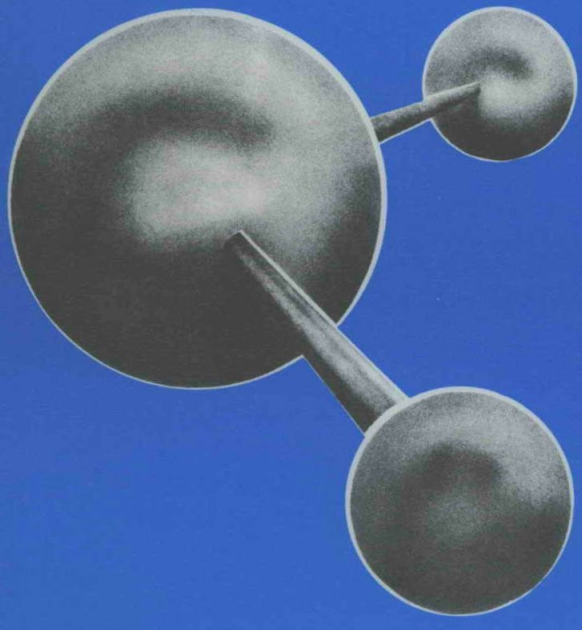

water research commission

ANNUAL REPORT

1 January 1978 to 31 December 1978

WATER RESEARCH COMMISSION

Annual Report

1 January 1978 to 31 December 1978

Water Research Commission
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Printed in 1979 in
the Republic of South Africa
by
V&R Printers (Pty) Ltd, Pretoria

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Water Research Commission
PO Box 824
PRETORIA
0001

1 March 1979

Dear Sir

We take pleasure in submitting to you, herewith, the report of the Water Research Commission. This report covers the period 1 January 1978 to 31 December 1978.

The balance sheet and statement of revenue and expenditure for the financial year 1 January 1978 to 31 December 1978, as certified by the Auditor-General, are furnished in chapter 12 of this report.

Yours respectfully

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CHAIRMAN

JP Kriel
VICE CHAIRMAN

The Honourable AJ Raubenheimer, MP
Minister of Water Affairs and of Forestry
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DR WA VERBEEK
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Secretary for Agricultural Technical Services

Chapter 1

Review of the year

The application of research results is the final dividend in supporting research. A traditional gap exists, however, between research and its application and with a view to bridging this gap the Commission has, wherever possible, incorporated the principle of partnership research in its support of research. This partnership research, in effect, means that an operational organization which has a direct interest in the application of research results is actively involved in the research and makes a direct contribution to the work. The incorporation of the partnership principle in the financing strategy of the Commission is a process which has been increasingly effected over the past few years. During the year the Commission has actively pursued the extension of this principle. Remarks by the Honourable AJ Raubenheimer, Minister of Water Affairs and of Forestry, in this regard, have been gratefully noted, especially those made during his visit in March 1978 to research projects dealing with water reclamation in the Cape Peninsula when he stated that the partnership principle was one of the best methods of bridging the gap between research and its application in practice.

Since the award of the first contracts about seven years ago there has been an evolutionary shift in the basis on which contracts have been negotiated and this shift is associated with the development of the Commission's coordination strategy and increasing awareness of the Commission's commitment towards technology transfer.

For convenience the Commission's financing of contract research may be divided into three phases.

The first phase

The first years of the Commission were characterised by a reconnaissance phase during which time the infrastructure and procedures had to be developed which would enable the Commission, inter alia, to clearly identify research requirements in consultation with operational organizations, to compile a master plan of research and to initiate projects accordingly.

During the same period the Commission embarked upon a financing programme to stimulate research and the organizations involved in such research were invited to submit opinions on research requirements and to make recommendations. A positive reaction resulted and a variety of projects were submitted to the Commission. Projects submitted were evaluated by the Commission on merit (normally in consultation with interested government departments), and in the case of submissions from universities, the extent to which research could contribute to the development of centres of expertise in the water field was considered. It was on this basis that the Commission decided to support some of the proposed projects.

