Chapter 1, legislation was promulgated during the year, limiting the orthophosphate concentration in treated effluent discharged in certain critical catchment areas to 1,0 mg/l (as P). This was necessary in order to contain the problem of eutrophication of water bodies caused by the discharge of nutrient rich effluents from conventional sewage purification works. The technology for phosphate removal to this low level is today readily available in South Africa, a great deal of which can be attributed to research effort sponsored by the Commission.

In the past the Commission supported two major projects at the CSIR and the University of Cape Town on the biological removal of plant nutrients by a modification of the conventional extended aeration activated sludge process. The introduction of a phosphate standard in South Africa has long been regarded desirable and therefore, the Commission synthesized and disseminated the available information on phosphate removal to interested organizations and institutions. A number of reports and a review on nutrient removal technology as developed and applied both locally and abroad are available. Furthermore, in order to promote technology transfer in this field the Commission in collaboration with a number of other institutions organized a seminar on nutrient removal from municipal effluents in 1979. The proceedings of this seminar are now available.

Currently the Commission is supporting two projects on the evaluation and optimization of the full-scale application of both biological and chemical nutrient removal from municipal effluents at treatment plants in Johannesburg and Pretoria. These projects are being carried out in collaboration with the National Institute for Water Research of the CSIR and the University of Cape Town. The research is already assisting in

generating the technical information required for the design and operation of nutrient removing sewage purification plants. More recently, an agreement has been signed with the University of Pretoria to investigate the underlying biochemical reactions which result in phosphate removal in the modified activated sludge process. It is anticipated that the results of this project will place current design and operational practices on a more sound fundamental basis.

Another major problem (referred to earlier) facing local authorities is the treatment and disposal of sewage sludge generated in the treatment of domestic and industrial wastewaters. Sludge treatment and disposal costs have become more and more expensive, chiefly due to the high capital cost of processing and treatment facilities, high energy and transportation costs and the high cost of land for disposal purposes. Sludge disposal is subjected to a number of restrictions from a health and pollution point of view and more stringent standards are likely to be necessary in the near future.

There is therefore an urgent need for the development of various treatment processes and disposal techniques which will enable sludge to be safely and economically disposed of and where possible its nutrient and protein value utilised. The Commission has been aware of this need for some time now and has taken several steps which have led to a programme of national research financed by the Commission.

Recommendations for research in this and the other problem areas concerning local authorities, emanate from a Research Review Committee with representation from this sector. This Committee was established by the Commission in 1977 to consider problems concerning water supply and economy, water reuse, pollution control, the treatment of effluents and the treatment and disposal of wastes which have a pollution connotation.

A Master Plan has been adopted for research into the treatment and disposal of sewage sludges and emanates from the abovementioned Research Review Committee and the Coordinating Research and Development Committee for solid and toxic wastes. Priority areas requiring immediate attention have been identified and some seven projects were commenced during the year under review. Several reports served as a basis for deciding what research is necessary and these include the report of the fact-finding mission that was sent overseas to investigate the possible application in South Africa of techniques used overseas, the report of an overseas consultant on the current state of technology of treatment and disposal of municipal sludges and a report compiled by the Commission dealing with current sludge treatment and disposal practices in South Africa.

The Master Plan of Research consists of four categories, namely Sludge Processing and Treatment; Sludge Disposal; Health Aspects; and Beneficial Sludge Utilisation. See in this respect the diagrammatic presentation of the Master Plan. The seven projects that were initiated during the year under review on a partnership basis with local authorities and research organisations are the following: Studies into the characterisation of sludge; research into the dewatering of sludge; research into the disinfection of sludge by means of pasteurisation and into the disinfection and stabilisation of sludge by means of thermophilic anaerobic digestion, research into sludge stabilisation and disinfection by means of aerobic autothermal digestion; research into the composting of sludge by forced aeration; research into the technological feasibility of single cell protein recovery from raw sludge; and research into the sea disposal of sludge.

RESEARCH PROJECTS

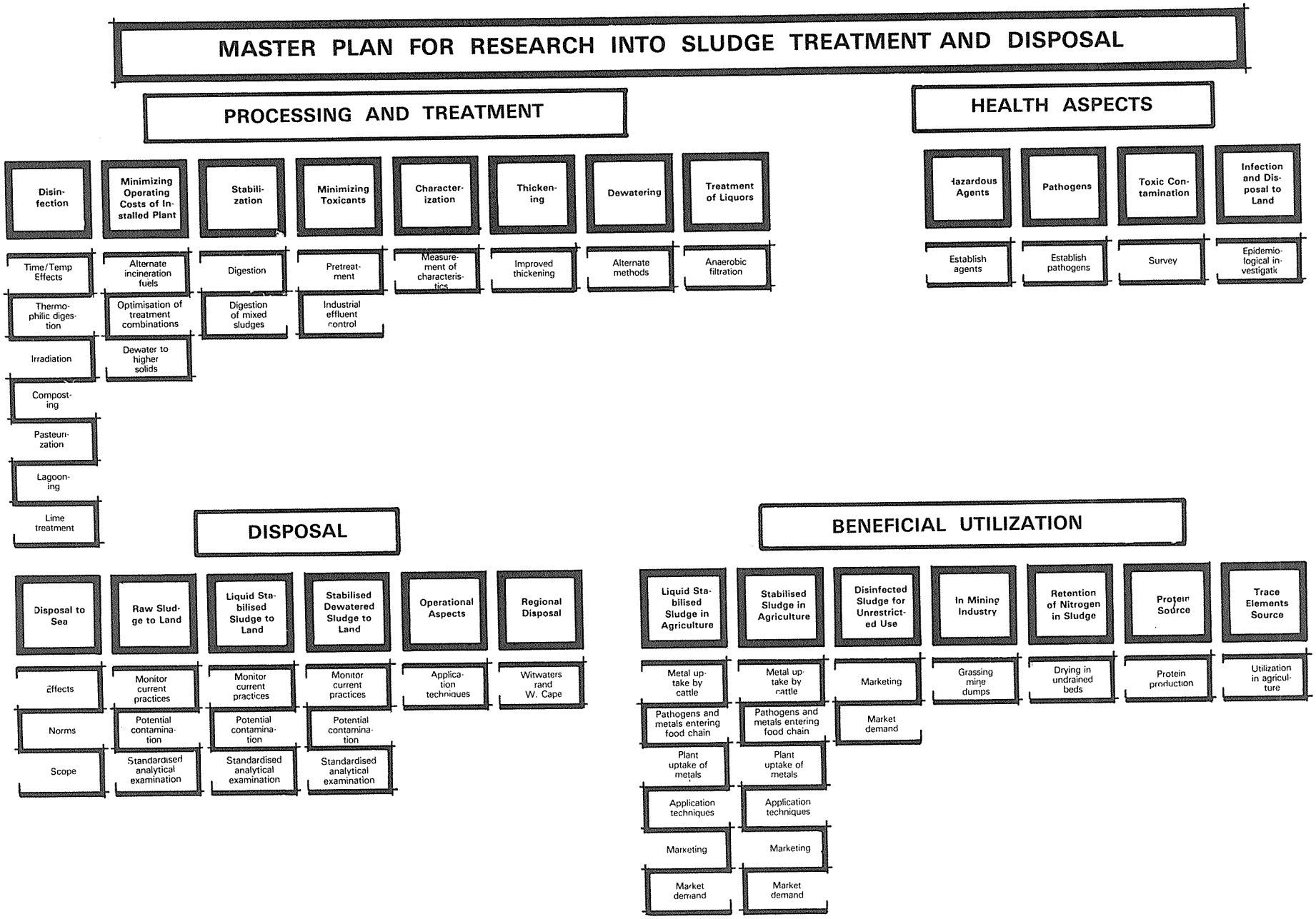
Research on the optimization of the modified activated sludge process for nutrient removal

(Existing project: Contract with the CSIR — National Institute for Water Research)

The ultimate objective with this research is to contribute, together with the other projects on the modified activated sludge process for nutrient removal, to the development of a guide for the design and operation of such plants. This project is carried out in close collaboration with the City Council of Johannesburg and the University of Cape Town.

During the year research was conducted both in the laboratory and at pilot plant scale to further the understanding of the process of biological nutrient removal. Previous preliminary findings were confirmed *viz.* that sewage collected at a time when the sewage strength was at maximum could be used to improve the nutrient removal over weekends, when sewage is usually of weaker strength. This technique proved to be very successful. Following this test the effect of air introduced into the process, by injection in the anaerobic stage, was examined. This study was undertaken because it is very often found at full scale practice that plants are designed in such a manner that air entrainment was suspected of being sufficient to prevent the efficient working of such plants. The test showed to what degree air introduction in the anaerobic stage can upset the process.

MASTER PLAN FOR RESEARCH INTO SLUDGE TREATMENT AND DISPOSAL



The pilot plant was used to evaluate if operation at a long sludge age was beneficial to the phosphorus removal process. However, it soon became apparent that the plant was not able to handle the mass of solids generated when operated at long sludge ages and the test was terminated. Subsequently, a modified Phoredox process, i.e. a three stage as compared to a five stage process, was evaluated to find out whether the same efficiency in nutrient removal can be achieved with a considerably smaller plant. Significant savings in the capital outlay are possible for smaller plants. Preliminary results indicate that the three stage process gives improved and more stable phosphorus removal, as well as a marginal increase in nitrate in the final effluent.

Sewage strength to the works varies both diurnally and weekly, thus in order to optimize the sewage purification process use was made of a model developed at the University of Cape Town to predict the most desirable mode of operation.

With the plant treating about one-third of its design load, the total oxygenation capability is not utilised and anoxic areas are therefore created in the main aeration basin. No significant fall-off in denitrification capacity was noted but reliability of phosphorus removal improved. Further improvements in performance have been predicted by making use of the UCT model, but as these may involve changes in zone order, the National Institute for Water Research was requested to carry out a preliminary evaluation on their pilot plant.

In a detailed study of balancing tank performance it was shown that chemical oxygen demand (COD) reduction averaged 140 mg/l which may be a major factor contributing to inconsistent phosphorus removal. Experiments at the Council's Northern Works have, however, shown that the COD of the balancing tank effluent and hence plant performance, can be improved by the addition of primary clarifier sludge.

Electron microscopy has proved a useful tool for examining bacteria thought to be associated with the uptake of phosphorus.

Research on the optimization of the modified activated sludge process for nutrient removal

(Existing project: Contract with the City Council of Johannesburg)

Research in terms of this contract is carried out in association with the NIWR of the CSIR and the Department of Civil Engineering of the University of Cape Town (UCT). The research is carried out at the Johannesburg Goudkoppie Sewage Works and the main thrust of the year's activities was to identify, and where possible, to quantify, factors which give rise to process instability and to develop plant operating strategies to overcome problem areas. A programme involving monitoring performance at various points in the plant was initiated and some 30 000 analyses carried out during the year.

The data confirmed that the process was capable of producing effluent phosphorus concentration well below 1 mg P/l provided certain criteria were met. Successful operation is critically dependent upon the organic matter : total nitrogen ratio of the influent to the biological reactor and to some extent on the actual magnitude of the organic matter concentration itself. Nitrates should be absent from the primary non-aerated zones and facilities must exist for the accurate and sensitive control of dissolved oxygen levels.

The removal of nitrogen and phosphate from biological filter effluents

(Existing project: Contract with the CSIR — National Institute for Water Research, and the City Council of Pretoria)

It is estimated that approximately 65 per cent of the sewage effluent generated in South Africa's critical catchments is treated in sewage works using biological filter systems. Unfortunately phosphate and nitrogen are not effectively removed in these systems, and research is therefore carried out with a view to developing techniques for conversion of the systems in order to enable such removal. Laboratory studies are being carried out by the National Institute for Water Research while the City Council of Pretoria is responsible for full-scale plant experiments at the Daspoort Sewage Works.

The laboratory studies included tests on chemical

phosphate precipitation by means of ferric chloride and a study on the utilization of the organic material in raw and digested sludge as a source of carbon and energy for the purpose of biological nitrate removal.

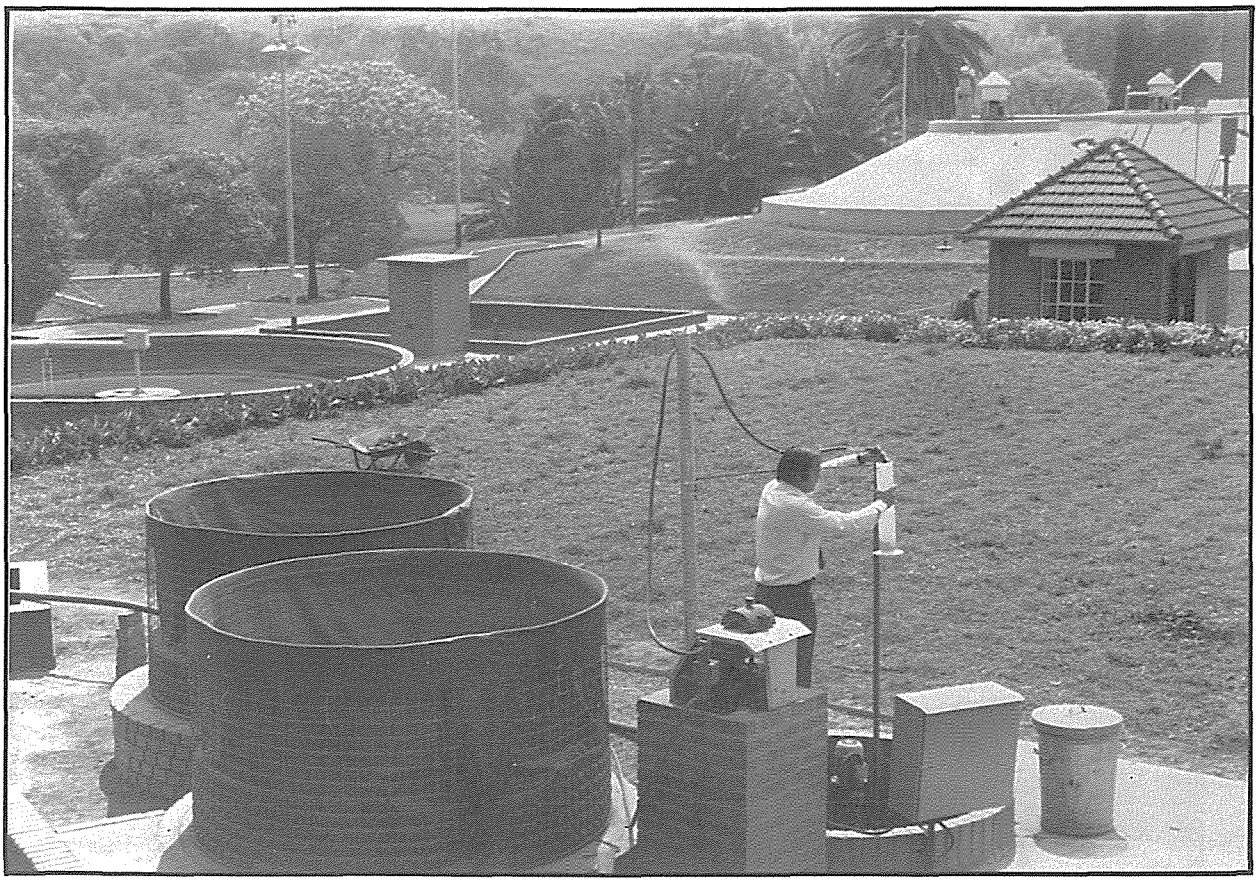
The full-scale study involves the removal of phosphate by treating raw sewage with ferric chloride prior to primary sedimentation. A fringe benefit derived from chemical treatment is the fact that the organic load can be reduced to such an extent that an increased hydraulic load is possible on the biological filters. This could be of great value in instances where existing sewage purification works are already operating at maximum capacity.

Two parallel systems, each with a flow of 2 270 m^3/d are used and ferric chloride is dosed in one system whilst the other serves as a control. The two systems are evaluated simultaneously with respect to the effect of chemical pretreatment on biological purification in biological filters and the subsequent anaerobic digestion of the biological-chemical sludge.

Results so far have indicated that the ferric chloride treatment of the raw sewage does not detrimentally affect the aerobic purification process. The decreased organic load on the biological filters results in a well-oxidised effluent and ammonia-nitrogen values as low as 1 mg/l have been obtained. In general the effluent has been of a higher chemical quality compared to the effluent of the control system.

Investigations are also under way with respect to the digestibility and dewaterability of the sludge and the extent to which the capacity of the biological filters may be increased. The desirability of ferric chloride treatment immediately after biological filtration and prior to final clarification, is also being investigated. The economic implications of chemical phosphate removal are also being studied.

A scene at Daspoort, Pretoria where full-scale tests for the removal of nitrogen and phosphate from biological filter effluents are being undertaken.



Research on the optimization of the modified activated sludge process for nutrient removal

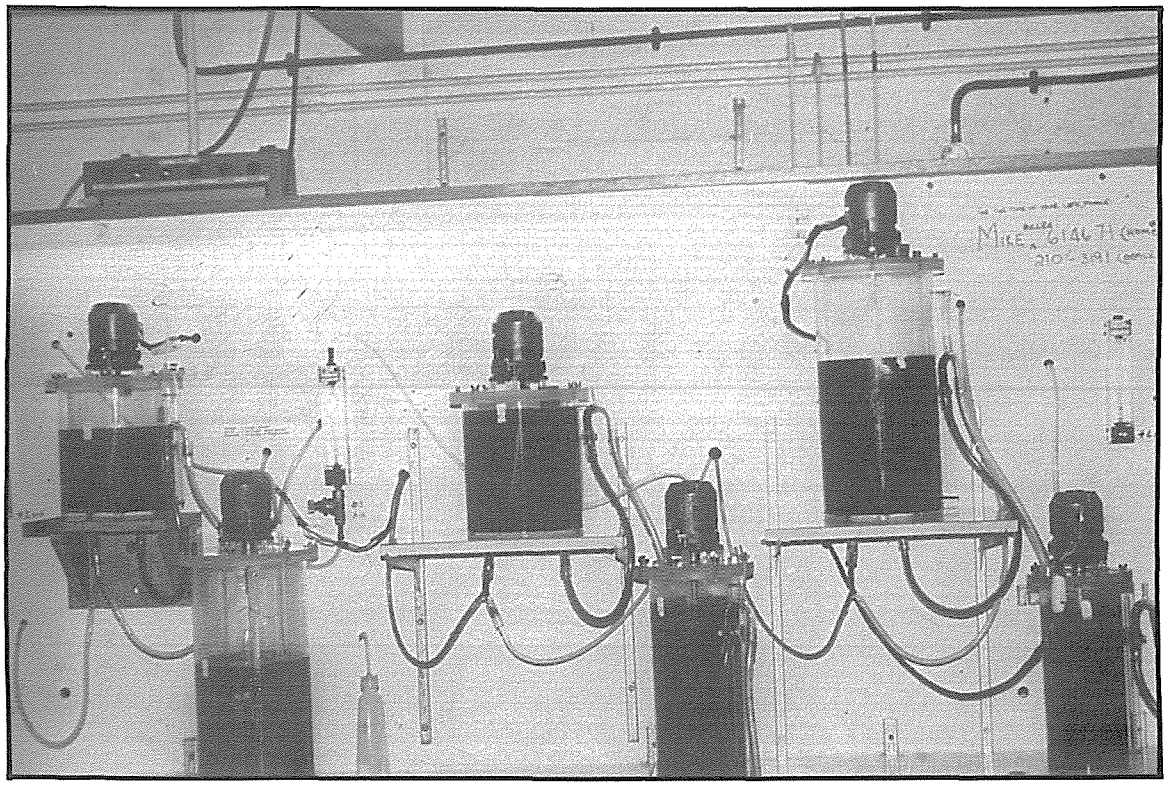
(New project: Contract with the University of Cape Town — Department of Civil Engineering)

A previous contract in terms of which the University of Cape Town (UCT) carried out research on the activated sludge process terminated and this new agreement was subsequently entered into. The objective is to further develop an already established general model describing the process and to produce a process design guide based on this research and on other projects in connection with the activated sludge process also sponsored by the Commission.

During the year the research carried out in terms of the previous contract came to fruition. The general model for the activated sludge process has reached the stage of development where it can describe the behaviour of any aerobic activated sludge process, e.g. extended aeration, contact stabilization and aerated lagoons, as well as series anaerobic-anoxic-aerobic systems, e.g. Bardenpho, Phoredox and UCT processes under both constant and daily cyclic flow and load conditions. The model differs radically from ones previously proposed and incorporates certain new concepts.

From the general model it was found possible to develop new criteria for defining the conditions that will cause phosphorus release in the anaerobic reactor and hence induce excess biological phosphorus uptake. In terms of these criteria phosphorus will be released in the anaerobic reactor if the concentration of easily biodegradable soluble COD surrounding the activated sludge bacteria in the anaerobic reactor exceeds 25 mg/l. Based on this criterion the Phoredox process was analysed theoretically by means of the general model and it was concluded that the process is limited in certain cases of application. In view of this a new process, called the UCT process, was developed in which the nitrate entering the anaerobic zone can be controlled by plant ope-

Laboratory equipment used by the Civil Engineering Department of the University of Cape Town in a study of the activated sludge process.



ration to near zero. The process can be operated to remove phosphate irrespective of the nitrate content in the final effluent, i.e. one of the most severely limiting factors for the Bardenpho and Phoredox processes.