The second phase

The gradual implementation of the Commission's coordinating function had a parallel impact on its financing of research. In the process of improving contact with government departments, local authorities and industry and in creating various study groups and coordinating research and development committees, the Commission was better able to identify and define research requirements in various fields. This allowed the Commission greater latitude in the initiation of problem-directed research, the identification of research gaps and the ability to determine priorities and not, as in the first phase, to react mainly to submissions.

During the second phase it became clear that one of the main tasks of the Commission should be the promotion of technology transfer. In addition it was evident that the principle of partnership research — i.e. where

an operational organization is actively involved in the research project by way of the provision of facilities, manpower and funds — was one of the most effective routes whereby technology transfer could be realised. This approach would also create contact between user and research worker. In this way the risk factor, which is one of the greatest impediments to technology transfer, would be considerably decreased since the user acquires firsthand knowledge of the new technology during the development phase.

The third phase

The Commission is now entering the third phase in its promotion of research. Of the 54 research contracts entered into 6 have run to completion and 13 have expired in 1978 and a further 18 will expire in 1979. Thorough consideration is therefore currently being given to such aspects as research which could profitably be continued by way of new contracts, whether it is possible to incorporate the partnership principle in these new contracts, which results can already be applied and by which routes application can be promoted.

It also became clear that new research avenues had to be developed and that as far as possible the partnership principle had to be implemented. It must be realised, however, that it is not always possible to conduct research on a partnership basis. This is especially so in the case of new research avenues where it is to be expected that research will be of a basic nature initially and that operational organizations can only become involved at the later development stage.

Co-financing of research

The principle of partnership research has not been incorporated into all the existing projects of the Commission but it is important to emphasize that most of the research organizations with whom the Commission has placed contracts make a considerable contribution from their own sources. This input is in the form of facilities, computer time, administrative services, manpower, etc.

Training as a supplementary advantage of the financing of research at universities

In supporting research projects at universities the Commission stresses the fact that the research objectives should remain of primary importance and that training of post-graduate students should be of secondary concern. However, if research workers, in the execution of their projects, manage to obtain higher degrees it is to be welcomed since this raises the state of expertise in the water field in the country and provides manpower which is better trained for the country's water industry. It would appear that 24 doctorates and 58 master's degrees have already ensued or will ensue in the near future from projects which have been or are financed wholly or in part by the Commission.

Furthermore, it would appear that projects supported by the Commission at universities have in a number of cases stimulated interest in the relevant study areas as is evidenced by the increase in the number of students enrolled in these study areas. This phenomenon is particularly noticeable in the field of hydrology where two universities have developed centres of expertise which are training students in this specialized area. This development is of special importance to the Department of Water Affairs since the Department has always encountered problems in obtaining trained hydrologists.

As a whole it may now be stated that due to the healthy infrastructure the Commission has developed by the establishment of CRD Committees and study groups, the establishment of centres of expertise, the development of a knowledgeable staff structure and by the reinforcement of contracts with authorities and industry, it can be expected that the Commission's future contract financing, will to a large extend be a result of negotiations the Commission itself has initiated and not the other way round, as has often been the case.

Research highlights

In its role of coordinating, initiating and financing water research the Commission has to direct its activities at the national interest. In order to meet this requirement interested government departments, provincial authorities and representatives of local authorities and of industry are consulted. This consultation takes place either directly or by means of the Commission's Coordinating Research and Development Committees on which the organizations are represented. In this way the water research requirements of the most important sectors of the Republic's water economy, viz local authorities, industry and agriculture, are being met.

During 1978 the Commission further extended its activities with regard to the coordination and financing of research on behalf of these sectors and in the relevant chapters most of these activities are fully reported. However, a few of the most important developments are highlighted briefly below.