Although the UCT and Phoredox processes remove phosphorus more effectively than other processes, there is also a limit to their phosphorus removal capacity. If the removal required is in excess of that possible by biological means, such removal can be achieved by in-plant addition of iron or aluminium salts, to remove that fraction of phosphorus not removed by biological means. An important finding for practical application is that the salts can be added at a constant rate to any zone in the process, irrespective of daily load and flow variations, due to the considerable phosphate adsorption capacity of the chemical sludge.

Single cell protein recovery from raw sludge

(New project: Contract with the Institute for Environmental Sciences, University of the Orange Free State)

This project is being conducted by the Institute for Environmental Sciences of the University of the Orange Free State and involves research into the production of single cell protein from raw sludges during the stabilisation process.

Conventional anaerobic digestion of sludge is the one pathway along which sludge may be stabilised. It is a widely adopted process throughout the Republic and involves two major groups of bacteria that decompose the organic matter in two major phases. Firstly organic material is degraded to volatile acids by acid forming bacteria and then the volatile acids are degraded to methane and carbon dioxide by anaerobic bacteria termed methanogenic bacteria.

A second pathway along which organic material might be stabilised under anaerobic conditions is by degradation to volatile acids by acid forming bacteria, as in conventional anaerobic digestion, followed by photosynthetic bacteria conversion of the fatty acids to microbial biomass. The photosynthetic bacteria are capable of almost complete quantitative conversion of volatile fatty acids into biomass by satisfying their energy needs from light energy.

This project entails an evaluation of the technological feasibility of sewage sludge fermented liquor conversion to photosynthetic bacteria. The work is being carried out at pilot scale under outdoor conditions and includes an investigation into the fate of selected pathogenic bacteria in the process, the dewatering characteristics of the solid residue and the cellular composition of the bacterial biomass.

Sludge dewatering and the treatment of sludge liquors

(New project: Contract with the City Council of Port Elizabeth)

The primary objective in sludge dewatering is the reduction of sludge moisture content to a degree which will allow efficient disposal by incineration, to landfill or by other means.

The sludge is processed from a fluid to a non-fluid form and its volume is considerably reduced. Sludge dewatered to a high solids content will reduce the fuel demand if the sludge is to be incinerated, and if the sludge is to be transported and landfilled, a dry cake is easier to handle and will produce very little polluting leachate.

The project has as its primary objectives, assessment of the suitability of various mechanical dewatering plants for the dewatering of a number of differently treated sludges; the economics involved; assessment of the quality of the process liquors; and the cost involved in treating these liquors.

The investigation is being carried out at the Fishwater Flats Reclamation Plant using various types of mechanical dewatering equipment which include a belt filter press, a plate filter press, vacuum filter and centrifuges.

Sludge from the primary and the secondary sedimentation tanks are separately thickened and blended, after which the sludge is then conditioned either chemically or by heat treatment or by a combination of both prior to mechanical dewatering. The process liquors, in the case of heat-treated sludge, will be treated in an experimental two-stage activated sludge pilot plant of 4,5 kl capacity in order to determine the treatability and/or biodegradability of these liquors.

Performance of the dewatering equipment will be measured as solids recovery and the quality of the centre against capital and running costs, including amortisation, power, chemicals, labour and maintenance.

Sludge disposal to sea

(New project: Contract with the City Council of Durban)

Although many of the coastal towns and cities of the Republic are well situated in relation to the use of the adjoining sea as a means of disposal of sludge, none specifically use this method. Where oceanographical and topographical conditions are favourable, the sea generally represents the most logical and economical receiving body for these wastes. Properly engineered and controlled sea disposal should do no damage to marine resources.

This project is being undertaken by the City Council of Durban with the assistance of the CSIR.

Durban owns two submarine outfalls which discharge settled sewage to sea from the Central and the Southern Works. These discharges commenced in 1968 and the effects of the discharges on the sea and beaches have been the subject of an intensive monitoring programme over several years continuing until the present time.

The primary objective of this project is to assess the effects on the marine environment and nearshore areas of the discharge of sewage sludge to sea through the existing sea outfalls. This means that, in addition to the discharged settled effluent, the sludge which was previously removed before discharge to sea, will now be returned to the effluent stream for sea discharge.

A two year monitoring programme has been designed and will involve sampling and analysing surface and bottom water, and the sediment in the vicinity of the discharge area for selected bacteria and micro-organisms, heavy metals, organic matter, suspended solids and toxic substances. In addition the beaches will be monitored for selected bacteria, other micro-organisms and organic matter and accumulator organisms such as mussels and oysters will be monitored for heavy metals and bacteria.

Pasteurization and thermophilic anaerobic digestion of sludge

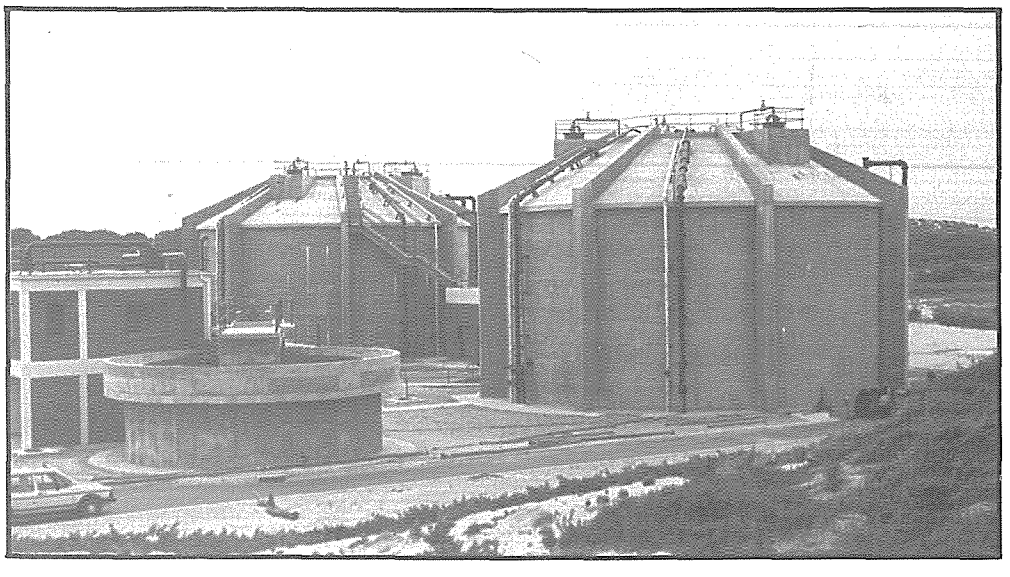
(New project: Contract with the City Council of Cape Town)

This project involves full-scale anaerobic digestion of sludge at elevated temperatures on the one hand and sludge pasteurisation on the other.

The overall objective of the project is to assess the disinfection potential of both treatment processes in terms of the inactivation of selected pathogenic and indicator micro-organisms.

Anaerobic waste treatment is an important biological waste treatment process that has been widely used for the stabilisation of municipal sewage sludges. Operation has been exclusively in the mesophilic temperature range (10°C – 42°C) in South Africa, with limited trials only in the thermophilic range (above 42°C).

Digesters at the Mitchell's Plain Sewage Treatment Works where thermophilic digestion trials are to take place.



As an effective sludge stabilisation process it offers a number of advantages, including a reduction in organic solids, the production of useful methane gas, improved sludge dewatering and some degree of pathogen reduction.

Operation in the thermophilic range (46°C — 55°C) has not been widely adopted although considerable work has been done at a full-scale plant in the United States. Advantages offered by the adoption of anaerobic digestion in the thermophilic range include increased reaction rates with respect to destruction of organic solids, increased efficiency with respect to the fraction of organic solids destroyed, improved sludge dewatering and increased destruction of pathogenic organisms. This latter point is of considerable importance since the disposal of municipal sludge in South Africa is primarily dependent upon satisfactory health clearance.

Pasteurisation of sludge at temperatures around 70°C for periods of 30 minutes has been established practice in parts of Europe for many years and it is now accepted that the process kills all vegetative pathogens, but the fate of the more hardy ova of the roundworm *Ascaris lumbricoides* is not known. Pasteurization of sludge is not without its problems, particularly with respect to dewaterability of pasteurised sludge, stability and odour problems. If it were not for sludge stability, dewaterability and nuisance problems, heat treatment to some lethal time and temperature for pathogen control could be universally applied.

The full-scale pasteurisation of sludge will be conducted at the new Cape Flats Wastewater Treatment Works and the thermophilic anaerobic digestion of sludge at the Mitchell's Plain Works.

Autothermic aerobic digestion of sludge

(New project: Contract with the City Council of Johannesburg)

The overall objectives of the project are to assess the disinfection potential of autothermic aerobic digestion in terms of the inactivation of selected pathogenic and indicator organisms and to evaluate the process for sludge stabilisation and mass reduction efficiency.

Autothermic or thermophilic aerobic digestion means aerobic digestion in a relatively high temperature range (46°C — 55°C) and implies a minimum inlet feed solids concentration of 3,5% and oxygen for supplying the dissolved oxygen for the process instead of air. Operation in the thermophilic temperature range means that the potential for the inactivation of pathogenic micro-organisms is much greater than operation in the mesophilic range. The process therefore appears to offer considerable advantages, for, apart from its pathogen reduction potential, the production of a stable odourless end product at reportedly short retention periods offers significant economic advantages.

The research programme being conducted at pilot scale includes an investigation into the mode of destruction of pathogenic organisms and into factors which contribute towards the shielding of these organisms from the hostile environment, assessing the effect of varying such parameters as solids loading rate and retention period, assessing odour release, quality of supernatant liquor, temperature control and dewatering properties of the treated sludge. Design criteria and suitable operating and control procedures for the process will be determined for use under South African conditions at the end of the contract period.

Research into the composting of sludge by means of forced aeration

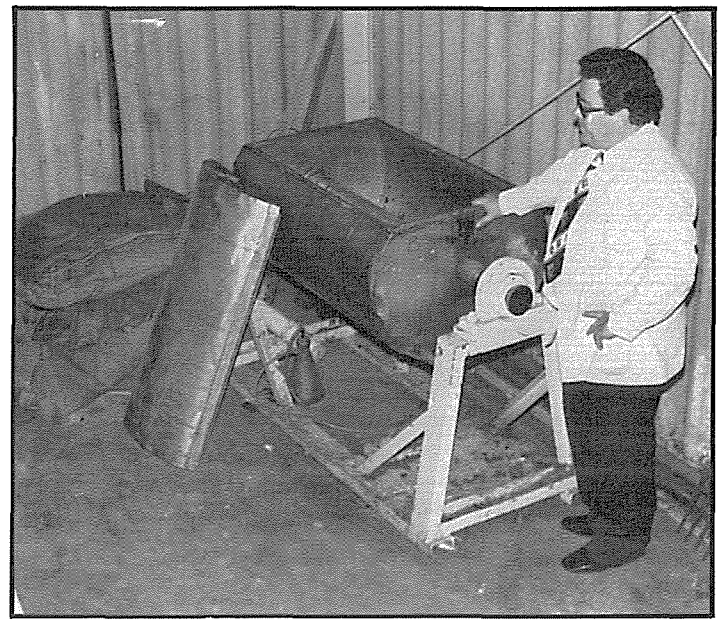
(New project: Contract with the CSIR — National Institute for Water Research)

It is well known that sewage sludge is an excellent soil conditioner and that it contains certain essential nutrients. Of considerable concern in South Africa, however, is the hygienic quality of treated sludge to be utilised or disposed of. Therefore, in any sludge treatment process the ability to eliminate or reduce pathogenic organisms to completely acceptable levels, is of prime concern.

This project involves composting of dewatered sludge in admixture with wood chips or similar material and through which air is mechanically drawn. The primary aims of the project are to assess the effectiveness of the process in its role as stabilisation process and in the inactivation of pathogenic and indicator organisms under various operating conditions and with various sludges and sludge mixtures. The process is similar to conventional windrow composting but differs in that the composting material is not turned and aerobic conditions are maintained by drawing air through the pile mechanically. Dewatered sludge is mixed with wood chips or similar material which serves as a moisture absorbent and provides porosity to the material, and which is removed from the final product by screening.

The research project provides for pilot-scale composting experiments to be conducted with primary sludge, digested sludge and waste activated sludge.

Equipment for the pilot-scale forced aeration composting of sludge.



Initial experiments conducted showed that a ratio of 1:2 of dewatered raw sludge:wood chips was sufficient to reduce the moisture content and carbon to nitrogen ratio of the mixture to below 60 per cent and 50 per cent respectively. While under-aeration reduces the heat generation rate and maximum temperature, over-aeration causes relatively rapid cooling of the composting material. In order to obtain sufficient time/temperature treatment for acceptable stabilisation and disinfection, it is apparent that the rate of aeration will have to be accurately controlled.

Research into the characterisation of sludge

(New project: Contract with the CSIR — National Institute for Water Research)

Sewage sludge consists of a wide variety of substances and consequently is a difficult material to characterise. It contains inorganic particulate matter, nutrients, heavy metals and other toxic and persistent substances and a host of pathogenic and non-pathogenic micro-organisms.

The primary aim of this project is to identify those sludge characteristics that are best suited to evaluate the treatability of various sludges and which may be used to assess the effectiveness of various treatment processes.

Sludge may be characterised by a number of parameters that have been developed, many of which are used to assess the behaviour of various sludges during thickening, transportation, stabilisation, conditioning and dewatering. These parameters, however, are not in themselves always sufficient to enable a chain of successive treatment processes to be designed. Suitable parameters are needed with which to characterise different sludges more fully so as to enable treatment and disposal plant design with predictable results.

During the year under review, a start has been made with assessing current sludge characterisation methods and the development of further methods to describe sludge more meaningfully so as to enable the design of more appropriate and more economical sludge treatment and disposal operations. Aspects that have been considered include chemical composition, physico-chemical characteristics and physical characteristics.

Chapter 6

Treatment of industrial effluents

The discharge of municipal and industrial effluents, unless adequately purified, into the water environment causes a serious problem to the limited water resources in many parts of the country. The necessary technology for the effective treatment of industrial effluents so that they can comply with the standards for discharge into the water environment and into municipal sewage systems is, however, not always available. In view of this the Commission has for several years been supporting research in connection with water management and effluent treatment in industry, in order to assist industry and to protect the quality of our water resources.

The Commission's policy regarding research in this field is that it must be for the benefit of the country as a whole. Therefore, liaison is done through the various National Associations of industry which are represented in the CR and D Committees established by the Commission.

The Commission is currently sponsoring nine research projects in connection with water management and effluent treatment in the industrial field. Six of these projects are in connection with the textile industry.

The textile industry is a major user of water but of the 33 major textile mills in the country only 19 discharge directly into municipal sewerage systems. Several of these mills find it difficult to comply with the effluent discharge by-laws of the relevant local authorities. The main objective of the research work is to develop appropriate techniques for the effective management and treatment of water and effluents in the textile industry, with a view to abating pollution of the environment into which these effluents are discharged, and reducing the specific consumptive usage of water by applying the principle of the closed loop recycle systems. Apart from affording a considerable saving in water consumption the application of this technique can also effect a substantial saving in reagent chemicals.

Considerable success has been achieved with the research projects on the treatment of the textile mill effluents, carried out by the University of Natal. This success is to a great extent due to the Commission's policy of partnership research *viz.* the involvement and participation of the end-user in the execution of the research programme. As has been said in Chapter 1 two textile companies have decided to construct full-scale plants, based on the research results. The one plant will be for the treatment of wool/synthetic dyehouse effluent and the other for the treatment of that emanating from the sizing/desizing process.

The effluent problems of the fellmongering and tanning industries, have been receiving attention from the Commission for a number of years. Research agreements with the CSIR through the Leather Industries Research Institute, (LIRI), consulting engineers and tanners ensured a multi-disciplinary approach to a variety of these effluents.

A partnership research agreement with a tannery at Silverton near Pretoria, and in close collaboration with LIRI and the City Council of Pretoria, has successfully been completed. Based on the research, the tannery has decided to proceed with the construction of a *full scale dissolved air flotation plant to treat all the effluent*. The treated effluent now conforms to all standards, except for the total dissolved solids (TDS) content, for discharge to the municipal sewer. The problem

with the too high TDS can be solved by the use of green hides (instead of salt cured hides) and by a compromise with the City Council as far as the standard for TDS, is concerned. The discharge of the effluent to the sewer will also solve a serious odour problem in the neighbouring residential area.

In order to ensure proper technology transfer an Action Committee has been appointed to see to the implementation of the recommendations made in the final report.

As a result of the promising results obtained with the dissolved air flotation treatment system in Silverton, a similar pilot plant was designed and installed at a tannery in King William's Town. This plant will operate on various types of effluent in conjunction with existing biological treatment pilot plants. Experimental work will be continuing at this tannery where two activated sludge plants, a high rate biological filter, a dissolved air flotation plant and the acid treatment and screening plant will be used to optimise treatment systems for any type of effluent that might be produced by tanners in South Africa.

The Commission is also sponsoring research on the technological application of the anaerobic digestion process for the purification of spent wine residues.

The major findings of the research programme were:-

- Removal of anionic and cationic surfactants by the ion exchange columns at the 94% and 92% level respectively, and their successful reuse in production dyeing.
- Production of good quality treated effluent with 83% reuse by removal of colour, chromium and suspended solids.
- The presence of non-ionic surfactants in the effluent resulted in the need for polyelectrolyte dosing prior to the clarifiers and low clarifier operating velocities.
- The removal of floc traces by gravity sand filtration needed low velocities and their removal was essentially by surface filtration.
- The pilot plant operated successfully under automatic control while the final product water quality was monitored.

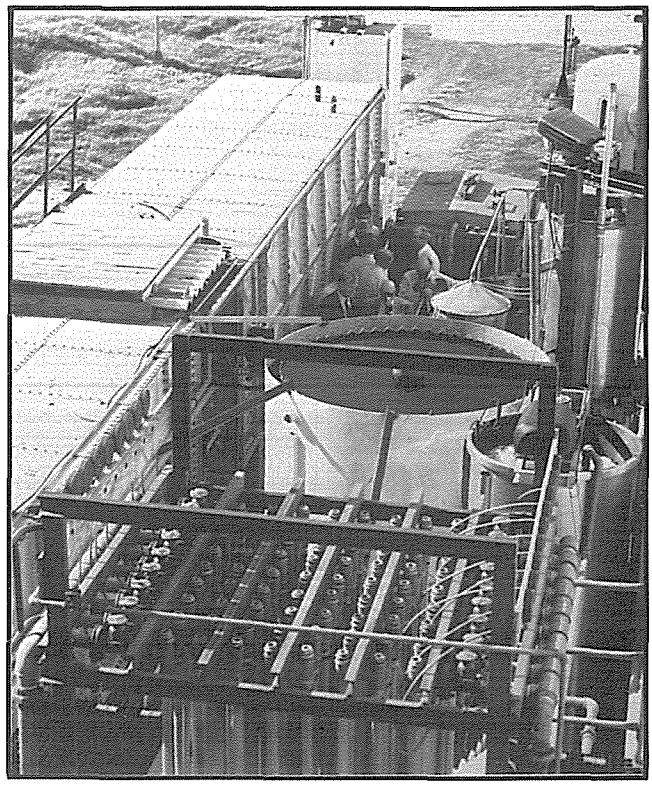
RESEARCH PROJECTS

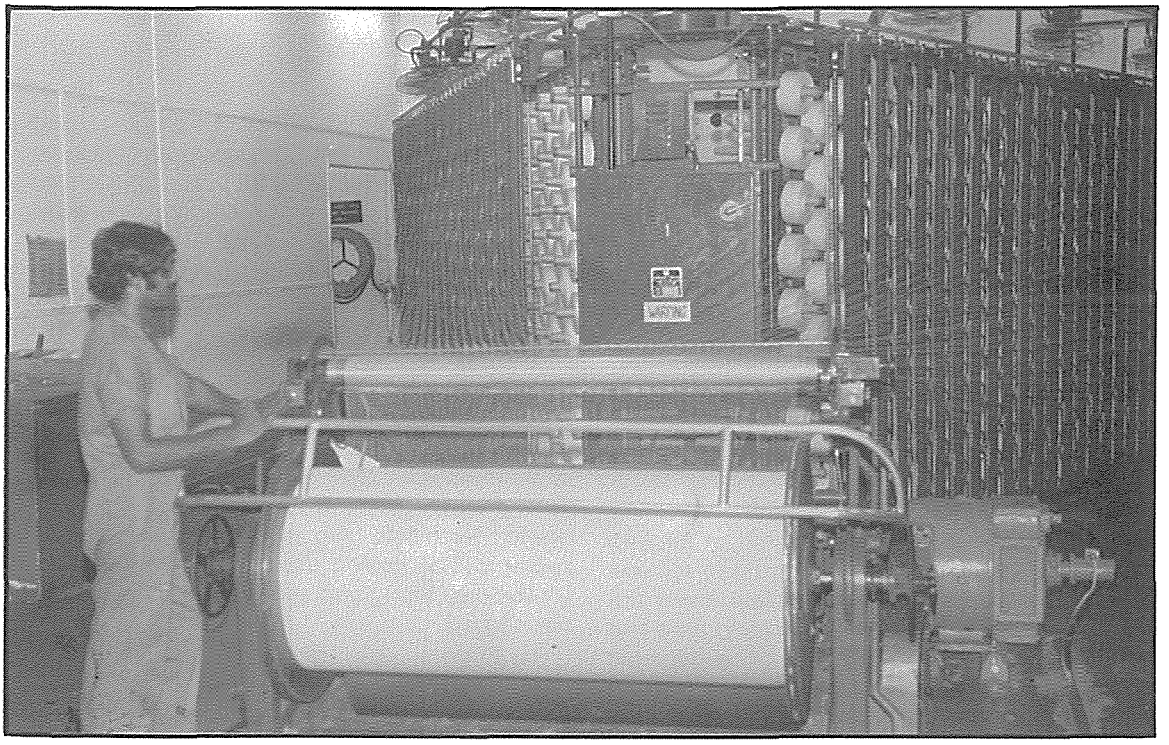
Research into water management and effluent treatment in the textile industry: Wool/synthetic fibre dyehouse effluent

(Existing project: Contract with the University of Natal — Pollution Research Group, Department of Chemical Engineering)

The closed loop recycle of wool/synthetic fibre dyehouse effluents has been demonstrated by a 85 m^3/d pilot plant, which has operated for almost two years at the largest worsted mill in South Africa. The pilot plant consisted of the unit operations of ion exchange for auxiliary dyeing chemical recovery; electrocoagulation and two-stage clarification (for colour, organics and heavy metals removal); and gravity sand filtration. The treated effluent was suitable for dyeing purposes and during the period of pilot plant operation 50 300 kg of fibre in five production dyeing machines, which covered the full range of various dyeing procedures, were dyed successfully.

A pilot plant for research on the recycling of dyeing effluent which has been in operation at a large worsted mill.





A scene in a textile mill in Natal where the Commission is financing pilot-scale research on sizing effluent. As a result of savings obtained, the company has decided to erect a full-scale unit.

This project has now been completed, resulting in a final report, covering the scientific results and the design of a full-scale treatment plant with its economic feasibility. The results will be published by the Commission as a guide to the treatment of wool/synthetic dyehouse effluent. The operating cost, including capital depreciation, of a 1 500 m^3/d plant is estimated to be 38,3 c/m^3 of effluent treated. The water recovery factor is 90%. The water savings, the effluent discharge savings and the reuse of recovered chemicals will offset the operating cost in most wool/synthetic fibre dyehouses.

Research into water management and effluent treatment in the textile industry: Sizing/desizing effluent treatment

(Existing project: Contract with the University of Natal — Pollution Research Group, Department of Chemical Engineering)

The desizing process of a cotton/synthetic textile mill contributes up to 25% of the pollution load in 10% of the effluent volume. By changing from starch to a synthetic polymeric size this effluent can be treated in a high temperature ultrafiltration plant with reuse of both the water and the synthetic sizing agent.

An ultrafiltration plant for treating desizing effluent has been designed and constructed at a cotton/polyester textile mill. The purpose of the pilot plant is to obtain information which will facilitate the design and operation of a full-scale treatment plant. The pilot-plant is fully automated and the product size concentration is controlled by means of an on-line density meter and a process control valve. The desizing effluent is processed at 70°C and both product water and recovered size are reused by the factory.

During nine months of pilot plant operation over $1,8 \times 10^6$ m of a variety of cloth constructions have been sized with reclaimed polymer size with excellent weaving performance. Infrared spectroscopic analysis of the reclaimed size and the virgin size has shown no significant changes in the configuration or conformation of the synthetic polymer.

The savings that could be affected by a full scale plant (85% of size/desize water requirements and 80% size chemicals) prompted the company to go ahead with the construction of a full scale plant during 1981. The abovementioned savings is such that the capital investment of the plant will be redeemed within one year of operation.

Research into water management and effluent treatment in the textile industry: Wool scouring effluent treatment

(Existing project: Contract with the University of Natal — Pollution Research Group, Department of Chemical Engineering)

This project has ended with the successful conclusion of the factory-scale trials on the modified desuinting/scouring system and the pilot-scale dynamic membraned ultrafiltration of wool scouring effluents.

The factory operation of the desuinting/scouring system was improved by the incorporation of settling tanks on two of the bowls of the scouring set to remove approximately 50% of the settleable solids from the scouring liquors. This prolonged the operating time and resulted in 20% savings in water usage. The dynamic membraned ultrafilter, which was developed for this effluent, gave excellent long term performance on the highly polluted wool scouring effluents. Rejection of grease and dirt was consistently 100% while 20% rejection of suint was maintained. The product water even at 90% water recovery was suitable for reuse as process water.

These research and development investigations have shown that this obnoxious effluent containing grease, suint and dirt can be systematically treated and reused as process water with savings in chemicals and heat energy.

Research into water management and effluent treatment in the textile industry: Wool scouring effluent treatment

(New project: Contract with the University of Natal — Pollution Research Group, Department of Chemical Engineering)

The overall objective of this project is to evaluate the performance of a pilot plant closed loop recycle lsystem for the treatment and reuse of wool scouring effluents. This new project is a continuation of the research and development work on the desuinting/scouring system and the dynamic membraned ultrafiltration of the effluents carried out in terms of a previous contract with the Commission. The project is conducted in close cooperation with the largest wool scouring company in South Africa.

The system consists of two parts *viz.* segregation of the effluents to facilitate optimum water reuse and treatment of the effluents for water reuse. The low volume desuinting effluent, which contains water soluble components from the wool and suspended solids will be settled and then evaporated. The condensate will be reused in rinsing and the concentrate from evaporation will provide a low grade potassium by-product to be used as fertiliser. The main effluent, which is from scouring, contains detergent emulsified grease and will be treated by dynamic membraned ultrafiltration. Approximately 95% of this effluent will be recovered for reuse in scouring with savings in chemicals and heat energy. The grease concentrate from ultrafiltration will be treated further to give anhydrous wool grease as a by-product. The rinsing effluent will be used as make-up for the desuinting and scouring sections and the excess discharged.

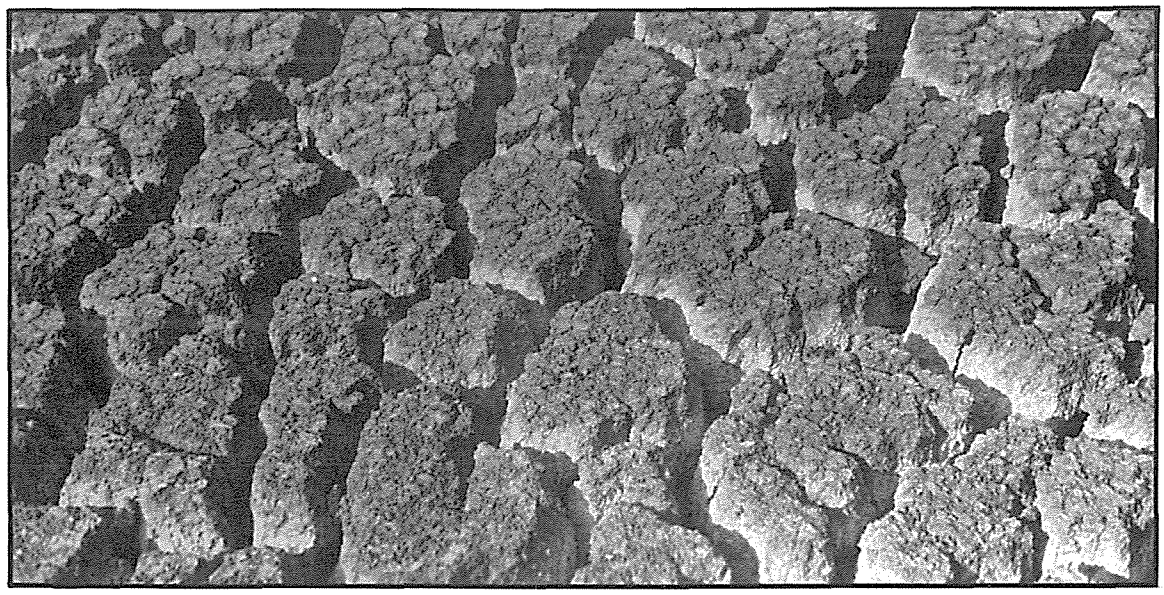
The pilot-plant has been designed to operate automatically on a production scale at the wool scouring factory. This will enable an objective evaluation to be carried out and will provide the necessary operating and design data for a full-scale treatment/recycle plant.

Evaluation of the performance of a horizontal decanter centrifuge in the removal of sludge from liquid scouring wastes

(Existing project: Contract with the CSIR — South African Wool and Textile Research Institute)

A total of approximately 45 million kg of raw wool, karakul and mohair is scoured annually in South Africa and from this 20 million kg of contaminants are removed using an estimated 450 million litres of water. The contaminants comprise grease, suint, sand, clay, etc. The major portion is sand and clay and the latter is coated with or associated with a relatively large amoung of grease and is described as sludge. This amounts to approximately 10,5 million kg of solids annually. In certain mills the bulk of the sludge is pumped to evaporation ponds along with the liquid effluent. These ponds are generally associated with odour problems, floating grease which reduces evaporation rates, and finally the periodic removal and disposal of settled solids.

The treatment of such liquid effluents and sludge



A close-up view of wool scouring sludge dried out in an evaporation pond.

to produce a spadeable sludge and a relatively clean effluent stream would aid in reducing the pollution load of the liquid effluent and the objective of this project is to evaluate the use of a horizontal decanter centrifuge for this purpose. A pilot plant comprising storage tanks, pumps and a horizontal decanter centrifuge was, therefore, installed at a wool scouring mill. The flocculant used in this investigation was the magnesium-rich waste residue (generally known as "bitterns") obtained from a local common-salt recovery plant.

Three different series of investigations were performed at the mill. In the first series the settings of the decanter centrifuge and the addition level of bitterns which gave the maximum grease and suspended solids removal for various sludges were established. In the second series the flocculant (bitterns) was mixed with the sludge prior to entering the decanter centrifuge, in order to evaluate the effect of residence time on the performance of the decanter centrifuge. From these studies it was concluded that, provided the optimum conditions were employed, the removal of grease and suspended solids from the sludges was very good and a centrate with a low residual grease content (< 1%) together with a spadeable sludge (solids content approximately 55%) were obtained. The third investigation was aimed at evaluating the performance of the decanter centrifuge during continuous operation for extended periods. Preliminary results from this series indicated that about 90% of the solids and about 73% of the grease were removed and that a centrate with a grease content of less than 1%, was formed.

Research into water management and effluent treatment in the textile industry: Pilot plant treatment of cotton/synthetic fibre dyehouse effluents with water reuse

(New project: Contract with the University of Natal — Pollution Research Group, Department of Chemical Engineering)

There are two main types of cotton/synthetic fibre dyehouse effluents *viz.* the polyester type (containing colloidal disperse dyes, dispersing agents, organic acid buffers, and spinning and knitting oils), and the cotton type (containing soluble dyes, salt and alkali as well as various other compounds such as detergents, retarders and cleaning agents).

As most dyehouses process both types of fibre, the effluent from a particular factory will be very complex.

Because the treatment of polyester dyehouse effluents for water reuse is relatively straightforward by flocculation techniques, the segregation of this effluent has been assessed. In order to overcome the poor settling characteristics (due to the presence of surfactants) of these effluents when flocculated, a process involving in-line alum coagulation and cross-flow filtration has been developed. The filter consists of woven fabric tubes arranged in a parallel-series configuration. A semi-technical scale unit has been operated at a factory site. Although the colour of the treated water did not meet the expected quality, more than 40 production dyeings have been carried out by the factory.

On the basis of the above-mentioned results (obtained in terms of a previous contract with the Commission), this new contract has been entered into with the Commission to cover a 100 m^3/d pilot-plant project with reuse of the treated water in production dyeing. The pilot plant has been designed and will operate under automatic control. It will consist of a cross-flow filtration unit and a hyper-filtration unit with poly (ether-amide) membranes. The pilot plant will be used to obtain the necessary data for the design of a full-scale unit and to assess the reuse of the product water.

Research in connection with water management and effluent problems in the hides and skins, curing, fellmongering and tanning industries

(Existing project: Contract with the CSIR — Leather Industries Research Institute)

The tanning and related industries are experiencing serious problems with their effluent disposal via irrigation and lagooning, because these practices cause odour problems and constitute a potential for pollution of the water environment. This project, which keys in with the process modification work being done by the Leather Industries Research Institute (LIRI) to conserve and recycle water and tanning chemicals, is vital for the future economic expansion of this industry and the protection of the water environment.

Tanning

Following the successful treatment of combined tannery effluent with an activated sludge pilot plant, this process has now been adapted to treat beamhouse effluent which constitutes about 30% of the hydraulic load and 75% of the organic load. The pilot plant is now capable of achieving a 70% reduction in chemical oxygen demand (COD) over extended periods.

As has been said in the introduction, the results obtained with the dissolved air flotation pilot plant at a tannery in Silverton near Pretoria, were so promising that a modified dissolved air flotation pilot plant was installed at a tannery in King William's Town, for further trials on combined tannery effluent. This pilot plant will be used in conjunction with the existing activated sludge plant in a series of experiments to optimise combinations of physico-chemical and biological treatment.

The acid-treatment and screening technique developed at a tannery in Wellington, for removing solids and some dissolved material from that portion of its beamhouse wastewater (lime-sulphide unhairing liquors) with the heaviest organic load, has been very successful. The tannery has since built a full scale plant which has been operating successfully for over six months.

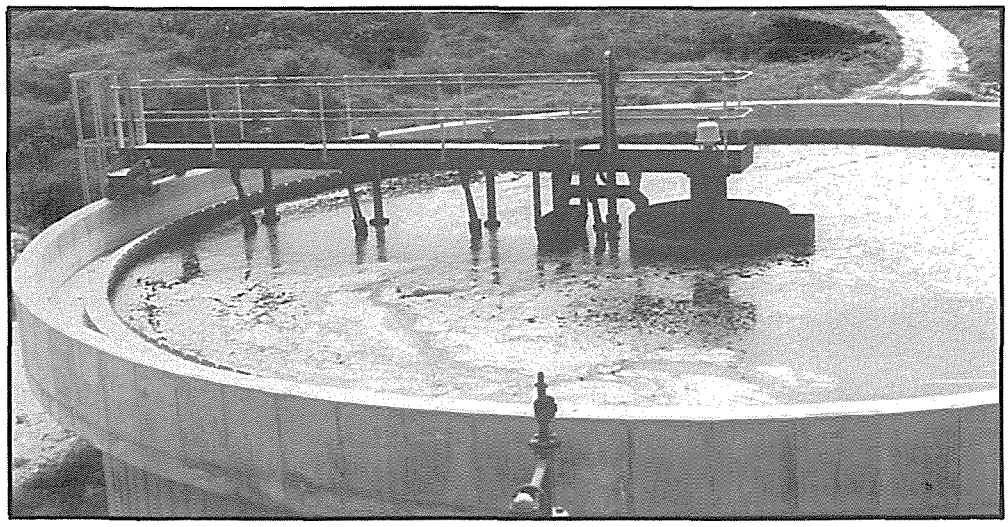
Fellmongering

The activated sludge pilot plant at SA Cape Fellmongers in Port Elizabeth has been operated very successfully on fellmongery beamhouse wastewater which is that portion of the fellmongery effluent with a very high oxygen demand, and the highest pH, sulphide and solids content. It has been shown over extended periods that preliminary treatment with a surface aerator reduces the pH value to approximately 9 and removes sufficient quantities of the sulphides so that the residual amounts do not affect the activated sludge process.

This study has been extended to mix, in the correct proportions, beamhouse wastewater and discarded soak liquors, the latter being high salinity water coming from the process prior to the beamhouse and used to remove the preservation salt from the skins. This was done to study the effect of salt on the activated sludge process so that this can be used to treat the total mixed fellmongery effluent. The results indicated that high salinity soak liquors (TDS 23 000 mg/l) had no effect on the efficiency of the treatment process.

A high rate biofilter has also been used to treat fellmongery beamhouse wastewater and is characterised by its ability to recover rapidly from shock loads, which is not the case with activated sludge since this takes many days to re-stabilise.

The activated sludge unit will shortly be used to test the effect on it of antiseptic agents being developed by LIRI as a substitute for the salt preservation of sheepskins, which adds to the salt load of effluents.



This settling tank at the Stellenbosch Sewage Works is used for research on the treatment of spent wine residues.

Research related to the purification and reuse of tannery effluent

(Existing project: Contract with a tanning company)

The project undertaken in conjunction with a tannery near Pretoria and in cooperation with the City Council of Pretoria has been successfully completed. The aim of the project was to investigate the treatment of mixed tannery effluent in order to render it acceptable for discharge to the municipal sewerage system. Parameters investigated in this respect were solid organic material, sulphides and salt content of the effluent.

A breakthrough was made regarding the treatment of mixed tannery effluent when it was found that dissolved air flotation with ferric chloride as coagulant gave excellent results. The chemical oxygen demand, suspended organic solids and chrome content are easily reduced by 85, 97 and 99% respectively. This produces an effluent which can be reused in some sections of the factory. In order to meet the City Council's requirements for discharge to the sewerage system, it is essential that at least 80% of the skins to be tanned should be green or unsalted hides. The marketing and availability of green hides are matters which are currently being studied by the relevant authorities. Should they become freely available and should the City Council make certain relaxations with respect to the permissible salt concentration in the sewerage system, the technique developed will be ideally suited for the treatment of the effluent in such a way that it could be discharged to sewer. This will solve many of the problems, such as the odour nuisance which arises when other disposal techniques are used.

The pilot plant studies at the tannery were so successful that the tannery management has decided to proceed with the construction of a full-scale unit for the treatment of all the effluent from the factory.

The report ensuing from this investigation will serve as a basis for a guide for the treatment of mixed tannery effluent and which will be released to South African tanneries.

Research on the technological application of the anaerobic digestion process for the purification of spent wine residues

(Existing project: Contract with the CSIR — National Institute for Water Research)

The main objective of this two-year contract, negotiated in 1977 and then extended for a further year, was to investigate at pilot scale the operational problems experienced with full-scale anaerobic treatment of wine distillery waste (spent wine) at the Stellenbosch Sewage Works. The investigation was done in cooperation with the Stellenbosch Municipality. Results obtained proved that spent wine residues are very amenable to anaerobic digestion and that this biological process, based on high volumetric load rates and low hydraulic retention times, results in efficient effluent purification. It was also demonstrated that the process is economically viable and reliable, if the system is properly designed and controlled.

A new contract has been negotiated between the Commission, the Stellenbosch Municipality and the CSIR for the full-scale verification of the research results which were obtained at the laboratory and pilot scale level. The project will be initiated as soon as structural and other modifications to the existing anaerobic digestion facilities, based on recommendations of the research results of the old contract, have been implemented.

Chapter 7

Desalination

The Commission has for some years been supporting research in connection with desalination in order to enable the optimal use and reuse of saline waters and effluents. During the year several important developments occurred: a workshop on desalination research was held to identify the need for the application of desalination; the CRD Committee for Desalination Research met to review the Master Plan and priorities; two research projects were completed; and research results are now being successfully applied by a company.

During 1976 the CRD Committee for Desalination Research approved a Master Plan for research in which some priority areas were identified. As a result the Commission entered into agreements in terms of which research was done on some of these aspects, and during the year two of these projects were completed. It was felt, therefore, that before further decisions were taken on the continuation of research, the current situation and research priorities should be thoroughly reviewed. A workshop was arranged to determine the needs with respect to desalination for water supply and for the treatment of effluents to meet disposal requirements. Representatives from industry, government departments and research organisations were invited to contribute to the workshop. As a result of the deliberation the Master Plan for desalination research was reviewed and approved at a meeting of the CRD Committee. The Master plan embraces all known desalination techniques with primary emphasis on reverse osmosis, ion exchange and electrodialysis. This Master Plan is attached to the Annual Report as an Annexure.

As far as reverse osmosis is concerned, priority has been awarded to the problem of effective pretreatment of feed water to prevent fouling and degradation of the membranes. Furthermore, local manufacture of dynamic membranes, the regeneration of membranes and the development of membrane support systems have been singled out for attention. As far as applications are concerned, high priority has been placed on the reclamation of water from effluents by means of reverse osmosis as well as on specific applications in industry and in the mining field.

The development of continuous countercurrent ion exchange for the reclamation of water from effluents with a view to specific industrial applications should also receive further attention. Research on electrodialysis as a desalination technique is gaining ground and attention should be paid specifically to the determination of membrane characteristics, applications in specific industrial areas and in the mining industry and also the treatment of saline water concentrations.

The following agreements, in terms of which desalination research was done, came to an end during the year: Research on the desalination of treated sewage; and research on the desalination of seawater by means of reverse osmosis at the pilot plant at Swakopmund. The final report on the former project has already been submitted to the Commission and the desirability of a follow-up project is currently being investigated. The final report on the latter is being prepared.