The Pretoria-Witwatersrand-Vereeniging-Sasolburg complex

Approximately 60 percent of the total urban population of South Africa inhabit the Pretoria-Witwatersrand-Vereeniging-Sasolburg complex and this area is responsible for a very important percentage of the gross national product. The area is characterized by a high demand for water and by the fact that treated sewage and industrial effluents as well as stormwater runoff are to an increasing extent finding their way to the Barrage which is the most important source of water supply. It is therefore comprehensible that this complex with its problems associated with water supply and waste water treatment, water reuse and pollution and which affect a large number of municipalities, should continue to enjoy the highest priority at the Commission. The PWVS project supported by the Commission deals with pollution control and water reuse especially as far as the southern catchments are concerned, and considerable progress was made during the year under review. Research by the Hydrological Research Unit of the University of the Witwatersrand (in conjunction with the consulting firm appointed as project managers by the Commission) led to the development and testing of an extensive mathematical model for the daily variation of mineral salts in the system. For different time horizons the model can determine the time series of salinity (total dissolved solids) in the southern catchment as well as at any point within the Barrage storage basin. The model is also capable of simulating and determining the effect of further industrial development or of any pollution control or water reuse possibilities which may be proposed. It may also be mentioned that although the model has basically been developed for the PWVS complex slight modifications will enable it to be used to solve similar problems in other catchments.

The project managers for the PWVS complex also indicated that there should be a comprehensive strategy to ensure that distributed water is of the highest possible quality, especially in the light of the large percentage of water that drains back into the system and subsequently lowers the quality of water supplies.

The three disciplines of health, chemistry and engineering are closely involved in these objectives and their interdisciplinary nature should be fully acknowledged and active programmes must be initiated in this regard.

Water economy measures

Although domestic consumption of water represents less than 10 per cent of the total water consumption in South Africa, water economy measures in this sector still enjoys a high priority especially since large sums of money are invested in the water purification plants and distribution networks. During the past four years the Commission has also supported research at the University of Pretoria with regard to water losses in pipe networks and water consumption patterns in urban areas. Furthermore the University also completed a project for the Commission on the disposal of sludge and waste water from water treatment plants. These projects have been concluded and no work was done during the year under review — the relevant projects were reported on in previous annual reports. The findings, however will be used in new investigations envisaged in the field of water economy measures. In this regard the National Building Research Institute of the CSIR has compiled a master plan and an agreement between the CSIR, the SABS and the Commission for further work in this regard is envisaged. It is expected that the proposed contract will result in a document for use by local authorities and consulting engineers with a view to more economical design of water purification schemes, distribution systems and appliances.

The removal of nutrients from effluents

The presence of plant nutrients such as phosphorus and nitrogen in effluents has for some considerable period of time enjoyed the attention of the Commission. In this regard the Commission, some years ago, entered into agreements with the CSIR and the University of Cape Town for extensive investigations into the biological removal of plant nutrients from effluents. These agreements are shortly to expire, but in view of the fact that the large-scale removal of plant nutrients from effluents is of cardinal importance to the country and since promising results were obtained from the projects, the Commission has entered into two new contracts. Both these agreements are based on the partnership principle and the Municipalities of Johannesburg and Pretoria, the CSIR and the University of Cape Town will be involved in the projects. One project will deal with the removal of nutrients in sewage works with biological filters whilst the other will investigate the large-scale application of research results obtained during previous projects in connection with the biological removal of nutrients in the modified activated sludge process.

It is envisaged that the results of these two new projects will lead to the design and operation of processes whereby effluents with a low nutrient content will be economically achieved. In this way the nutrient load from point sources, for example sewage purification works, will be significantly decreased with an accompanying decrease in eutrophication.