As mentioned in Chapter 1, a very important development during the year has been the agreement between the Commission and a private concern, in terms

of which the Commission will provide the required information for the manufacture of cellulose acetate tubular membranes for reverse osmosis units to the firm concerned. The knowledge and expertise for the manufacture of this type of membrane stem from the project on the development of membrane support systems and modules. The firm has also made a contribution to the development of reverse osmosis units by developing a module which can be manufactured cheaper than the imported counterpart, and, in terms of the agreement with the Commission, the firm will endeavour to actively promote the manufacture and marketing of reverse osmosis membranes and modules. The Commission has reserved the right to review the agreement after a period of time in the light of progress made in manufacture and marketing.

This chapter contains reports not only on the three research projects mentioned above, but also on a fourth project which was terminated during the year. This project deals with the technological development of ion exchange for the desalination and tertiary treatment of effluents in terms of which a 100 m^3/d pilot plant was designed and would have been built.

RESEARCH PROJECTS

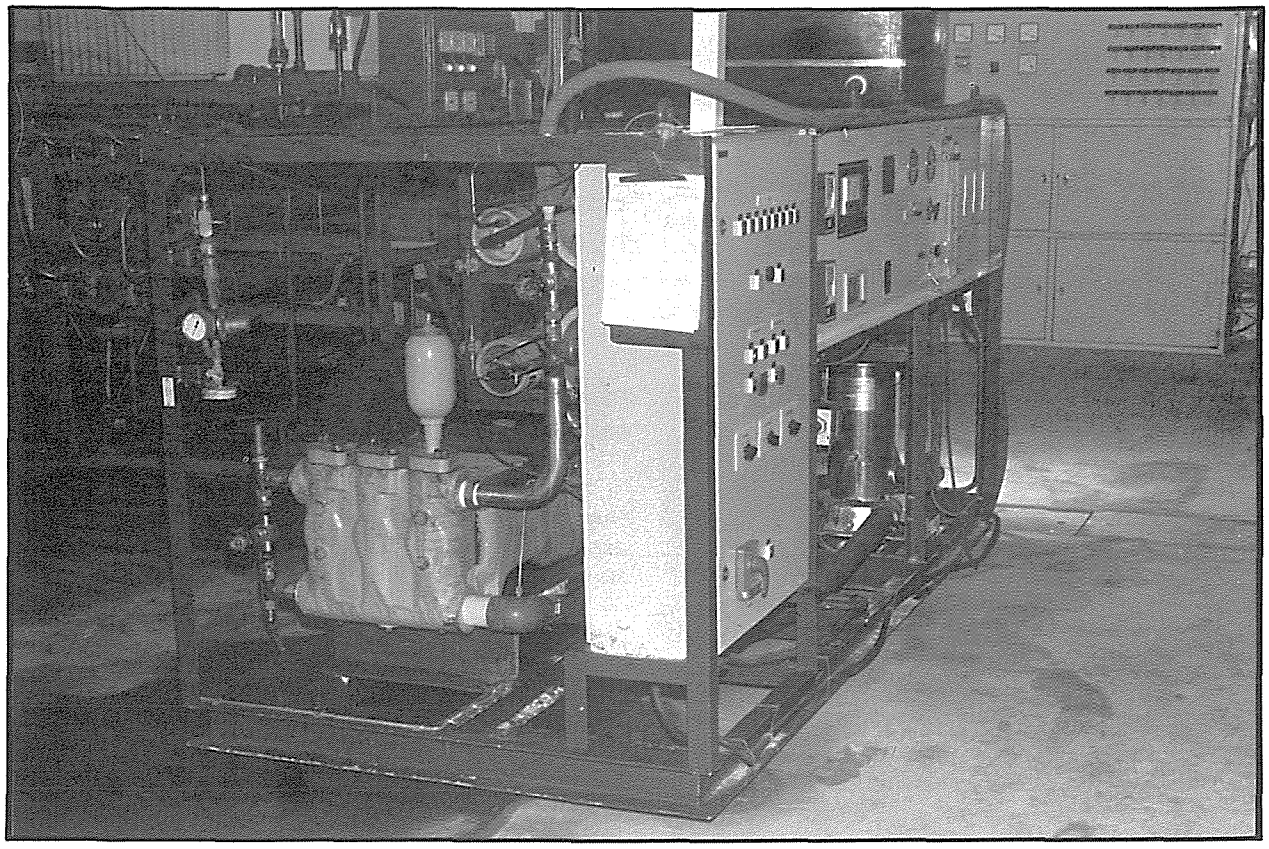
Research on and development of desalination of sea water at reverse osmosis pilot plant, Swakopmund

(Existing project: Contract with the Department of Water Affairs (South West Africa) and the CSIR — National Institute for Water Research)

In 1976 it was estimated that additional water would be required to supplement the water supply to the central Namib area by 1982. Consequently a project was instigated on a pilot-plant scale with the aim of obtaining essential data for the design of a full-scale sea water desalination plant based on reverse osmosis.

The main objectives of the research programme were to establish design criteria for a pretreatment

A desalination unit used for research on the desalination of sea water at Swakopmund.



system for the raw seawater, and to evaluate the performance and life-time of various commercially available sea water reverse osmosis membrane systems.

The pretreatment system which was used, comprised the following: chlorination to 0,5 mg l^{-1} residual; coagulation and flocculation with alum and polyelectrolyte; sludge blanket clarification or flotation; sand filtration; and polishing filtration by diatomaceous earth filter, to remove algae and suspended solids.

At first the system produced acceptable results but after a few months it was not able to produce a seawater feed for the reverse osmosis units of the specified quality. Although the reasons for this phenomenon are not conclusively known, it has been suggested that a rise in the dissolved organic content of the seawater, associated with an increase in planktonic activity due to the increased temperature of the coastal waters, could have been the cause.

During early experimental work it had been noted that under conditions of positive chlorine residual and through exposure to sunlight, the sea water underwent a significant change. Based on this observation, a novel and simple pretreatment system was developed and finally put into operation. This system comprises the following steps: impoundment of the seawater for two to three days with a free chlorine residual (about 0,3 mg l^{-1}) under direct sunlight; sand filtration (no coagulants being required); and polishing by diatomaceous earth filtration. This system produced sea water of an acceptable quality for the reverse osmosis process.

Three membrane systems were selected for the evaluation studies. These were spiral wrap/cellulose acetate; hollow fine fibre/polyamide; and spiral wrap/polyamide thin film composite.

A reasonable evaluation of each of the membranes' performances was possible, but predictions as to the probable life expectancy of the membranes, operated under near ideal conditions, could not be made. Testing should be continued (possibly on a reduced scale), especially since improved new generation high performance membranes are now beginning to appear on the market.

The project has now been completed.

Research on the development of membrane support systems and modules

(Existing project: Contract with the CSIR — National Institute for Water Research)

This has been a year of consolidation and refinement in the membrane production techniques previously developed. The research and development effort has been fairly uniformly spread amongst the various tasks allocated for the year.

Optimisation studies on the cellulose acetate tubular membranes have shown the necessity for controlling parameters not previously recognized. This has led to a further improvement in membrane reliability. This optimisation is still proceeding. The production of polysulphone tubes (for ultrafiltration applications) and their subsequent treatment to produce tubular composite membranes has shown distinct promise, although this system is still at an early stage of development.

The progress on module development has centred on the production of an integral pressure support system on the membrane tube itself with high burst pressures occasionally being achieved.

The production of flat sheet membranes has required considerable redesign to the machinery to allow for greater flexibility and control. Considerable improvement in the production techniques over the year has enabled continual casting of membranes, but these are of inferior quality to those produced by laboratory techniques. This aspect is still receiving attention. However, these membranes are of satisfactory standard to be used in the "glueline" studies, which have shown the necessity for the use of "glues" to seal the membrane surfaces together under moist conditions.

Field testing of the cellulose acetate tubular membranes has continued with excellent results, demonstrating that the membrane production unit has definite commercial potential.

Technological development of ion exchange for the desalination and tertiary treatment of effluents: Planning, design, construction and operation of a 100 kl/d pilot plant and evaluation of its performance

(Existing project: Contract with the University of Cape Town (Department of Chemical Engineering) and a local chemical company)

During the year under review the work centred on two aspects *viz.* the use of alternative regeneration systems, and the design and costing of a 100 kl/d pilot plant.

The use of lime and sulphuric acid, instead of the ammonia and nitric acid previously used as regenerant chemicals, produces a cheaper product water but has certain operational difficulties. In the anion column the problems are to maintain a high regenerant concentration at the very low solubility levels of $Ca(OH)_2$, and to achieve adequate fluidisation conditions with the density of the lime slurry and the resin approaching one

another very closely. These difficulties can be overcome by the use of a continuous stirred reactor to contact the lime and weak base anion resin, followed by a series of column wash stages. In the use of sulphuric acid in regeneration of the cation resin, the problems lie in the deposition of calcium sulphate and in avoiding excessive loss of the acid. These have been dealt with by using concentrations and flow rates of sulphuric acid which prevent deposition in the column, followed by a sulphuric acid recycle to prevent acid loss.

A preliminary design of the 100 kl/d pilot plant was completed and the budgetary costing undertaken by two separate design and construction companies. The high cost of the pilot plant, together with the fact that desalination of reclaimed sewage effluent will not be required in the Western Cape area until the 1990's, have made it undesirable to proceed with the detailed design and construction of the pilot plant at this stage and it was therefore agreed between the parties to terminate the agreement. It is envisaged that the laboratory work will be continued so as to provide a complete package for the subsequent design and construction of a large-scale plant, as and when the need for reuse combined with desalination is more urgent. The finalisation of the present investigation will include the testing of the product water for its potability.

Research on the desalination of treated sewage

(Existing project: Contract with the CSIR — National Institute for Water Research)

In the reclamation of water from sewage effluents by means of physical-chemical processes inorganic salts are not removed and tend to build up within the cycle of reclamation and reuse. This build-up of inorganic salts may impair the reuse potential of reclaimed water and this project was initiated to investigate the application of reverse osmosis and ultrafiltration for desalination of treated effluents.

This work has clearly demonstrated the technical feasibility of the reverse osmosis process for producing water of excellent quality from treated secondary sewage effluents. The rejection of organic matter, as represented by the chemical oxygen demand, is in excess of 90 per cent, so too is the rejection of most inorganic salts, with the exception of oxidized nitrogen compounds.

Membrane fouling is a problem, but with spiral membranes cleaning methods have been shown to be effective in restoring the product flux to acceptable levels. In tubular membranes sponge ball cleaning methods are particularly useful and contribute towards maintaining plant output.

Despite the success of the cleaning methods used there is room for improvement and this would appear to be in the area of feed pretreatment. In this regard promising results have been achieved with in-line coagulation/filtration systems.

The economic feasibility of the reverse osmosis process for reclamation of water from effluents appears to be extremely promising although costs are still expected to be higher than for conventional advanced waste water treatment processes.

Operation of the reverse osmosis process is extremely simple and operator and supervisory requirements appear to be modest. The only real stumbling block at present to the more widespread use of reverse osmosis is the absence of a really effective clarification process so that membrane fouling is reduced to manageable levels.

This project has been concluded and a final report submitted to the Water Research Commission.

Chapter 8

Urban and industrial water consumption

Total water consumption in urban areas, including both the domestic and industrial sectors, is continually rising and the economic use of water in these sectors could result in considerable savings in the country's water balance as a whole. The Commission has for a considerable time been aware of this fact and has, therefore, entered into several agreements in terms of which research has been done or will be done in this connection. Some of these projects have terminated and have been reported on in earlier annual reports. This chapter reports on two projects currently in progress and which deal with water economy measures in urban areas and with the optimisation of dry and dry-wet cooling at power stations in South Africa.

The project in connection with water economy measures has now entered its second year and is executed in terms of a tripartite agreement between the Commission, the SABS and the CSIR. It had its origin in proposals of the CRD Committee for Water Economy Measures in Urban Areas which had been established by the Commission. The CRD Committee compiled a Master Plan and the project's research programme was based on this. The main objective of the project is to bring about significant water economies by means of the design and use of water supply fittings and to develop criteria to update the relevant sections in the National Building Regulations. During the year special attention was paid to the collection of data in connection with appliances responsible for water losses and the effect of water economy fittings on water use. The cooperation of various local authorities has been obtained to assist with these investigations.

The research project on dry and dry-wet cooling at power stations is undertaken in terms of a tripartite agreement between the Commission, ESCOM and the CSIR. Large volumes of water are used daily for cooling purposes at power stations. It is estimated that approximately two-thirds of the water used by industry in South Africa (excluding mining) are used for cooling, especially at power stations. The substitution of conventional wet cooling by dry or dry-wet cooling, however, can effect a considerable saving in water consumption.

At the end of 1979 the Commission sent a fact-finding mission abroad to learn about the most recent developments in the field of dry and dry-wet cooling. During the year under review certain modifications were made to research programmes on the basis of information obtained by the mission. It was also resolved to investigate cooling systems utilising mechanically induced air movement in addition to natural draught systems. It has also been decided to collect additional atmospheric data in an area where ESCOM is planning to erect a fully dry-cooled power station. The purpose is to collect data and do research on thermic stability of air layers and its possible effect on the cooling efficiency of a mechanical draught installation, especially as far as the possible recycling of hot air is concerned.

RESEARCH PROJECTS

Research on water economy measures for water distribution systems in urban areas

(Existing project: Contract with the South African Bureau of Standards and the CSIR — National Building Research Institute)

The main objectives of this project are to achieve a meaningful saving of water through the correct design and use of water supply fittings and to establish criteria which can be used in future up-dating of the relevant parts of the National Building Regulations compiled by the South African Bureau of Standards (SABS).

A considerable amount of "backroom" work was being done by all parties involving surveys of people's water-use habits, literature surveys and the compilation of other basic information by both the National Building Research Institute (NBRI) and the SABS. Two papers incorporating some of this "backroom" work were presented during the year at a Seminar on Water Supply and Drainage Services in Developing Countries, organized by the NBRI.

A number of local authorities have been actively participating in the project, and the NBRI has working agreements with the local authorities of Johannesburg, Bloemfontein, Port Elizabeth and Cape Town and with Pinetown Corporation and the East Rand Administration Board (ERAB). Work being undertaken by these organizations includes data collection with regard to water usage patterns and incidences of drain and sewer blockages in urban areas with conventional fittings and appliances and with water saving fittings and appliances. They are also monitoring water consumption which involves the separation of the total water consumption into household consumption and garden consumption. Twenty low flush-volume WC's are presently being installed into houses now being constructed for middle income residents by the ERAB.

WC flushing efficiencies and discharge characteristics of WC cistern flush valves are being evaluated in the laboratory. Automatic flushing urinals have for a long time been a major cause for concern and are also included in the test programme.

Of great importance to local authorities is the test being carried out on locally marketed multijet fanwheel type water meters and positive displacement types as meter accuracy has also been a cause for concern to local authorities.

In carrying out its allotted tasks in terms of the contract the SABS has set up a Working Committee to advise on, and help with the task of drawing up nationally applicable water regulations. During the year the Committee has been restructured to consist of representatives of the Water Departments of a number of the larger municipalities, while the representatives of manufacturing concerns, the design profession and the plumbers have been retained as specialist advisers to the main committee. This committee has prepared drafts of regulatory matters, and of one code of practice so far. It has also set up a framework for the compilation of comprehensive water regulations.

Research on the optimisation of dry and dry-wet cooling systems at power stations in South Africa

(Existing project: Contract with ESCOM and the CSIR — Air Pollution Research Group and Corrosion Research Division)

Heat is converted into electrical energy at thermal power stations by passing high pressure steam through turbines which drive generators and produce electrical energy. The laws of thermodynamics state that only a portion of the heat can be converted into electrical energy. Power stations use large cooling systems in order to utilize as much as possible of the heat and the unused portion is discharged to the atmosphere. The purpose of this project is to research the interaction of wet and dry cooling systems with the atmospheric environment, with a view to optimising operating parameters. The Air Pollution Research Group (APRG) is responsible for measuring atmospheric parameters external to the cooling system as well as measuring spatial weather characteristics at proposed power station sites so that optimum location and operating parameters at future cooling systems may be chosen. The Electricity Supply Commission (ESCOM) is responsible for measuring atmospheric and water parameters internal to the cooling system.

After an overseas tour by the Technical Subcommittee (representing ESCOM, the CSIR, and the Commission) of this project, it was decided that the first priority was to generate relevant experimental data. Consequently an APRG programme and capital items budget for 1980 were prepared and ratified by the Water Research Commission. Currently the purchase and building of equipment are in progress.

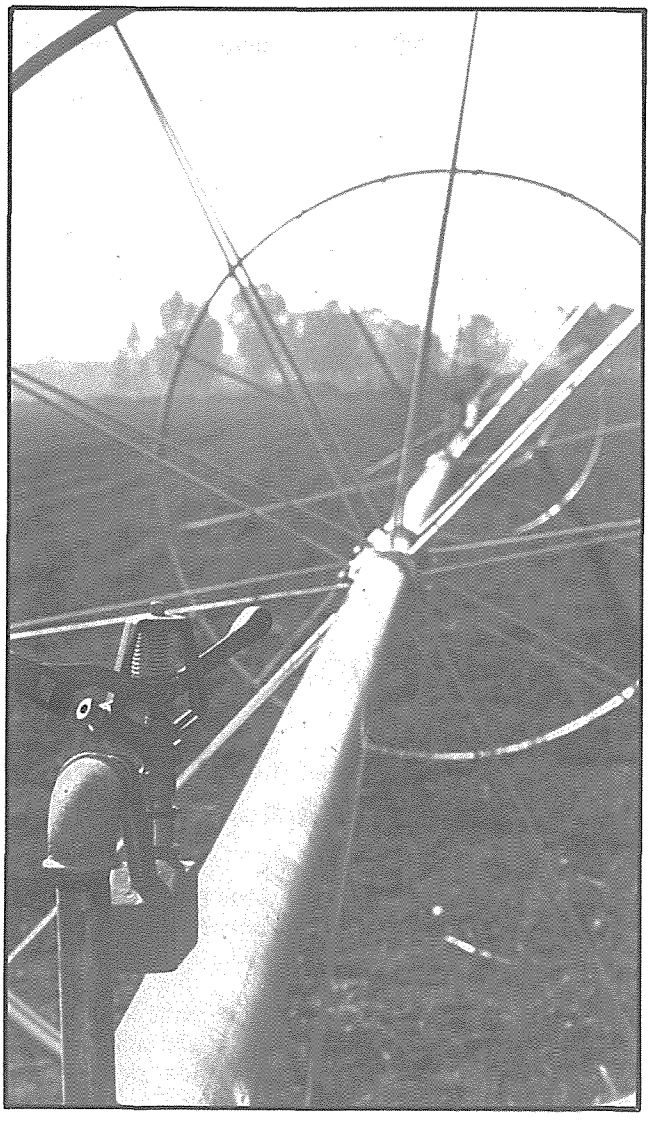
An experiment was conducted to study temperature and wind fields around the number six dry cooling tower at Grootvlei Power Station during conditions at ground based radiation temperature inversion. During this experiment ESCOM measured the performance of the cooling tower. Initial results show large ground level

temperature differences of up to 4° C, which is comparable with the vertical temperature difference between ground level and 50 m height. Wind fields around the cooling tower show a complex pattern consistent with a downward air flow near the tower.

Analysis of these data, in cooperation with ESCOM, is proceeding. However, the initial results have indicated a need for three-dimensional data in future experiments rather than the two-dimensional data obtained here. The contract also provides for a study on the corrosion of cooling elements in wet and wet-dry cooling environments by the Corrosion Research Division. In view of developments in dry cooling technology it has been agreed to concentrate the corrosion studies on dry cooled systems only.

Chapter 9

Irrigation



Until fairly recently, irrigation farming in South Africa has been in the fortunate position that water used for irrigation purposes on the 330 government and other irrigation schemes has, apart from periods of water restrictions, been relatively freely available at a relatively low cost. During the past twenty years the costs of water supply have increased rapidly whilst the availability of water has decreased. As mentioned in Chapter 1, the demand for water in industry, mining and urban development is increasing more rapidly than the demand in the agricultural sector, and, although consumption in the latter sector is also expected to rise, the percentage of the total annual consumption allocated to agriculture, therefore, will decrease from the current 75 per cent to 45 per cent of the total by the end of the century. This means that the agricultural sector will, in future, have to compete vigorously for its rightful share of the available water supplies and that effective usage is just as important as in other sectors.

Against the background of limited water sources in South Africa and the necessity to utilize all waters as beneficially as possible, the Commission of Enquiry into Water Matters, in 1970, expressed the opinion that a saving of 25% in the consumption of irrigation water should be sought. This objective can be achieved only if irrigation is practised on a more scientific basis, improved irrigation methods are used, and wastage eliminated. However, measures aimed at water economy should not impede production, especially if the expected population growth is borne in mind. The Commission accepts as part of its responsibilities the promotion of irrigation research which should eventually lead to achieving these objectives and that the highest possible yield per unit water be obtained.

Irrigation research is unique in the sense that it is not only soil, crop and climatically bound, but also

seasonally bound. Apart from the fact that research has often to be repeated at different sites, it also has to be done over a relatively long term. This then means that irrigation research imposes high demands in terms of funds and manpower. In supporting irrigation research, the WRC endeavours to exploit and use the expertise available at universities, and where necessary to recruit overseas specialists to augment the available manpower, also in government departments. In this way several departments of universities are already involved in irrigation research projects which are supported financially by the Water Research Commission.

Two irrigation research projects have already been completed and a further five will be terminated during the next year. However, it has already become clear that some of these projects will require additional research in order to ensure that results are applied in practice. Thus, for example, the project on the efficiency of water abstraction from fine sandy irrigation soils by various root systems is a project which has succeeded a previous project on an investigation into soil compaction under irrigation at the Vaalharts Government Irrigation Scheme. The Department of Soil Science of the University of the Orange Free State is responsible for both projects.

The successful practical application of irrigation research results still presents problems in a number of ways. The divergent nature of irrigation farming, in terms of both geographic distribution and crops produced, is primarily responsible for this. The level of training and financial capabilities of the irrigation farmer also play a role. In addition, a considerable period of time often elapses between results becoming available and their practical application. The WRC endeavours to promote the application of results in irrigation practices and in the design of irrigation schemes, by distributing final project reports to extension officers of the Department of Agriculture and Fisheries and to the Directorate of Water Affairs. The development and exploitation of other available media for the successful transfer of irrigation results, such as radio and agricultural magazines, will also be investigated.

Coordination of irrigation research

In 1978 the Coordinating Committee for Irrigation Research (CCIR) was established as an overall coordinating body in order to promote the coordination of irrigation research in South Africa. This committee, which operates under control of the Department of Agriculture and Fisheries, with representatives of the Department of Water Affairs, Forestry and Environmental Conservation and of the Commission, aims at eliminating unnecessary duplication of irrigation research, ensuring optimal application of funds and manpower for irrigation research, and identifying needs and priorities in irrigation research.

Even at the foundation meeting of the CCIR it became clear that a register of irrigation research projects would be essential for the sensible execution of the coordination function. As a result a survey was conducted of all research projects relating to irrigation and which are undertaken by government departments, universities and other organizations. For the purpose of the survey the irrigation field was divided into six subsections, *viz.*

- Plant/water (climate) relationships and interactions
- Soil/water (plant) relationships and interactions
- The technology and mechanization of irrigation and drainage
- Agricultural resources exploitation under irrigation
- Irrigation scheduling and water supply
- Economic aspects of irrigation

According to the survey there are currently 73 research projects being carried out in the six subsections. Of these, 40 are being done by the Department of Agriculture and Fisheries, mainly through its Soils and Irrigation Research Institute and the Fruit and Fruit Technology Research Institute. Furthermore, 31 are being undertaken by various universities — mainly the Universities of the Orange Free State and Stellenbosch — and the remaining two by the SA Sugar Association at Mt Edgecombe. The Water Research Commission currently supports seven of these projects; more particulars are supplied in the remainder of this chapter.

RESEARCH PROJECTS

Water requirements of agronomic and vegetable crops

(Existing project: Contract with the University of Pretoria — Department of Plant Production)

The aim with this project is the systematic investigation of the water requirements of crops with a view to the planning and refinement of irrigation programmes. Methods are being investigated to modify programmes

in such a way that available water will be utilized as effectively as possible for obtaining optimal yields.

Research during the previous year indicated that measurement of plant temperatures could make a significant contribution to achieving the objectives of the project. The results of the current year show that in the case of dwarf beans and wheat the period between irrigation applications can be lengthened considerably without detrimental effects on final yield, provided that more water is applied. Thus, for example, it has been found with dwarf beans, that if the average class A pan evaporation amounts to 6 mm per day, a total of 120 mm of irrigation water at 36 mm per application would yield better soil moisture conditions for optimal yields, than a total of 132 mm of irrigation water at 12 mm per application. In the case of wheat the same tendency has been observed. With average class A pan evaporation running to 4,5 mm per day over the whole of the growth season, a total irrigation of 365 mm of water at 60 mm per application during the flowering period to ripening resulted in some cases in higher yields when compared to 40 mm of water per application over the same period. Increased irrigation applications at a lower frequency do not necessarily lead to decreased water consumption, but do however, lead to lower financial expenditure in respect of irrigation equipment and labour.

Research on decreasing water consumption, if possible, will in future be done more purposefully by means of the leaf temperature technique which has been further refined during the year.

The effect of internal plant moisture stresses on the growth and production of certain agronomic crops

(Existing project: Contract with the University of the Orange Free State — Department of Agronomy)

During the year under review one irrigation trial was run at the Vaalharts Agricultural Research Station. Wheat was again used as test crop for experiments during the winter months. The object with this investigation was to cultivate wheat at various levels of moisture supply by applying irrigation in such a way that moisture stresses would be induced at various growth stages. The relative sensitivity of the plant to drought during the various growth stages was determined as the effect of moisture stresses during short periods on yield components.

Rain occurred during winter and although the moisture stresses which had been planned could not all be obtained, the data will still constitute a valuable supplement to the data of previous seasons. Important information has been gained in respect of the moisture quality of the soil during the growth season and in conjunction with the water potential in the plant. Additional data obtained included data with regard to the leaf area index, as well as dry mass of the plant, and soil moisture readings. In this way a picture has emerged regarding the vegetative development of the plant, as determined by the various treatment methods. These data will also give an indication of the E_t/E_o ratio of wheat over the growth season.

During the course of the experimental period for wheat, sufficient data was collected in order to determine the reaction of the plant to moisture stresses at various growth stages. More information is required, however, to calculate moisture stress days accurately. The importance of rain shields has once again been apparent and it has also become clear that research should be done with regard to the effect of plant moisture stress on photosynthesis and respiration.

To this end a new agreement has been entered into with the University in terms of which research will be done on the effect of various periods and intensities of internal plant moisture stress on photosynthesis, respiration and water consumption efficiencies of some agronomic crops.

Research on the effect of different times and intensities of internal plant moisture stress on photosynthesis, respiration and water use efficiency of certain agronomic crops

(New project: Contract with the University of the Orange Free State — Department of Agronomy/ Horticulture)

Irrigation research is being done in the OFS area to investigate the effective, economic application of water in agriculture in this central area of the Republic. From a previous project undertaken in terms of an agreement with the Commission the sensitivity of wheat to internal plant moisture stress during the various growth stages had been determined (see report elsewhere). As a follow-up to this study, a new agreement has been entered into with the Commission and with this project the moisture consumption of agronomic crops during various stages is to be investigated. The daily moisture consumption for each growth stage, not only under ideal moisture conditions, but also under different moisture stress intensities will be determined. This information is essential to irrigation scheduling by means of the evaporation pan and/or other methods. The extent to which different moisture stress intensities in the various growth stages affect the physiology of the plant, as

reflected in the photosynthesis and respiration rates, will also be determined.

The first experiments will commence in 1981 on the Riet River Research Station. Although the experiments will be conducted on this site, results (because of similarities in, *inter alia,* climate) could be projected on the Vaalharts Irrigation Scheme and the Ramah Irrigation Area of the Van der Kloof Canal System which forms part of the Orange River Project.

The efficiency of water extraction from fine sandy irrigation soils by different root systems

(Existing project: Contract with the University of the Orange Free State — Department of Soil Science)

Compacted layers, a phenomenon which occurs reasonably freely in irrigation soils in South Africa, limit root development to the topsoil. These shallow root systems lead to inefficient extraction of the irrigation water which has been applied. Results of a previous project on soil compaction, which had also been supported by the Commission, showed that modified soil cultivation practices, known as controlled implement traffic, results in more deeply distributed root systems.

The project has two objectives. It is aimed, first, at evaluating the efficiency with which specific root systems, as modified by cultivation practices, extract groundwater and plant nutrients, and, second, to incorporate the various components of the extraction process in a mathematical model in order to obtain a better understanding of the process. By dividing the extraction process into its components a better understanding may be obtained of the effect of modifying the root system by means of different soil cultivation practices. This in turn can be used to optimise frequency of irrigation and the volume of water needed per application.

Pot tests with wheat and maize were done to investigate the effect of total root length per plant and root thickening on the water extraction process. Results showed that the effect of root thickening was negligible. In contrast, an increase in root length increased the hydraulic conductivity ability of the plants. This would seem to indicate more effective water extraction but also increased water consumption.

A question has arisen about the extent to which increased water consumption will be reflected in a higher harvest yield and during the 1979—80 season, therefore, a field experiment with maize was conducted. Four soil cultivation practices, each resulting in a different pattern of root distribution, were investigated. Irrigation was applied in accordance with the demands of the shallowest root system established by means of the cultivation practice conventionally used by farmers. In all cases the highest harvest yields were obtained where deeper root systems occurred as a result of controlled implement traffic. The water consumption efficiency (calculated as kg seed produced per hectare per mm of water applied) in the case of treatment with controlled implement traffic, was 49% higher than that of conventional cultivation practices.

Research on the scheduling of irrigation of wheat in the irrigation areas of the Orange Free State

(Existing project: Contract with the University of the Orange Free State — Department of Agrometeorology)

The objective of this project is to establish an information service in order to ensure maximum wheat production per unit of irrigation water at the Vaalharts and Jacobsdal irrigation schemes. A weekly irrigation schedule will be compiled using only weather data from the two areas and a water balance model being developed at the Agro-meteorological Observatory at the University. Information pertaining to irrigation, as well as the probability of rain during the next five day period, will be released by means of press and radio to the farming industry in the relevant areas. During the past season all functions which form an integral part of the water balance model have been evaluated. The water balance model which predicts the soil moisture content as well as the leaf water potential has been developed and compared with experimental observations. Results have been satisfactory. The computer programme for the calculation of precipitation probabilities has already been compiled and fully tested.

The whole investigation is being repeated and all functions in the model, as well as certain suppositions will be confirmed. A few control functions such as hydraulic conductivity, leaf water potential and evapotranspiration as well as the model in its current format will be compared with experimental observations.

The water balance model, as well as the program for calculating rainfall probabilities, will also be used to provide an irrigation farmer at Hartswater with information on irrigation on a weekly basis. The model will be tested continuously against an experimental determination of leaf water potential and soil moisture content. The site being used for this purpose will have a moisture stress site as well as one being irrigated conventionally as control. At the end of the season the grain yield of the three sites will be compared in order to evaluate the effectiveness of the model.

A research scientist conducting tests on an experimental wheat plot at the University of the OFS where a project on the scheduling of irrigation of wheat is being carried out.

Development of effective irrigation methods for application to steep lands, with special reference to micro-methods

(Existing project: Contract with the University of Stellenbosch — Department of Civil Engineering, Chair of Irrigation Engineering)

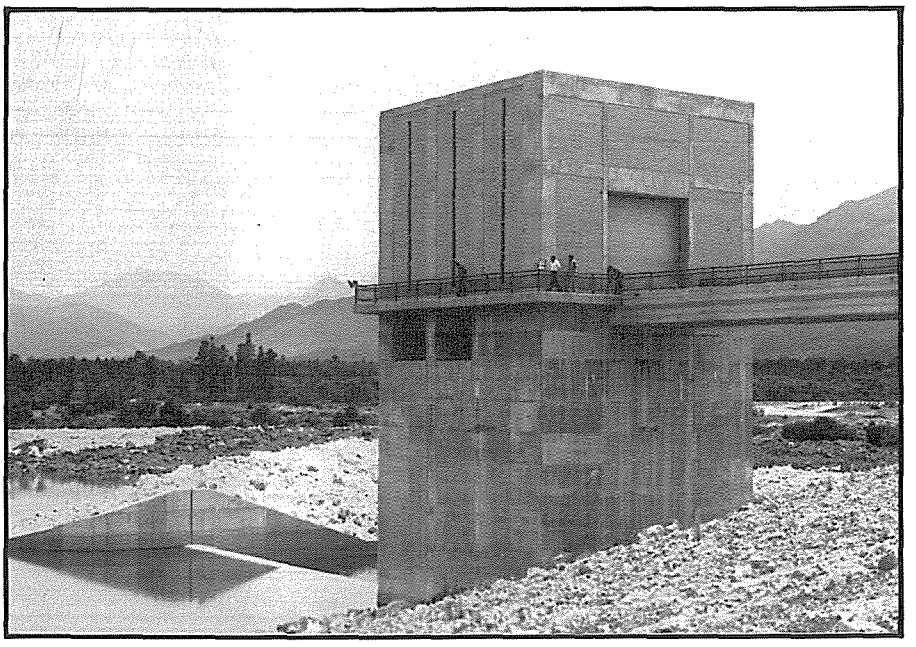
The objective of this project is the investigation of equipment and methods for improving the gauging and control of irrigation water in supply as well as in irrigation systems. The investigation is aimed, on the one hand, at the specific requirements pertaining to the supply systems for irrigation water which will be made available to the Riviersonderend-Berg River project from the Theewaterskloof scheme in terms of the project white paper, and, on the other hand, at the use of the irrigation systems on steep lands. This information will have some value during the final planning and design of the supply and irrigation systems (at this scheme and possibly also at others).

During the year tests were conducted on a laboratory model of a supply system for irrigation water which can be controlled automatically. As a result of this, recommendations can be made on the choice of equipment and the design of a system for providing water on demand at any time.

Field tests have been done on four types of irrigation systems, *viz.* microjets, microfurrows, drip irrigation and sprinkler irrigation, in order to investigate the effectiveness of each on a steep site on Welgevallen experimental farm in Stellenbosch. The irrigation requirements of cabbage, the test crop, are also being determined in order to apply total irrigation water as accurately as possible. The even distribution of the water and inevitable losses are also being studied. Meteorological data such as evaporation, wind velocity and wind direction, and nett sun radiation are being collected on site to serve as background against which improvements to the irrigation systems may be planned. The root system of the cabbage is being studied to determine the depth to which the soil should be irrigated, with a view to limiting losses which result from seepage of irrigation water.

At this stage insufficient information exists to allow a comparison of the four systems. However, in-

The inlet tower in the Theewaterskloof Dam which is referred to in the project on effective irrigation methods.



formation obtained thus far is being used for continually improving the systems, with a view to the eventual compilation of a manual on the design of the most effective irrigation systems for steep lands.

Evapotranspiration and water use studies by means of weighing lysimeters: Evapotranspiration as a function of soil, plant and atmospheric factors

(Existing project: Contract with the Department of Agriculture and Fisheries — Soil and Irrigation Research Institute)

The aims of the project are to understand and predict water uptake by and water loss from certain crops, to identify methods of early detection of crop water stress, and to assess the effects of different degrees of water stress on crop growth, development and yield.

As before, investigations were carried out with wheat grown from June to October 1979 and with soybeans grown from December 1979 to April 1980 at Roodeplaat near Pretoria. Evapotranspiration was again monitored with four precision weighing lysimeters one of which was always kept in a well-watered condition. The water supply to the other lysimeters was manipulated with a view to obtaining water stress at various times during the season. When necessary a moveable rain shelter was used to help maintain a desired treatment. A comprehensive set of meteorological measurements was recorded throughout the season. Phenological records were kept and data on crop yield and yield components noted. In addition to lysimeter treatments, field irrigation treatments based on the predictions of an irrigation scheduling computer model were evaluated.

Observations during the year under review confirmed that daily evapotranspiration can for practical purposes be reliably estimated from meteorological data until 70% to 80% of the plant available water has been depleted. At or near this level of depletion, time trends in several other potential indicators of crop water stress besides evapotranspiration rate also underwent sharp changes. This provided a large measure of confidence in both the critical level of allowable soil water depletion and in the measures used to detect the onset of crop water stress as soil water is depleted.

The successful prediction of evapotranspiration over a wide soil water content range led to a close simulation by the irrigation scheduling model of the measured soil water balance under field conditions. It was however found that changes in the amount of advected energy (due mainly to the size of the oasis effect) can slightly influence the calibration of the crop factor which relates crop evapotranspiration to potential evapotranspiration.

A further benefit of incorporating the modelling of growth and yield in this research would be the information which could then be provided on expected water use efficiencies under different environmental and irrigation regimes. Besides this aspect, future research will also be aimed at the problem of quantitatively explaining measured values of plant available water in different soil profiles.

Research on the soil factors affecting the optimal utilization of irrigation water in the National States

(Existing project: Contract with the University of Fort Hare — Department of Soil Science)

As a result of the problems associated with dry land crop production, the production of agricultural products under irrigation plays an important role in the food requirements of the National States.

During the year studies on the two main aspects of this project continued viz. the determination of profile available water capacity (PAWC) in soils, and the determination of infiltration patterns under flood irrigation.

The conventional method of determining PAWC using matric suction data was compared with the field method developed in this research project, called the plant symptom-PAWC method. Five soils were used. The conventional method was found to be unsatisfactory since in 4 out of the 5 soils PAWC values based on matric suction data were only approximately half as large as those determined under field conditions.

PAWC determinations were made on small plots at selected sites in the Ciskei. Values for maize on Sterkspruit, Glendale, Williamson and Shorrocks series were 94 mm, 102 mm, 84 mm and 108 mm respectively. For wheat on Williamson and Shorrocks series PAWC values were 80 and 119 mm respectively.

In addition a pilot irrigation trial was carried out with maize on small plots (Jozini series) to determine whether or not irrigation scheduling based on the plant symptom-PAWC technique would result in more economical use of irrigation water, when compared with a conventional method based on Class A pan evaporation and an estimate of available water from matric suction data. The result indicated no significant difference in the yields per unit of water applied for these two methods.

Additional results obtained by the transportable, boxed, undisturbed profile method of determining PAWC show that this procedure is promising. Values obtained by this method to date are fairly consistently slightly higher (approximately 18%) than equivalent field values.

As far as the infiltration patterns under flood irrigation are concerned, acquisition of field data on the hydraulic behaviour of an irrigation bed has been started on a routine basis for standard size beds on various slopes. One set of data is available for a clean cultivated fallow condition on a Jozini soil. A computer model for stream flow advance and recession, with infiltration has been acquired and is being transcribed for the computer.

Soil physical characterization techniques are now being evaluated for routine use.

Chapter 10

Surface hydrology

South Africa is dependent mainly on runoff in rivers and streams for its water requirements, so much so that approximately 90 per cent of the total water is derived from this source. It is estimated for South Africa as a whole, that the mean annual runoff amounts to approximately 8,6 per cent of the mean annual rainfall and that less than 60 per cent of this runoff can be made available for use by means of existing techniques.

In view of the limitations imposed on our water resources, it is clearly of cardinal importance for the planning of further development, that estimates of water resources be continuously updated. The estimation and planning process is highly dependent on the use of sophisticated numerical techniques (such as rainfall/runoff models) which need continuous development and refinement as more data become available. The development of these techniques requires a sound knowledge of hydrological processes and their complex interaction. The Commission gives high priority to hydrological research and has initiated 15 projects since its inception of which 7 have been completed so far and 8 are reported on in this chapter.

With the increasing demand for water, much attention will have to be given to assessment of the effects of land-use and management practices on stream flow, erosion and water quality. The available research data and methods of prediction do not meet with all the requirements and further research is required. This aspect is receiving attention in the research projects supported by the Commission.

During the year under review a new project on the continuous streamflow modelling of South African rivers was started in terms of a contract with the University of Natal. This project had adopted an unusual but promising approach to modelling of rainfall/runoff relationships. Whereas the usual approach is to use rainfall data in order to model effective rainfall and hence streamflow, this project uses streamflow to model effective rainfall. The objective is then to determine the relationships that exist between effective rainfall and measured catchment rainfall in a wide variety of catchments in South Africa. Knowledge of these relationships could lead to far more effective estimation of streamflow in catchments without stream gauges but where rainfall data exist. The streamflow data being used in this project constitute the longest, most reliable records available and were captured initially at the University of Natal for a project on the concept of the runhydrograph, sponsored by the Commission. From this project a runhydrograph manual was derived.

Coordination of hydrological research

The Committee responsible for overall initiation and coordination of hydrological research in South Africa is the Coordinating Committee for Research on the Hydrological Cycle (CCRHC) which was established jointly by the Commission and the Department of Water Affairs, Forestry and Environmental Conservation in 1977. It functions under the control of this Department. As has been said in Chapter 1, the CCRHC decided that

a priority research field in hydrology was the determination of the effects of rural land-use on stream runoff. In order to obtain clarity as to the priority of objectives within this multidisciplinary field, a workshop of all interested parties was held and the matter was discussed in depth by delegates from a large number of universities, statutory bodies and government departments. In order to provide guidance and coordination for the discussions, the Commission brought the well-known authority, Professor John Hewlett of the School of Forest Resources (University of Georgia) to South Africa as a consultant. Prof Hewlett contributed a great deal to the workshop by sharing his experience gained in other countries and by illustrating problem areas that he had observed during his field trips in South Africa. The decisions made at the Workshop and the view expressed by the delegates are presently being coordinated and documented by the CCRHC.

RESEARCH PROJECTS

Research on water resources

(Existing project: Contract with the University of the Witwatersrand — Hydrological Research Unit)

Assembly of rainfall, evaporation and streamflow data for a specific catchment is an arduous time-consuming process. This is even more the case when the task has to be conducted for extensive areas of the country and when all relevant major uses of water, characteristics of all reasonably large reservoirs as well as areas of land under forest and under irrigation have to be added to the list of the data to be assembled.