Research on flood occurrences and damage

In 1975 the Commission entered into agreements with the Bureau for Economic Research (BER of the University of Stellenbosch) and the Institute for Social and Economic Research (ISER of the University of the Orange Free State) with a view to the development of methodological principles for the identification and evaluation of flood damage, the application of the method to certain river stretches for the determination of flood damage, and the definition of the relationship between physical damage and flood conditions. It is envisaged that the final report based on this research will be published in six parts of which the first three are already available. At this stage however, it is already clear that the approach to this investigation and the ensuing methods will in many respects be unique and of great value to various organizations. It is expected that the reports will serve as manuals for the evaluation of flood damage for the Department of Water Affairs and local authorities. In the Commission's initiation and coordination of water research, interaction between projects often occurs and a good example of this is between these projects and the project on flood occurrences at the Hydrological Research Unit of the University of the Witwatersrand. It would appear that if the damage functions obtained through the work of ISER and BER were to be entered in the flood plain model of the University of the Witwatersrand it would be possible to make important predictions of possible flood damage along rivers with varying soil utilization patterns and flood tendencies and which could be of great value to planners and policymakers.

The treatment and disposal of sludge and solid toxic wastes

Local authorities are being confronted on an increasing scale with problems associated with the treatment and disposal of sludge and solid toxic wastes. Some danger of water pollution attaches to the steadily increasing volumes of sludge and waste and it has become urgently necessary that solutions should be found for these problems. As a result the Commission has for some considerable period given serious attention to this matter and has amongst other things utilized overseas expertise and maintained close liaison with local authorities. During the year Dr AL Downing, former Director of the British Water Pollution Research Laboratory and a current member of the Water Research Council and of the Committee of the European Economic Community, completed a report for the Commission. This report contains the current state of technology of treatment and disposal of municipal sludges; the use of sludge for agricultural purposes; techniques and effectiveness of the disinfection of sludge; and health aspects pertaining to this matter. On the request of representatives of local authorities the Commission also organized a fact-finding mission abroad with the aim of investigating techniques used in practice for possible application in South Africa. The mission, which collaborated closely with Dr Downing, consisted of representatives of local authorities, the National Committee for Environmental Sciences and the Commission. The reports of the mission and of Dr Downing will now serve as a basis for deciding what research is necessary in this problem area to assist local authorities.

Dr AL Downing, a member of the British Water Research Council, who compiled a report for the Commission on the current state of technology in the treatment and disposal of municipal sludge

Coordinating research and development committee for water quality

Together with all developed and many developing countries in the world, South Africa experiences many threats to its water quality. Present-day control over conventional domestic and industrial pollution is very effective but mineral pollution in South Africa, due to its limited river flow and water resources, is more critical than in many other countries and this adds a new dimension to the pollution problem. In this regard specific mention may be made of mineralized, industrial and mining effluent and drainage water of irrigation schemes. It is not always appreciated that problems in this regard are not limited to those areas of prevention and treatment but that considerable needs exist for the improvement of methods of measurement, calculation and prediction of water quality and quality trends.

In recognition of this need the Commission earlier established an *ad hoc* Study Group for Water Quality, and in 1978, established a permanent Coordinating Research and Development Committee (CRD Committee) for Water Quality. As part of the negotiations that had taken place with the CSIR in 1977 in connection with the role of the Committee for Inland Water Ecosystems (reported on in the 1977 Annual Report), two of the latter Committee's Working Groups (the Mineralization Working Group and the Water Quality Working Group) were transferred to the new Coordinating Research and Development Committee for Water Quality. The Mineralization Working Group has continued its valuable work on mathematical modelling of salinity in the Sundays-Fish Rivers, and has made preparations for the extension of that programme to the Berg and Breë Rivers of the Western Cape. A further Working Group, on the Statistics of Water Quality Sampling, has been formed and is meeting a real need. Two other subjects to which the CRD Committee has given some attention are needs associated with computerized water quality data banks, and analytical interlaboratory comparison programmes.