The Hydrological Research Unit (HRU) model has been set up and fed with data for all reasonably satisfactorily gauged sub-catchments throughout the Vaal, Limpopo, Olifants, Inkomati, Zululand, Tugela and Natal drainage regions. Calibration of the monthly model in these catchments has largely been completed and parameters are being mapped with the object of regionalizing the values so that the behaviour of ungauged catchments can be simulated.

For purposes of reporting on the results of the Water Resources Survey which remains the principal task under this contract, South Africa has been divided into main drainage regions or groups of regions. Although not one of the reports on a region is as yet ready for release, practically the whole eastern sector of the Republic has been mapped and the simulation model has been calibrated for large areas. It has been necessary to delay publication of the results for this large area in order to facilitate regionalization of the model parameters.

It is anticipated that the reports covering the whole of the Vaal and Limpopo/Olifants drainage regions as well as all the rivers north of the Tugela will be issued in the near future.

Hydrological investigation of rural catchments in Natal with specific reference to flood events

(Existing project: Contract with the University of Natal — Department of Agricultural Engineering)

During the year under review the main thrust of the research work has been towards the improved estimation of input parameters for the Soil Conservation Service (SCS) rainfall-runoff model. The SCS model has already been adopted for use by the National Road Transportation Board and the Natal Roads Department.

The research has shown that marked improvements over the Standard SCS procedures can be achieved if a curve number (CN) adjustment is made for antecedent moisture condition and initial abstraction adjustments are made. Investigation is also under way to establish whether runoff lag is a storm, antecedent condition and a drainage-density dependent variable. A distributed water-yield model which is sensitive to readily available soil and crop data, is also being tested on 12 Natal catchments of varying size. The initial results are very encouraging.

An investigation into antecedent moisture conditions associated with extreme rainfall events, has reached an advanced stage. Over 700 rainstations each with approximately 50 years of daily rainfall data are involved in the analysis and a start has been made with the drafting of the final map which summarises the results. The collection of high quality data in the Cedara and De Hoek/Ntabamhlope catchments forms an important component of the research programme and includes a comprehensive land use survey which is done on an annual basis. The results are recorded on computer maps of canopy cover, vegetation type, radiation balance and other land use variables. A sediment sampler has been installed in one of the catchments but due to the drought conditions that prevailed in Natal during the year, insufficient flow events have occurred to adequately test the instrument.

Three scientific papers published in scientific journals have resulted from this research project.

An agrohydrological study of Natal

(Existing project: Contract with the University of Natal — Department of Agricultural Engineering)

The thorough assessment of Natal's water resources pertaining to the agricultural sector is essential for good water resource management.

The main thrust of this research is in the direction of irrigation modelling, rainfall erosivity studies, compiling of rainfall and temperature maps and the development of agrohydrological indices for Natal. A distributed irrigation requirements model has been developed for Natal, based on a 5-day water balance accounting for rainfall, temperature, crop and soils data to output potential and actual evapotranspiration, soil moisture deficit, water surplus and irrigation requirements at 10 km intervals. There has been a steady demand for information from this model by the Department of Agriculture and Fisheries, Natal Parks Board, Natal Town and Regional Planning Commission and engineering consultants.

Rainfall erosivity studies are included in this project because they have, at this stage, exclusively agricultural application in soil conservation planning and management. In collaboration with the Division of Agricultural Engineering (Department of Agriculture and Fisheries) several new equations/indices for estimating rainfall erosivity have been developed, using daily rainfall data. Rainfall erosivity is a major factor in the soil erosion process. This erosivity varies greatly throughout South Africa and it was therefore necessary to carry out this study on a regional basis. The information gained from this study forms an integral part of the soil loss estimation techniques used by conservation planners.

Hydrological research in Zululand

(Existing project: Contract with the University of Zululand — Department of Geography)

The research programme for 1980 had a primary emphasis on improving the antecedent moisture component of the Soil Conservation Service (SCS) Model. By mid-1980 significant advances had been made in this field by incorporating evapotranspiration and drainage losses in the estimation of antecedent moisture conditions. Previously, estimates of this variable were based on antecedent rainfall totals alone. The techniques developed to estimate evapotranspiration and drainage are simple to use and require limited meteorological data inputs, namely, daily rainfall depths and the daily mean air temperature, thus facilitating their application in most parts of South Africa.

Further research into estimating catchment antecedent moisture conditions has focussed on testing a selection of antecedent precipitation indices, as well as determining the optimum number of antecedent days which needs to be considered to give the most accurate measure of catchment antecedent moisture conditions. Antecedent precipitation indices have generally been found to be inadequate for reflecting the moisture status of a catchment, while the number of days antecedent rainfall optimally associated with catchment moisture conditions appears to be related to the characteristics of the soil and physiography of the catchment.

The testing of physiographically based equations for calculating long-term runoff characteristics, such as the mean annual runoff, has continued. These equations were developed on data from a sample of small catchments in Natal but have also yielded satisfactory results in the South West Cape and Eastern Transvaal.

Much attention has been given to examining the infiltration characteristics of the soils of the Ntuze catchment. The characteristics of the infiltration curves are being related to the physical properties of these soils.

A hillside runoff plot has been established in the Zululand catchments and flows are being continuously measured at three levels, namely, surface, sub-surface and groundwater flows. The infiltration characteristics of the soils on this plot have been determined and routine soil moisture and rainfall measurements are made.

Research on continuous streamflow modelling of South African rivers

(New Project: Contract with the University of Natal — Department of Civil Engineering)

The objective of this project is to obtain a greater understanding and a better description and prediction of stream flow rates and their variabilities throughout the Republic than are currently available. The methods used to model and parametize the streamflow records (with hopefully eventual extension to ungauged locations), embody amongst the most modern and powerful computer-based systems engineering techniques.

Models exist which can describe monthly flows which are suitable for computation of water resources

system reliability. Other models (such as the unit-hydrograph and the runhydrograph) can describe the probability of floods of different shapes and sizes. Deterministic models such as the Stanford Watershed Model (SWM) exist which are designed to model river flow continuously, yet no satisfactory stochastic (probalistic) model is known to exist which can model low flows on a continuous basis. Low flow modelling, which the proposed streamflow can accomplish, is essential for the management of rivers and their catchments, where water quality is of concern. One particular use of the proposed model is its forecasting capability. Effluents have to be treated with a mind to the concentrations that will result in the waterbodies that transport them. Prediction of the likely low-flow characteristics of an ungauged catchment will enable sensible design decisions to be made concerning the type of treatment plant necessary for certain effluents in certain locations. This model is seen to be essentially complementary to deterministic models such as the SWM model and the Pitman model.

In some studies such as those currently ongoing at Bethlehem, modification of the weather and/or modification of the catchment may or may not have a noticeable effect on the run-off from the catchment concerned. The proposed model, being a stochastic model, lends itself to statistical analysis to determine whether significant changes in the catchment or the effective precipitation have taken place. This can be accomplished in an objective and scientific manner.

The unit-hydrograph and the runhydrograph are design tools which enable the engineer to anticipate what type of flood "regime" is likely at a particular point on a river. They are of no use for forecasting the flood that is likely from a particular storm that is imminent or precipitating on a catchment. By contrast, the proposed continuous streamflow model can be used directly for flood prediction, in other words flow forecasting, and the estimates of the parameters that describe it can be sharpened continuously as more data become available. It can even be modified to have a memory that decays with time, so that changing catchment characteristics can be accommodated.

The development of a data bank of autographic raingauge records in South Africa

(Existing project: Contract with the University of Natal — Department of Agricultural Engineering)

Many engineering design and control problems centre on depth-duration-frequency information i.e. the expected magnitude of a storm event of a given duration and for a given return period. The basic data needed for such calculations are not readily available in South Africa. This project is making a contribution towards meeting the need for a data bank of computer-compatible digitized records from autographic raingauge charts.

The data which are generated are at present being used for studies of rainfall-runoff relationships and kinetic energy of rainfall. The kinetic energy of rainfall is a most significant factor in the estimation of soil losses and the production of sediment from catchments.

The project has been given a significant boost due to the development of a sophisticated but user-orientated interactive error checking program. This program ensures that the data processor is able to generate error free data.

The records from Natal rainfall stations are being digitized by this project and the digitized data will subsequently be incorporated in the rainfall data bank of the Weather Bureau.

Hydrological research in the Ecca and Wilderness catchments

(Existing project: Contract with the Rhodes University — Department of Geography)

The primary emphasis of this research project falls on rainfall-runoff modelling in the semi-arid Ecca research catchments (a tributary of the Great Fish River), and in the sub-humid Wilderness catchments. A secondary aspect of the project is the observation of water quality rainfall runoff relationships.

During the year under review problems with two malfunctioning flow-measuring flumes in the Ecca catchments were solved by the alteration of these structures into crump weirs, utilizing the existing structure in the new design. Weir-pools in the Ecca, filled by large deposits of bed load during the July and August 1979 floods, were excavated to their original capacity, providing sound stage/discharge relationships.

A new digitizer/micro processor system was installed and all data-processing has been reorganised on a computerized basis which allows chart interpretation to the finest practical time resolution.

The year also saw the rainfall runoff modelling investigations getting under way:

A general view of part of the river and lakes system at Wilderness in the Southern Cape where hydrological research is being financed by the WRC.

- The testing of some existing lumped-parameter catchment models using Ecca catchment observations as input data, was initiated.
- A reconstruction of historic river discharges into the Wilderness Lakes system using Pitman's daily catchment model and a single-event flood model, has been completed.
- A multiple regression analysis of storm and runoff characteristics for the various Ecca-catchments as well as an investigation of runoff source area definition in those catchments, have been completed.
- A tentative monitoring programme in the Ecca catchments of surface and groundwater salinities as well as of sediment transport in certain stream channels, was initiated.

The abovementioned hydrological and water quality monitoring activities will continue and the rainfall-runoff modelling programme will be consolidated.

Digitizing of autographic rainfall data

(Existing project: Contract with the Department of Transport — Weather Bureau)

This project is aimed at synthesizing all available autographic rainfall data in a central data base. The results of this project should, to a large extent, meet the urgent

demand for digitized rainfall data in computer readable form. The data can also be used advantageously in several of the other hydrological research projects supported by the Commission.

Some basic processing of the data is necessary and it should be made readily available to all users such as hydrologists, engineers and meteorologists.

To achieve these aims it will be necessary to —

- determine which stations' data are available on autographic cards;
- digitize the data;
- record the digitized data in a central data base;
- determine which standard processings should be done; and
- ensure that the data are available for distribution.

During the year under review the survey of available data was completed. The computer system for digitizing the data has been developed and staff have been trained to do the digitizing. Two years of data at all Weather Bureau stations has already been digitized.

Digitizing of data for specific priority areas will now be initiated. The storage of digitized data in the data base will be continued and the standard processing and retrieval procedures will be developed for implementation.

Chapter 11

Flood occurrences and flood damage

Although flood plains of rivers were initially exploited mainly for agricultural purposes, development for residential, commercial and industrial usage has been taking place on an increasing scale. As a result of this, flooding of flood plains has caused great losses and hardship to individuals and communities alike.

The extent of flood damage in South Africa is relatively small in comparison with damage resulting from water shortages. The extent of flood damage, however, should not be underestimated, and as an illustration of this, the total flood damage for various stretches of the Orange, Vaal, Riet, Seekoei and Hartbees Rivers as a result of the 1974 floods, amounted to R42,2 million. Damage of this magnitude leads invariably to the question of whether flood damage and the concomitant hardship could not have been prevented or reduced.

There are a number of different methods that may be used to limit flood damage, such as the prevention or curtailment of flood plain development; making the inhabitants and local authority responsible for the risk of flood damage; the construction of flood protection works to decrease the extent of possible flood damage; and a combination of the abovementioned methods.

Against this background the Department of Water Affairs, Forestry and Environmental Conservation approached the Commission to initiate research on flood damage in order to develop methodologies to identify and evaluate flood damage; to apply these methodologies to certain river stretches in order to determine the flood damage; and to determine relationships between physical damage and flood conditions and by so doing to develop mathematical models for damage resulting from specific flood conditions.

Agreements were entered into with the University of the Orange Free State and the University of Stellenbosch, in terms of which the Institute for Social and Economic Research (ISER) and the Bureau for Economic Research (BER) respectively, would undertake the relevant research. Information from these research projects is essential if well founded decisions on the type and extent of protection measures for reducing or eliminating flood damage are to be taken. For this reason, the original agreements for research into flood damage, which had originally concentrated on non-urban flood damage, were extended to include river stretches where urban damage predominated, namely the 1975 floods which occurred in the Vaal River.

Flood damage is an aspect which is directly related to flood occurrences. In this respect there is a need for a mathematical model which, with rainfall, catchment characteristics and antecedent conditions as input data, can predict the expected flood and route through rivers and impoundments and in this way obtain an indication of the depth and duration of the flood at points of concern. This, together with factors relating to flood

damage referred to previously, will give an indication of the required operation of the sluice gates so as to minimise downstream damage. Research on this aspect is being carried out by the Hydrological Research Unit of the University of the Witwatersrand in terms of an agreement with the Commission.

In overall terms, the results of the research projects for the purposes of planning, design and catchment management and management of impoundments and flood plains, will be of significant value.

RESEARCH PROJECTS

Research on flood occurrences

(Existing project: Contract with the University of the Witwatersrand — Hydrological Research Unit)

The main objective of this project is to obtain information to be used for routing the runoff as a result of floods in a catchment through the river system and through a downstream flood plain, in such a way as to minimize damage.

The programs for operating the suite of flood plain management models developed in terms of this contract, are in demand from several parts of the world, particularly Australia. User manuals for these programs appear in the HRU reports but to facilitate operation of the models the programs, together with test data and worked examples have been committed to magnetic tape and copies of these tapes have been distributed among users.

The well-known Storm Water Management Model (SWMM) developed by the U.S. Environmental Protection Agency has been mounted in the Wits Computer and is being fairly widely used. Promising results have been achieved with the ILLUDAS model for urban flood prediction and a modified updated version will soon be made available to the profession.

Storm studies for SWA/Namibia were completed and the results incorporated in HRU Reports 3/79 and 2/80. While report 3/79 contains the results of the analysis of daily rainfall data relevant to design flood determination in relatively small arid catchments, report 2/80 provides design storm data for estimating flood for larger arid catchments.

Collaboration with the National Institute for Telecommunications Research continues in the hope of being able ultimately to use the signals from a weather radar monitoring the catchment to improve flood prediction.

Research on flood damage

(Existing project: Contract with the University of the Orange Free State — Institute for Social and Economic Research)

Research in terms of this contract included an investigation into the Vaal River floods of 1975. The investigation was completed during the year and the report submitted to the Commission. Unlike the 1974 floods in the Orange and Riet Rivers, urban damage is very pronounced, especially in the stretches between Standerton and Vaal Dam and Vaal Dam and the Barrage. Damage to farms, however, predominates in the stretches between the Barrage and Bloemhof Dam and the Bloemhof Dam and the confluence of the Vaal and Orange Rivers.

Total material damage for the whole of the area under investigation amounted to R8 422 106, of which farming losses amounted to 57,5 per cent, damage within urban development 39,7 per cent and losses to government and other institutions 2,8 per cent. Total damage per kilometre of river amounted to R7 271.

Owing to the more densely populated areas in the stretch between the Vaal Dam and the Barrage, total damage amounted to R23 817 per kilometre of river, whilst the figure for the stretch between Standerton and the Vaal Dam amounted to R9 834. If these figures were to serve as a norm in determining priorities with respect to stretches where flood control should be applied, it is evident that these two stretches should be first to receive attention. On the whole, most damage occurred in the longest stretch i.e. Bloemhof Dam to the confluence of the Vaal and Orange Rivers (R2 490 522), followed by the stretch between Standerton and Vaal Dam (R2 433 826). In the former, farming losses represented 93,5 per cent of the total and in the latter, urban damage predominated with 73,6 per cent.

In the search for prediction models two types have been used *viz.* formal (statistical) models and informal models. As a result of insufficient information, formal models could only be developed for building damage and could not include farming damage as well. Variables which gave the most reliable results were depth of flow and floor area flooded. Models for determining damage to single storey dwellings and outbuildings of sound construction have been developed and which look promising for the prediction of flood damage in other stretches of river. Previous research results have been confirmed, i.e. that it is impossible to determine an extensive set of loss functions for all degrees of damage on the basis of a real flood event. One of the reasons for this is that there is a lack of sufficient refined information on all the physical flood parameters which

may be applied to the various categories of damage, such as depth and duration of flood, drag force and silt content of the flood waters. In addition, insufficient repetitions with respect to all categories of damage occur which will enable statistically significant relationships to be determined.

In the case of informal loss functions the damage data have been arranged in intervals of depth of flooding. However, the utilization of this is limited to the specific stretch for which damage data have been determined and where the aim is the estimation of future flood damage for floods of similar or lesser extent.

Good progress has been made with the compilation of guidelines for determining flood damage in South Africa. A start has also been made in writing a comprehensive report on flood damage within urban development in which guidelines for the utilisation of flood plains will receive special attention.

Chapter 12

Rainfall stimulation

In view of an expected serious shortage of water soon after the turn of the century, the Commission considers it essential to investigate, in cooperation with the Department of Water Affairs, Forestry and Environmental Conservation, all possible alternative sources of water.

In this regard, an increase in rainfall as a result of artificial stimulation, should it be possible, will probably constitute the largest and most economical contribution. This is evident from the fact that according to preliminary estimates, the accuracy of which still has to be proved, only about 5 per cent of the atmospheric moisture moving over South Africa reaches the ground in the form of precipitation. Of this (as mentioned in Chapter 10), about 8,6 per cent reaches rivers as runoff, of which 60 per cent can be advantageously utilised. This means that only 0,26 per cent of the moisture moving over South Africa annually can be utilised as a stable water supply source.

If the quantity of atmospheric moisture which reaches the surface can be increased by 20 per cent (i.e. from 5 per cent to 6 per cent of the total moisture moving over the country in the atmosphere) and this increase can be satisfactorily controlled, our usable water resources could be quadrupled. Such a large increase cannot be expected to occur in practice, but these figures illustrate the large potential, if moisture, apart from natural precipitation, can be abstracted from the atmosphere in a controlled manner. The stimulation of rainfall is one of the possible methods for the utilisation of more atmospheric moisture. It is therefore of the utmost importance for the future of South Africa to establish whether rainfall stimulation is possible and to what extent it will influence runoff.

It is claimed in countries such as Israel, the USA and Russia that rainfall can be increased with a reasonable degree of success, by means of cloud seeding with substances such as silver iodide and dry ice. Statistically, however, it is difficult to provide absolute proof of these claims. As a result of research conducted over a period of 17 years in Israel it is claimed that under certain circumstances rainfall can be artificially increased by between 15 and 23 per cent.

In the report of the American Modification Advisory Board published in 1978 a strong case is made in favour of a more extensive and intensive research programme for rainfall stimulation. The report mentions that, at the time of reporting, experiments with respect to rainfall stimulation and hail suppression have been carried out in 74 countries. These experiments, however, were generally initiated without intensive prior scientific investigation into the cloud physics and dynamics and the precipitation mechanism of the relevant region, and results obtained were often not very meaningful.

The Department of Water Affairs, Forestry and Environmental Conservation and the Commission are at this stage only interested in the hydrological effects of rainfall stimulation, i.e. in the possible increase of water yield (in the form of river flow) in the relevant catchments.

In view of the possibilities offered by rainfall stimulation as an additional source of water, the Commission considers it advisable that even now, background information should be collected and that the expertise in the field should be developed in the Re-

public. With this aim, the Commission supports two separate projects.

One project is being executed at Bethlehem by the Weather Bureau (in terms of a contract with the Department of Transport) in cooperation with the Department of Water Affairs, Forestry and Environmental Conservation, and consists of two phases *viz.* rainfall stimulation and the effect of any increase in rainfall, as a result of cloud seeding, on the hydrology of the experimental catchments. Both facets are being investigated simultaneously but a routine cloud seeding programme will not be commenced until the background information pertaining to climatological and meteorological circumstances has been obtained.

The other project is being undertaken at Nelspruit in terms of an agreement with the Laeveldse Koöperasie Beperk and deals with the potential for rainfall stimulation in the Lowveld. The Co-operative has an operational hail suppression project in the Lowveld, but the research sponsored by the Commission does not deal with hail suppression, but with the effect of cloud seeding for hail suppression on the local rainfall and in general with the rainfall stimulation potential of the Lowveld and in this respect links with the hail suppression project. For the execution of the rainfall stimulation project the services of a specialist group of research scientists from the USA, are employed.