Research on behalf of the textile industry

For a considerable period of time the Commission has been supporting research on water management and wastewater treatment in the textile industry being done by the University of Natal in collaboration with industry. Considerable progress has been made with this research. Intensive investigations into the nature and treatment of effluents in this industry have been launched with a view to the development of codes of practice by which guidelines for good housekeeping and for control of water use and effluent production will be established. Investigations are aimed at effluents of the three processes in the textile industry which consume the largest quantities of water, *viz* wool scouring, wool sizing and desizing and dyeing. Significant progress has also been made with the closed-loop recycling of these processes. Pilot scale studies at factories are being done in terms of partnership agreements with the relevant firms which contribute certain inputs to the project. In fact, progress with the investigations into the desizing process has been such that various firms have emerged with requests that pilot plants be erected at their factories. Good progress has also been made with the reclamation of dyeing auxiliaries.

Irrigation research

The Commission has already entered into 8 agreements with universities and the Department of Agricultural Technical Services in terms of which irrigation research is undertaken. One of these projects, *viz* 'Investigations of soil compaction at the Vaalharts Irrigation Scheme' was successfully completed during the year and the final report will be made available to interested organizations with a view to the application of results. A new project on the scheduling of irrigation of wheat in the irrigation area of the Orange Free State has also been initiated. It is also interesting to note that the results obtained from another Commission project at the University of the OFS in connection with the effect of moisture stress on crop production are being used as an important input in this new project. This is another example of the increasing interaction between Commission projects. During the year the Coordinating Committee for Irrigation Research (CCIR), in which the Department of Agricultural Technical Services, the Department of Water Affairs and the Commission are involved, was established. It was agreed that the Department would create internal committees which will render assistance in respect of planning of research projects and the later evaluation of progress reports.

Water reclamation

During the year a manual entitled 'Manual for Water Renovation and Reclamation' was published. It is based on research of the past decade by the National Institute of Water Research of the CSIR. During the past 5 years the Commission has been involved in financing the research and has also made funds available for printing the manual. The purpose of the manual is to supply useful information to design engineers, research workers and organizations having an interest in the reclamation of waste water. It has been made available to all the larger municipalities, consultants and interested government departments and statutory organizations. A second publication 'A Guide for the Planning, Design and Operation of Water Reclamation Plants' is currently being prepared and is expected to be ready early in

1979. This document will specifically be aimed at decision-makers, planners and managers and for this reason it is being compiled by a well-known firm of consulting engineers under contract to the Commission.