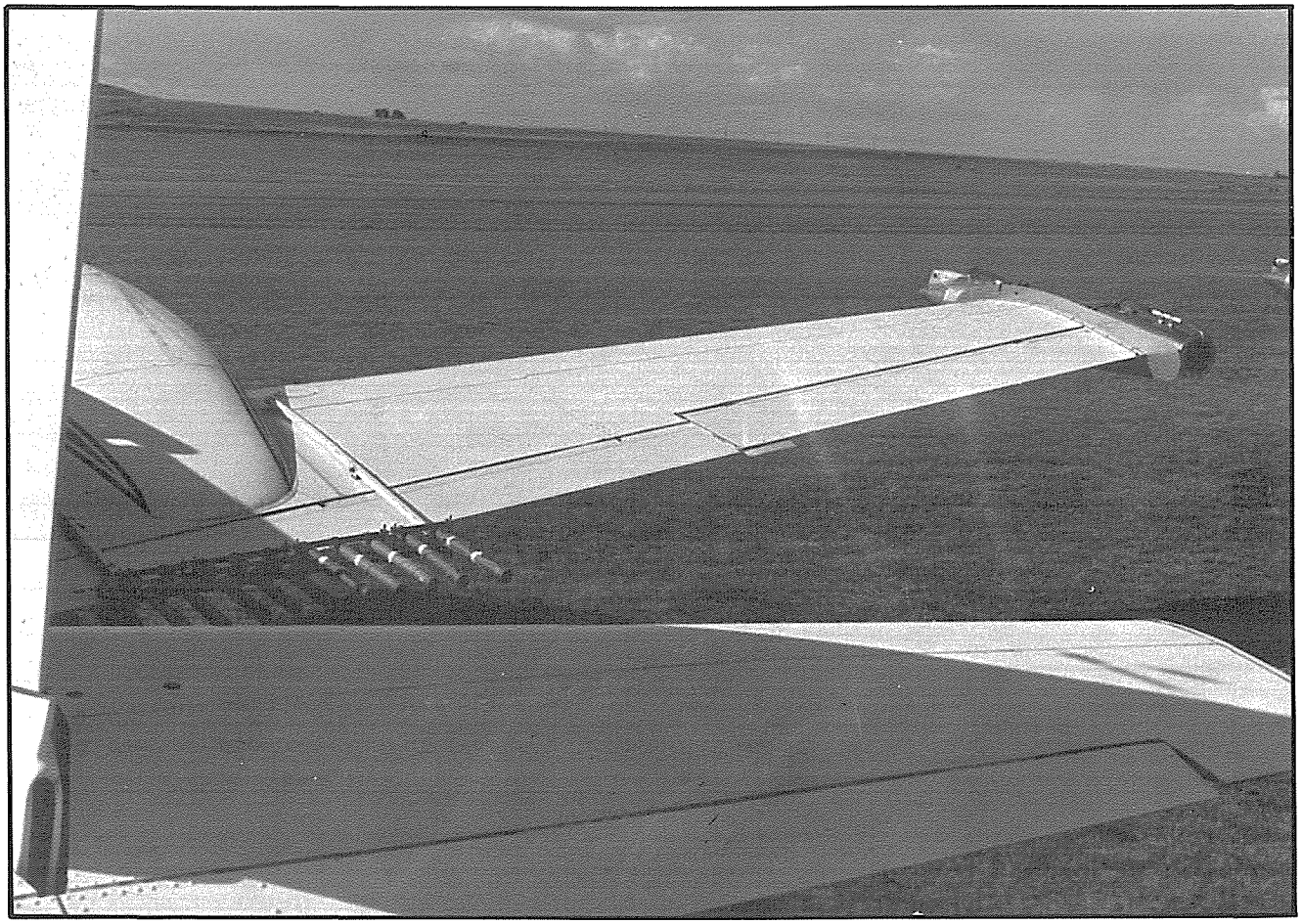
RESEARCH PROJECTS

Research on the artificial stimulation of rainfall at Bethlehem

(Existing project: Contract with the Department of Transport)

The objectives of this project are, firstly, to conduct basic scientific research in connection with cloud physics and dynamics and the mechanism of precipitation of the particular area, followed by specific opera-

Cloud seeding equipment may be seen on the wing of an aircraft being used in the Bethlehem project.



tional cloud seeding tests to determine the possibility of artificially increasing the rainfall in the North Eastern Free State. Secondly, the Department of Water Affairs, Forestry and Environmental Conservation is studying the effect on any increase in rainfall on the hydrology of the experimental catchments to determine to what extent an artificial increase in rainfall will increase the runoff.

During the year under review the criteria for the clouds to be tested have been revised, making it possible to study a larger category of clouds. Clouds which had been chosen in the past as test cells contained precipitation sized particles in more than 75% of the cases and it was decided to include also smaller cells for further study.

Cloud condensation nuclei (CCN) counts confirmed that air masses in the Bethlehem area usually contain CCN concentrations which are continental in nature. The measurements at cloud base show generally lower CCN concentration than at the ground surface.

A study on seeding showed that for seeding to be injected at cloud base in the updraft region and to be carried up in the cloud to the $-5°C$ level and then grow to precipitation sized particles, a time of roughly 20 minutes is needed. Thus the cloud life time should be longer than 20 minutes for the seeding material to show effect.

The number of recording gauge sites has been increased to 88, all at sites also reporting daily rainfall. In addition 23 automatic weather stations are in operation. This means a density of recording gauges of approximately 1/250 km^2, compared with 1/350 km^2 the previous season.

As far as the hydrological component of this project is concerned, the main emphasis has been on the development of data acquisition networks, data storage and control systems and computer programs for the reduction of data. The main research effort will use mathematical rainfall-runoff models and a start has already been made on this aspect.

The method of research is planned as a combination of mathematical modelling and field experimentation. Data are acquired in the field for both model input and the verification of model results. Six catchments are used for this project. All preliminary physical data required about these catchments have been obtained and mapped or placed on computer file for storage. The soils, geology and land-use of the catchments have also been determined and mapped. All necessary geomorphological indices have been determined and reported.

From the research so far the following conclusions can be made:

- It appears that the influence of roads on catchment hydrology is unimportant for these catchments giving rise to only about 3% of the total runoff for every 100% increase in surface area.
- The variation and type of soil will play a vital role in the assessment of the hydrological response.
- The historical data are inadequate for this project and great care must be exercised in the collection of good data for the rest of the project.
- A much greater understanding of the hydrological regime has already been acquired and this should continue with personnel spending more time in the catchments themselves.

Research on the stimulation of rainfall at Nelspruit

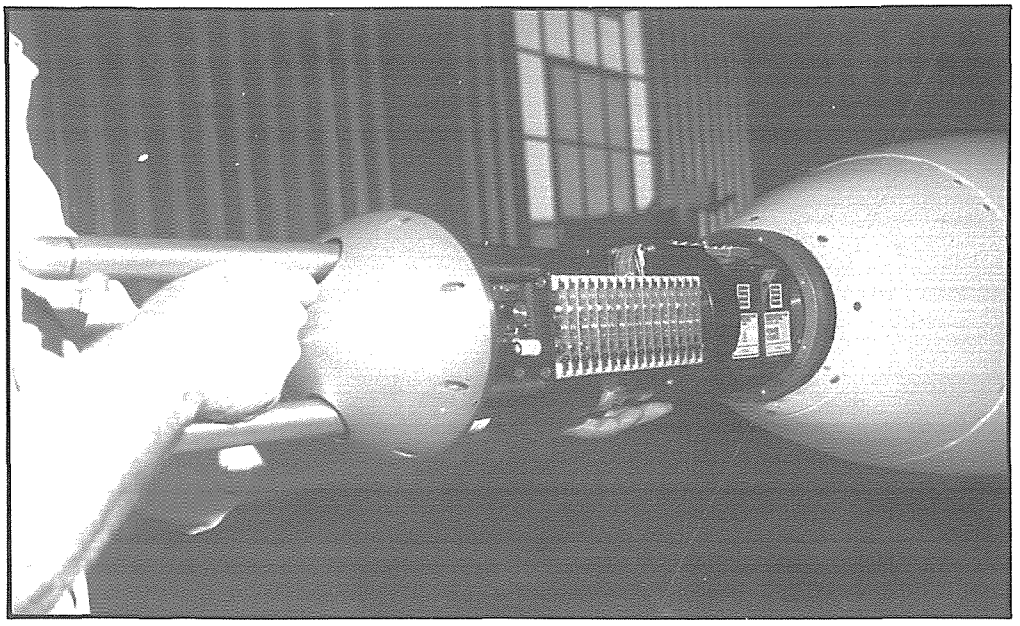
(Existing project: Contract with the Laeveldse Koöperasie Beperk)

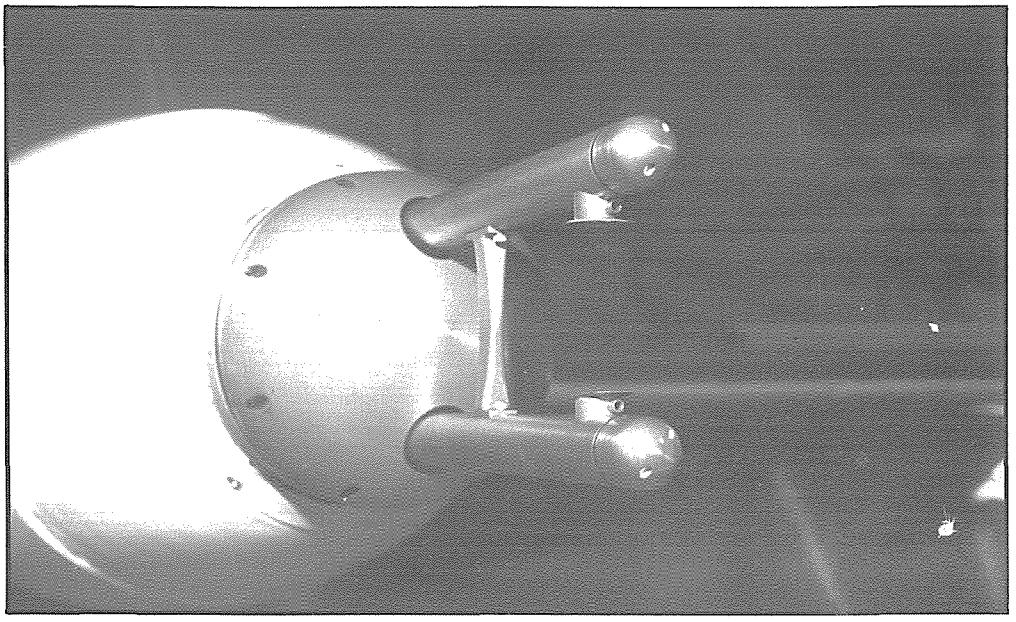
The main objectives of this project are to obtain additional scientific information on the effect of cloud seeding for hail suppression on rainfall and to assess the potential of the Nelspruit area for rain augmentation. The Laeveldse Koöperasie Beperk (LKB) has for several years been involved in a cloud seeding programme for hail suppression in this area, and information resulting from this programme, is also used in the project financially supported by the Commission.

The research is being carried out by a team of scientists at the University of Virginia, USA, under contract to the LKB. The analysis of the rainfall in and around the cloud seeding area *viz.* the Lowveld around Nelspruit, is conducted in the U.S. and the field work is done at Nelspruit.

The rainfall record consists of daily reports from 1930 up to the present. By using these data as well as all other available climatic measurements from the same area (radiosonde data from Pretoria and Nelspruit, surface weather reports, etc.) a rainfall climatology for the area is being constructed, using some of the most sophisticated statistical tools available. Once the 'average' rainfall climatology has been well established, then departures from this norm, such as those that might be caused by a cloud seeding effect, may be detectable.

At Nelspruit, one of the project's Lear jets has been equipped with a cloud physics measurement package which contains some of the most up-to-date cloud physics measurement tools available today. One of the instruments uses a rapidly scanned laser beam to acquire in-flight images of the submillimetric particles which form the initial building blocks in the processes leading to precipitation formation. With this equipment,





Two views of apparatus, for cloud physics measurements, fitted to one of the Lear jets being used in the Nelspruit project.

the changes caused by the introduction of seeding material (with dry ice or silver iodide) have been documented for the first time in the Nelspruit area. Continued use of this invaluable equipment on the Lear jet supplied by LKB will lead to a clear understanding of the processes that dominate in the precipitation formation regimes (both rain and hail) that are important in the Lowveld. A clearer understanding of the natural processes will lead to the recognition of the conditions in which timely intervention by cloud seeding may lead to changes in precipitation, that will benefit agriculture by augmenting rainfall and mitigating hail damage.

Chapter 13

Transfer of information and technology

In terms of the Water Research Act, one of the most important functions of the Commission is the collection, assimilation and dissemination of knowledge with respect to water research and its application, and the promotion of development work for such application. The Commission has always afforded a high priority to this function and has developed a number of means whereby this may be promoted.

As mentioned in Chapter 1, the Commission is aware that the application of research results represent the final dividend in its research investment. It has also been emphasised that the Commission considers it prudent to incorporate technology transfer (TT) even in the planning stages of research projects. This is achieved primarily through partnership research, i.e. the involvement of operational organisations in the planning and execution of research. The potential user of the results is therefore directly engaged as a partner in the research.

Information transfer (IT) and TT are concepts which go hand in hand. Normally the end result of IT is the creation of an awareness of and stimulation of interest in new technological developments. TT, on the other hand, is not limited to IT but includes it, and is the sum of all activities which lead to the application of a new technology where the written, visual and audio media are tools to accomplish the transfer. TT is therefore a longer, more involved and active process with the ultimate aim of successfully transferring and applying the technology. As a result of this the Commission has a comprehensive, planned programme of IT and TT.

In addition to the built-in partnership principle in research agreements, for the promotion of TT, the programme of information and technology transfer involves primarily the publication of various types of publications (on a purely scientific level, practical-scientific level and popular-scientific level); maintenance of an information centre, namely the SA Water Information Centre; arrangement of demonstrations, courses, seminars and symposia; exchange of information with other organisations; membership of relevant organisations; promotion of contact between people; and the exchange of scientists.

Publications

Commission publications provide for three levels *viz.* pure scientific, popular-scientific and practical-scientific levels and in this respect *Water SA, SA Waterbulletin* and practically orientated publications (e.g. manuals) respectively, are published.

Water SA

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

Until the publication of *Water SA,* no South African journal was in existence which dealt exclusively with water, and its appearance created a forum for South African scientists and engineers to introduce their research results nationally and internationally. The journal strives to publish original work in all branches of water science, technology and engineering, such as water resources development; aspects of water and effluents in which industry and local authorities are in-

volved; water pollution hydrology and geohydrology; agricultural water science; limnology; the hydrological cycle; etc.

Water SA enjoys world-wide coverage. Abstracts of articles in the journal appear in the following abstracting services: Chemical Abstracts; Biological Abstracts; Engineering Index; Pollution Abstracts; Oceanic Abstracts; Current Contents; Water Resources Abstracts (American Water Resources Association); Hydata; Selected Water Resources Abstracts; Desalination Abstracts; Waterlit; Water Research Centre Information; Aqualine; Abstracts Journal (Institute of Scientific Information of the USSR Academy of Sciences); and Soils and Fertilisers (including Irrigation and Drainage Abstracts). Currently there are more than 1 500 subscribers to *Water SA* of whom more than 400 are abroad.

Water SA is run on the same lines as most scientific journals. The policy, and requirements which are set, appear in each edition as guidelines to authors. On receipt of an article it is referred to two or more referees who are knowledgable on the specific subject. The editor then critically evaluates the article against the background of the referees' reports and decides on its acceptance and possible alterations to be made and then informs the author. Through this procedure, an effort is made to maintain a high standard of article.

SA Waterbulletin

This bilingual newsletter which was launched in August 1975 by the Commission contains articles, news snippets and items of interest on local as well as overseas aspects of water. Activities of various institutions in the water field in the Republic are emphasized in the bulletin. Good cooperation has been built up with producers and distributors of new equipment and processes associated with the promotion of water matters, and information on equipment and processes appear regularly in the section on equipment.

During the year under review a column on technology transfer was also launched in which regular announcements are made on publications, symposia and other events of a practical nature and which are expected to assist in bridging the gap between research and application.

Manuals and reports

Whilst research is underway and when a project is concluded, results are evaluated in respect of possible application and depending on the nature of the results a decision is taken on their publication, dissemination and application. It may be that the final report has been compiled in such a way that it could be selectively distributed in that format. However, a decision may also be taken to package the results in the form of a manual in order to enhance the application possibilities. Interim reports and results are handled in the same way.

During the year the Commission published the following practically orientated publications:

- Digitizing and routine analyses of hydrological data (in cooperation with the University of Natal)
- Potential flood producing rainfall of medium and long duration in Southern Africa (in cooperation with the University of Natal)
- A guide to the control of water losses in pipe networks (in cooperation with the University of Pretoria)
- Nutrient removal from municipal effluents (proceedings of a seminar arranged by the Institute of Water Pollution Control in cooperation with the Water Research Commission, the NIWR, the SA Institution of Civil Engineers and the SA Institution of Municipal Engineers)
- Guidelines for the control of eutrophication in South Africa (in cooperation with the NIWR)
- The limnology of selected impoundments in South Africa (in cooperation with the NIWR)

Whenever such practically orientated publications appear they are selectively distributed and also announced in *SA Waterbulletin* should other interested persons wish to obtain copies.

Column in *IMIESA*

Since January 1979 a column on the Water Research Commission has been appearing monthly in *IMIESA*, the official organ of the Institution of Municipal Engineers of Southern Africa. Since its inception in 1971, the Commission has developed a wide range of activities which are of direct importance to local authorities. For a considerable period of time there has been a need for regular feedback of information to local authorities and this column is an effort aimed at keeping local authorities abreast of activities and research being done on their behalf.

The South African Water Information Centre

The South African Water Information Centre (SAWIC) is run on behalf of the Commission, and under contract, by the CSIR as an independent unit and provides various information services in the water and related fields. During the year the number of users of the ser-

vices and the extent of the services showed a steady growth.

As mentioned in Chapter 1, one of the most important developments of the year has been the agreement reached with Systems Development Corporation (SDC) in the USA in terms of which *Waterlit* will also be included in the services of SDC. The bibliographic data base *Waterlit,* developed by SAWIC, will therefore now be served by one of the largest distributors of data bases in the world. *Waterlit* will be made available via SDC's *Orbit* system and will therefore be open to retrospective searches. As a result of this development, research and development work in connection with water in South Africa will be publicised to an even wider degree and further contacts for South African water research scientists will be established.

The number of references for *Waterlit* has grown to 40 000 items selected from 440 journals. More than 400 retrospective searches are undertaken annually on the base and 179 persons regularly receive the latest information added to *Waterlit* via the selective dissemination of information service.

The distribution lists of the current awareness services of the Centre have been drastically cut to eliminate inactive users. However, these services are still well supported. The services include the following: *Selected Journals on Water, Water Patent Bulletin,* and *SA Waterabstracts.*

This year the Centre launched a dynamic marketing effort to bring its services to the attention of a larger group of potential users. The result of the efforts has already become manifest in the increase in the number of persons requesting information from the Centre.

Utilization of overseas expertise

The Commission still considers it of the utmost importance to keep abreast of the latest local and overseas developments in the water field. As far as overseas contact is concerned, the Commission has developed a number of methods for strengthening and using this, such as:

- The exchange of publications between the Commission and overseas organizations has been in progress for several years. During the year arrangements were made for the exchange of publications with a number of new organisations. Information obtained in this way is then selectively disseminated and included in the data base *Waterlit* of the South African Water Information Centre.

- The Commission is a member of several international and overseas organizations from which the most recent information is regularly received. These organizations are the International Association on Water Pollution Research; the International Water Supply Association; the Water Research Centre in the United Kingdom; the American Water Works Association, the Research Foundation of the American Water Works Association's Information-Coordination Programme on Water Reuse, and the Water Pollution Control Federation in the USA.

- Visits by officials of the Commission to institutions and participation in conferences overseas.

- Entering into contracts with overseas specialist consultants in order to advise the Commission in specific areas.

Chapter 14

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 1980 to 31 December 1980.

The Commission derives its income from rates and charges on water usage and on scheduled irrigation land. The tariffs for the 1980 financial year were 0,2 c/m^3 for water supplied for urban, industrial or domestic use, and an amount varying between 20 c and 40 c/ha of land scheduled for irrigation.

WATER RESEARCH COMMISSION

STATEMENT 1

BALANCE SHEET AS AT 31 DECEMBER 1980

1979	Liabilities	1980		1979	Assets		1980	
R		R	R	R		R	R	R
	Sundry creditors —				*Capital assets —			
96 300	Revenue paid in advance		85 861,76	5 000	Land (Cost)		5 000,00	
	Fund account —				Motor vehicles	13 157,56		
5 580 601	Balance at 31/12/1979	5 580 601,21			*Less:* Depreciation	3 086,53		
	Plus: Excess of income over expenditure, 1980	665 319,10		13 158			10 071,03	
			6 245 920,31		Office equipment	56 556,11		
					Less: Depreciation	2 827,81		
				37 589			53 728,30	
					Office furniture	29 550,53		
					Less: Depreciation	1 477,53		
				29 101			28 073,00	
								96 872,33
					Investments		4 879 622,78	
					Plus: Accrued interest, 1/10/80 to 31/12/80		63 870,07	
				4 681 488				4 943 492,85
					Current assets —			
					Sundry debtors —			
					Outstanding revenue:			
					Prior to 1980	12 615,99		
					1980	462 603,14		
				336 382			475 219,13	
				488 232	Project advances (Statement 3)	741 890,38		
				6 125	Subsistence and transport advances	240,00		
				300	Deposits	300,00		
							742 430,38	
				150	Cash on hand		150,00	
				79 376	Cash in bank		73 617,38	
								1 291 416,89
R5 676 901			R6 331 782,07	R5 676 901				R6 331 782,07

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

Pretoria, 5 June 1981

(sgd.) M.R. HENZEN
Chairman

The above Balance Sheet has been audited in accordance with the provisions of section 42(4) of the Exchequer and Audit Act, No. 66 of 1975, read with section 14(1) of the Water Research Act. No. 34 of 1971, and in my opinion it has been drawn up so as to reflect a true and fair view of the financial affairs of the Water Research Commission.

Pretoria, 29 June 1981

(sgd.) H.J. VAN ECK
Acting Auditor-General

Office of the Auditor-General

WATER RESEARCH COMMISSION

STATEMENT 2

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD 1 JANUARY 1980 TO 31 DECEMBER 1980

1979	Expenditure		1980
R			R
492 495	Salaries and allowances		610 240,04
14 313	Subsistence		22 140,55
5 091	Motor transport		5 352,40
78 035	General transport		83 906,05
475	Commission members' allowances		350,00
2 749	Postal and telegraph services		3 971,43
10 670	Telephone services		11 511,56
10 798	Printing and stationery		8 151,26
1 002	Advertisements		—
30 695	Publications and information		27 668,90
10 522	Lease and maintenance of office equipment		5 253,63
5 186	Entertainment		6 744,37
26 716	Office rental		27 182,56
3 250	Maintenance of and alterations to offices		1 087,52
1 419	Electricity		2 812,24
—	Maintenance and lease of furniture		222 50
2 053	Typing services		22,00
5 010	Insurance and licences		3 364,02
40 176	Collection fees		38 965,53
883	Audit fees		876,00
167	Legal costs		210,00
4 910	Registrations and subscriptions		7 635,82
2 611	Miscellaneous petty expenses		2 358,88
8 712	Depreciation		7 391,87
2 429 252	Research projects (Statement 3)		2 190 273,47
	Contracting of researchers and expertise:		
165 118	Weather modification at Bethlehem	121 732,67	
22 669	*Evapotranspiration and water use studies* by means of weighing lysimeters	20 628,90	
8 046	Digitizing of autographic rain gauge data	55 801,44	
2 236	Instrumentation and automation of flood irrigation systems	—	
			198 163,01
166 439	Research and other grants		185 698,00
219 608	Specialist and consultation services		204 531,31
285 906	Excess of income over expenditure		665 319,10

1979	Income			1980	
R		R	R	R	R
	Rates:				
	Government irrigation schemes with canal systems:				
	Received	37 755,53			
	Less: Adjustment in respect of previous years	5 916,98			
			31 838,55		
	Plus: Outstanding 1980		39 326,46		
78 798					71 165,01
	Government irrigation schemes without canal systems:				
	Received	1 413,51			
	Less: Adjustment in respect of previous years	475,66			
			937,85		
	Plus: Outstanding 1980		3 722,74		
6 083					4 660,59
	Irrigation Board Schemes:				
	Received	27 084,59			
	Plus: Adjustment in respect of previous years	707,55			
			27 792,14		
	Plus: Outstanding 1980		1 052,61		
28 379					28 844,75
	Charges:				
	Metered water from Government Schemes:				
	Received	2 504 255,07			
	Plus: Adjustment in respect of previous years	50 153,40			
			2 554 408,47		
	Plus: Outstanding 1980		377 422,45		
2 668 782					2 931 830,92
	Municipalities:				
	Received	968 699,40			
	Plus: Adjustment in respect of previous years	17,28			
			968 716,68		
	Plus: Outstanding 1980		12 973,70		
959 107					981 690,38

			S.W.A.:		
			Received	58 580,55	
			Plus: Outstanding 1980	28 105,18	
		80 224			86 685,73
		22 499	Unallocated rates and charges		1 705,86
		1 838	Interest on rates and charges in arrear		2 351,87
			Interest on investments:		
			Received	148 164,77	
			Accrued	63 870,07	
		211 218			212 034,84
		284	Sundry income		434,07
R4 057 212	R4 321 404,02	R4 057 212			R4 321 404,02

WATER RESEARCH COMMISSION

STATEMENT 3

STATEMENT OF PROJECT EXPENDITURE AND ADVANCES FOR THE YEAR 1980

Project	Expenditure		Totale advances outstanding as at 31/12/80
	1979	1980	
	R	R	R
Development of research on the reclamation of water at the Athlone Sewage Works, Cape Town	24 814	31 313,54	33 036,26
Technological development of water reclamation on the basis of the Windhoek plant	18 292	21 482,15	*(753,03)
Eutrophication of rivers and dams	68 899	—	—
Technological development of water reclamation and pollution control — Daspoort	2 500	—	—
Reclamation, storage and abstraction of purified sewage effluents in the Cape Peninsula	90 147	64 296,12	34 781,47
Research on the activated sludge process	—	54 128,06	—
The removal of metal ions from dilute solutions in an electrolytic precipitator	724	—	—
The role of aquatic macrophytes in Swartvlei, Wilderness, in maintaining trophic conditions	23 115	—	—
Hydrological investigation of small cathments in the Grahamstown area	16 036	—	—
Hydrological investigation of small rural catchments with specific reference to flood events	25 994	—	—
Hydrogrical investigation of small catchments in the Mtunzini district	21 552	—	19 247,84
An investigation on the optimal utilization of water in the Eerste River in sandbeds or by other means	114 422	—	17 233,05
South African Water Information Centre	121 478	136 494,79	*(33 774,40)
The development and evaluation of techniques for the determination of the exploitation potential of ground water resources in the Southern Free State and Northern Cape	173 902	188 553,35	32 925,75
The development and evaluation of techniques for the determination of the exploitation potential of ground water resources along the Doornberg fault zone and in the Kalahari	98 743	35 232,57	*(22 428,74)
Research on water consumption patterns in urban areas	18 072	—	—
Research on the removal of sludge and wash water at water purification installations	6 953	—	—
Research on water losses in pipe networks	3 418	—	—
Geohydrological studies in the Gamagara catchment using environmental isotopes and complementary techniques	11 534	—	—
Research on flood damage Bureau for Economic Research	478	—	—
An investigation into soil compaction under irrigation at the Vaalharts State Irrigation Scheme	6 968	—	—
An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	1 577	1 529,14	10,10
Research on flood damage — Institute for Social and Economic Research	33 563	20 999,48	4 000,52
Research on the microbiological quality and health aspects of water for reuse	165 572	84 904,16	65 591,21
Research on the soil factors effecting the optimal utilization of irrigation water in National States	68 039	32 571,59	6 336,85
Research on water requirements of certain agronomic and vegetable crops	25 832	57 628,51	*(6 010,23)
Research on the purification and reuse of effluents from the hides and skins curing, fellmongery and tanning industries	58 019	127 758,54	11 219,54
Research on and development of desalination of sea water by reverse osmosis on the pilot plant at Swakopmund	35 153	40 837,00	4 563,00
Research on desalination of treated sewage	49 792	7 064,00	*(86,00)
Research on the development of membrane support systems and modules	32 409	32 669,00	5 667,00
Research on the technological application of the anaerobic digestion process for the purification of spent wine residue	7 930	—	—
Water management and effluent treatment in the Textile Industry	213 955	—	54 500,00
Research on the development of effective irrigation methods for application on steep lands, with special reference to micro-methods	8 746	63 152,97	1 730,91
Research on flood occurrences	46 769	27 193,33	2 223,53

Research on water resources	34 167	56 176,17	*(12 634,51)
Water pollution and effluent reclamation in the Pretoria-Witwatersrand-Vereeniging-Sasolburg Complex	151 685	129 675,34	731,31
Research on the scheduling of irrigation of wheat in the irrigation area of the Orange Free State	27 085	16 883,59	4 231,45
The artificial replenishment and abstraction of purified sewage effluent in the Cape Flats	77 346	—	—
Research on rainfall stimulation at Nelspruit	63 366	134 443,21	*(2 268,88)
The geohydrology of the sand deposits in the Cape Flats	22 535	—	—
Research related to the purification and reuse of tannery effluent	6 056	287,49	—
Research on the development and application of aspects of equilibrium chemistry and precipitation kinetics to water stability problems encountered in water reclamation	—	—	9 909,85
Evaluation of the performance of a horizontal decanter centrifuge on the removal of sludge from liquid scouring wastes	9 700	11 000,00	—
The removal of nitrogen and phosphate from biofilter effluents	11 191	34 171,31	6 201,71
Hydrological research in the Ecca and Wilderness catchments	46 797	61 711,24	2 201,93
Research on the optimization of dry and dry-wet cooling systems at power stations in South Africa	19 576	109 472,49	1 117,51
Research on the optimization of the modified activated sludge process for nutrient removal (Johannesburg City Council)	109 292	8 236,00	2 083,28
Research on the optimization of the modified activated sludge process for nutrient removal (NIWR)	81 091	100 420,00	1 589,00
Hydrological investigation of rural catchments in Natal with specific reference to flood events	22 709	—	52 590,10
An Agro-hydrological study of Natal	2 197	—	5 802,88
The development of a data bank of autographic raingauge records in South Africa	24 373	—	23 127,12
Hydrological research in Zululand	—	—	33 613,53
The efficiency of water extraction from fine sandy irrigation soils by different root systems	28 349	21 003,56	11 296,44
Technological development of ion exchange for the desalination and tertiary treatment of effluents: Planning, design, construction and operation of a 100 kℓ/day pilot plant and evaluation of its performance	—	—	72 430,32
Operation of the Stander Water Reclamation Plant and related investigations into certain health aspects	54 097	—	—
Research on economy measures for water distribution systems in urban areas	26 743	110 073,75	*(28 905,39)
Research on water reclamation and pollution control: Operation of Stander Water Reclamation Plant by the City Council of Pretoria, the implementation of surveillance programmes relevant to health aspects and the application of catchment quality control	15 500	155 337,03	*(67 067,91)
Research on eutrophication in the Hartbeespoort Dam	—	54 500,00	—
Epidemiological studies pertaining to the reclamation and reuse of purified sewage effluent in the Cape Peninsula	—	36 511,83	*(22 261,83)
The construction and operation of the Cape Flats prototype water reclamation plant and the surveillance of reclaimed water quality	—	—	241 000,00
Optimization of the modified activated sludge process for nutrient removal (University of Cape Town)	—	96 493,75	*(84 493,75)
Water management and effluent treatment in the textile industry: Pilot plant treatment of cotton/synthetic fibre dyehouse effluents with water reuse	—	—	102 000,00
Research on water management and effluent treatment in the textile industry: Wool scouring effluent treatment	—	—	110 300,00
The treatment and disposal of municipal sludges: Single cell protein recovery from raw sludge	—	10 234,83	4 765,17
The treatment and disposal of municipal sludges: Sludge dewatering and the treatment of sludge liquors	—	118,60	231,40
The treatment and disposal of municipal sludges: Sludge disposal to sea	—	—	15 000,00
Research on the influence of different times and intensities of internal plant moisture stress on photosynthesis, respiration and water use efficiency of certain agronomic crops	—	1 714,98	12 285,02
The treatment and disposal of municipal sludges: Autothermic aerobic digestion of sludge	—	—	19 000,00
The treatment and disposal of municipal sludges: Composting of sludge by forced aeration	—	8 000,00	*(2 000,00)
The treatment and disposal of municipal sludges: The characterization of sludge	—	6 000,00	—
	R2 429 252	R2 190 273,47	R741 890,38

*Excess expenditure over advances for projects.

WATER RESEARCH COMMISSION
STATEMENT 4

BUDGET 1981

	R	R
ESTIMATED INCOME		
Rates and charges in terms of Section 11 of the Water Research Act		3 804 500
Interest on investment		180 000
		3 984 500
Appropriation from accumulated funds		1 491 300
TOTAL ESTIMATED INCOME		5 475 800
ESTIMATED EXPENDITURE		
Administrative expenses:		
Salaries and allowances	849 000	
Subsistence and travelling expenses	141 800	
Postal, telegraph and telephone	19 000	
Printing, stationery, advertisements and publications	67 000	
General expenditure	130 000	
		1 206 800
Research Projects:		
Approved projects		
Technological development of water reclamation on the basis of the Windhoek plant	51 630	
South African Water Information Centre	165 000	
The development and evaluation of techniques for the determination of the exploitation potential of ground water resources in the Southern Orange Free State and Northern Cape	128 400	
Research on flood damage - Institute for Social and Economic Research	2 000	
Research on the microbiological quality and health aspects of water for re-use	150 500	
Research on the soil factors effecting the optimal utilization of irrigation water in the Bantu homelands	28 000	
Research on water requirements of certain agronomic and vegetable crops	4 200	
Research on the purification and re-use of effluents from the hides and skin curing, fellmongery and tanning industries	91 430	
Research on development of membrane support systems and modules	43 700	
Water management and effluent treatment in the textile industry: Sizing and desizing effluent	83 250	
Research on the development of effective irrigation methods for application on steep lands, with special reference to micro-methods	53 700	
Research on flood occurences	20 000	
Research on water resources	143 000	
Research on the scheduling of irrigation of wheat in the irrigation area of the Orange Free State	35 300	
Research on rainfall stimulation at Nelspruit	51 000	
Research on the development and application of aspects of equilibrium chemistry and precipitation kinetics to water stability problems encountered in water reclamation	12 490	
The removal of nitrogen and phosphate from biofilter effluents	50 500	
Hydrological research in the Ecca and Wilderness catchments	57 300	
Research on the optimization of dry and dry-wet cooling systems at power stations in South Africa	147 300	
Research on the optimization of the modified activated sludge process for nutrient removal (City of Johannesburg)	71 700	
Research on the optimization of the modified activated sludge process for nutrient removal (NIWR)	110 000	
Hydrological investigation of rural catchments in Natal with specific reference to flood events	58 100	
An agro-hydrological study of Natal	5 500	
The development of a data bank of autographic raingauge records in South Africa	21 500	
Hydrological research in Zululand	24 300	
The efficiency of water extraction from fine sandy irrigation soils by different root systems	32 900	
Research on economy measures for water distribution systems in urban areas	153 900	
Research on water reclamation and pollution control: Operation of Stander Water Reclamation Plant by the City Council of Pretoria, the implementation of surveillance programmes relevant to health aspects and the application of catchment quality control	172 000	
Epidemiological studies pertaining to the reclamation and reuse of purified sewage effluent in the Cape Peninsula	84 000	
The construction and operation of the Cape Flats prototype water reclamation plant and the surveillance of reclaimed water quality	192 000	
The optimization and evaluation of the full scale treatment of spent wine residue	25 000	
Optimization of the modified activated sludge process for nutrient removal (University of Cape Town)	103 000	
Water management and effluent treatment in the textile industry: Pilot plant treatment of cotton/synthetic fibre dyehouse effluents with water re-use	83 000	
Research on water management and effluent treatment in the textile industry: Wool scouring effluent treatment	79 600	
Research on continuous streamflow modelling of South African rivers	28 900	
The treatment and disposal of municipal sludges: Single cell protein recovery from raw sludge	15 000	
The treatment and disposal of municipal sludges: Sludge disposal to sea	30 000	
Research on the water requirements of certain agronomic and vegetable crops	50 700	
Research on the influence of different times and intensities of internal plant moisture stress on photosynthesis, respiration and water use efficiency of certain agronomic crops	111 000	

The treatment and disposal of municipal sludges: Pasteurization and thermophilic anaerobic digestion of sludge	17 000	
The treatment and disposal of municipal sludges: Autothermic aerobic digestion of sludge	17 000	
Research on biochemical processes which result in phosphate and nitrogen removal in the modified activated sludge process	14 000	
	2 818 800	
Possible projects		
Proposed	140 000	
Tentative	475 000	
		3 433 800
Contracting of researchers and expertise		315 200
Research and other grants		260 000
Specialist and Consultation services		260 000
TOTAL ESTIMATED EXPENDITURE		5 475 800

ANNEXURE

APPLICATION OF DESALINATION TECHNOLOGY IN WATER TREATMENT

Master Research and Development Plan

The following notations apply regarding priority ratings:

P1: Research in this field should commence as soon as possible.

P2: It is desirable that work in this field be done if funds and manpower are available, but has a lower priority rating than P1.

D: Maintain watching brief until changed circumstances and developments in technology warrants attention.

I: REVERSE OSMOSIS AND ULTRA FILTRATION

	Basic Research	Laboratory and semi-tech scale studies	Pilot Plant Design and Construction	Pilot Plant Evaluations
1. NEW AND IMPROVED MEMBRANE DEVELOPMENT	P1			
2. DEVELOPMENT OF MEMBRANES FROM LOCAL MATERIALS	D			
3. DYNAMIC MEMBRANES	P1	P1	P1	P1
4. MEMBRANE TESTING:				
4.1 Development of test methods	P2		P2	
4.2 Membrane testing		P2		P2
5. FACTORS AFFECTING MEMBRANE LIFE	P1			
6. MEMBRANE FOULING	P1			
7. PRETREATMENT	P1	P1	P1	P1
8. DEVELOPMENT OF MEMBRANE SUPPORT SYSTEMS				
8.1 Tubular	P1	P1		P1
8.2 Spiral wound	P1	P1		
8.3 Hollow fibre	D	D	D	
8.4 Porous supports (dynamic membranes)	P1	P1	P1	
9. DESIGN FACTORS				
9.1 Hydraulics		P2	P2	
9.2 Turbulence promotion		P2	P2	
10. DISPOSABLE MODULES	P1	P1		
11. REGENERATION OF MEMBRANES		P1		

	Basic Research	Laboratory and semi-tech scale studies	Pilot Plant Design and Construction	Pilot Plant Evaluations
12. SMALL UNITS		D		P2
13. APPLICATIONS				
13.1 Water reclamation from sewage effluent	P1	P1	P1	P1
13.2 Specific industries	P1			
13.3 Specific mining	P1			
13.4 Brackish waters		P2	P2	P2
13.5 Removal of toxic ions		P2		
13.6 Sea water		P2	P2	P2
14. ENERGY RECOVERY		D	D	D
15. CONTROL SYSTEMS		P1	P1	P1
16. MATERIALS AND CORROSION			D	

II: ION EXCHANGE

	Basic Research	Laboratory and semi-tech scale studies	Pilot Plant Design and Construction	Pilot Plant Evaluation
1. KINETICS AND EQUILIBRIA OF SPECIFIC SYSTEMS	P1	P1		
2. RESIN DEVELOPMENT				
2.1 Conventional resins	P2			
2.2 Dense resins	P1			
2.3 Adsorption resins	D			
2.4 Selective resins	P2			
3. RESIN TESTING				
3.1 Conventional resins		P1		
3.2 Dense resins		P1		
3.3 Thermally regenerable resins		D		
3.4 Adsorption resins		D		
3.5 Selective resins		P2		
4. DEVELOPMENT OF ION EXCHANGE SYSTEMS				
4.1 Continuous countercurrent systems			P1	P1
5. APPLICATIONS				
5.1 Water reclamation from sewage effluents			P1	P1
5.2 Specific Industrial	(P1)			
5.3 Specific mining	(P2)			
5.4 Brackish waters		P2	D	D
5.5 Removal of toxic ions		P1	P1	P2
6. CONTROL SYSTEMS		P1	D	D

III: ELECTRODIALYSES

	Basic Research	Laboratory and semi-tech scale studies	Pilot Plant Design and Construction	Pilot Plant Evaluation
1. MEMBRANE TECHNOLOGY				
1.1 Membrane production	D			
1.2 Determination of membrane properties				
1.2.1 selectivity		P1		
1.2.2 fouling factors	P1			
1.2.3 water permeability		P1		
1.2.4 toxic ion removal		P1		
2. INNOVATIVE TECHNOLOGY				
2.1 Open stack	P1	P1		
2.2 Reversing polarity		P1		
3. APPLICATIONS				
3.1 Brackish water desalination		P1		
3.2 Seawater desalination		D		
3.3 Specific mining (P1)				
3.4 Specific industrial (P1)				
4. FEED WATER PRETREATMENT (Ad hoc)	D	D		

IV: SEAWATER DISTILLATION TECHNOLOGY (D)

V: FREEZE TECHNOLOGY (D)

VI: OTHER TECHNOLOGIES (D)

6.1 Thermal precipitation

6.2 Coupled transport

V DISPOSAL OF BRINES AND CONCENTRATES

	Priority
1. DEEPWELL	D
2. EVAPORATION	
2.1 Solar Ponds	P2
2.2 Spray Ponds	D
2.3 Evaporative Plant	D
2.4 Brushwood Towers	P2
3. THERMAL PRECIPITATION	P1
4. ELECTRODIALYSIS	P1
5. SALT WATER LAKE ENVIRONMENTS	
5.1 Techno-economy study	P1
6. FREEZE PROCESSES	D

VIII: GENERAL

		Priority
1.	Economic implications of mineral water quality	P1
2.	Survey of industries and mines with disposal problems as a result of high TDS effluents	P1
3.	Data bank on desalination costs by various processes	P1
4.	Data bank on brine disposal alternatives and costs	P1
5.	Register of desalination plants in South Africa	P1
6.	Evaluation of performance of full scale plants	P1
7.	Data bank on desalination systems and components	P1