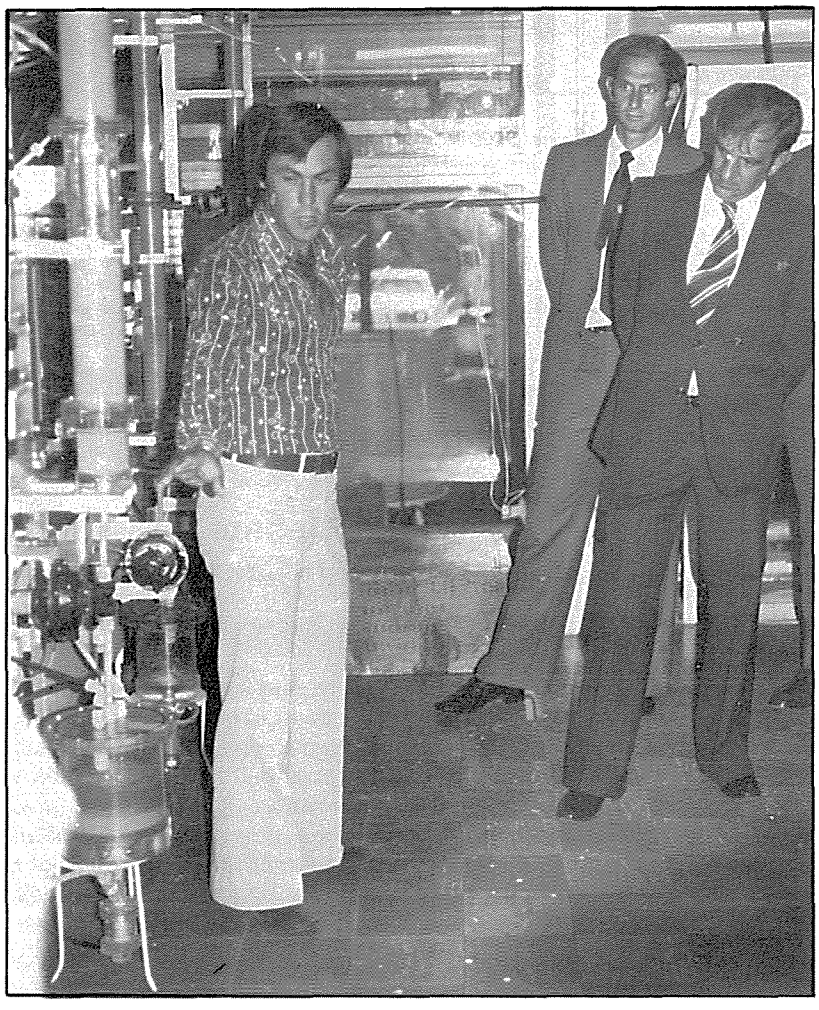
Briefly

1. Visit of the Minister of Water Affairs to research projects on water reclamation

In March 1978 the Honourable the Minister of Water Affairs, Mr AJ Raubenheimer, in company with Members of Parliament and the Senate, visited research projects in the Cape Peninsula dealing with water reclamation and supported by the Commission. The programme included inter alia a visit to a water reclamation plant on the Cape Flats and explanations of the respective projects in which the following organizations are also involved: the Municipality of Cape Town, the National Institute for Water Research and the Universities of Cape Town and Stellenbosch. During the visit the Minister said that in the near future a local authority would have to take the lead in implementing the large-scale reuse of water and that if he were interpreting the signs correctly, Cape Town could be this authority.

2. Gold medal of the South African Chemical Institute

The Gold Medal for 1978 of the South African Chemical Institute has been awarded to the chairman, Dr GJ Stander. The award has been made in recognition of his outstanding contributions, both fundamental and



During the year the Minister of Water Affairs, Mr AJ Raubenheimer, visited research projects in the Cape Peninsula relating to water reclamation. Mr Raubenheimer (right) is pictured here in the ion exchange laboratory of the University of Cape Town.

The Gold Medal for 1978 of the South African Chemical Institute (SACI) was awarded to the Chairman of the Water Research Commission, Dr GJ Stander. Taking a closer look at the medal are (f.l.t.r) Mrs C Stander, Dr Stander and Prof DEA Rivett, President of the SACI.

applied, in the field of water research which not only led to significant breakthroughs in respect of pollution control, water reclamation and water management practice, but which also gained wide recognition for himself, and for the Republic, at an international level. The Gold Medal is available for award annually and is presented in recognition of extraordinary service to chemistry or chemical technology in South Africa; it is the highest award made by the Council of the Institute.

3. Participation in the ninth Conference of the International Association on Water Pollution Research (IAWPR); Stockholm

Members of the staff were amongst the approximately 40 delegates from South Africa who attended this conference in June 1978. Two senior advisers of the Commission, Messrs PE Odendaal and OO Hart, presented papers.

4. Debate on water reclamation in California

During a debate on the theme: 'This house believes that there is no reason why Californians should not be allowed to drink reclaimed waste water now' and which was arranged by the California Water Pollution Control Association, Mr Hart also presented a paper. Other South Africans who participated in this event are Prof LS Smith of the Department of Health and Mr AJ Clayton, City Engineer of Windhoek.

Chapter 2

Water reclamation

It is generally accepted that water reclamation will play a very important role in certain critical catchments in South Africa as a supplementary water supply source and also to meet the future demands for water. Since 1969 water reclamation has played an extremely important part in Windhoek where reclaimed water is used directly for supplementing the municipal supply. Ever since its inception the Water Research Commission has awarded high priority to the promotion of water reclamation. This will ensure that the necessary expertise on the technology of water reclamation will be available and that government, provincial and local authorities and other interested bodies will progressively be informed of the latest developments in this regard.

As proof of the importance the Commission attaches to research on water reclamation, mention may be made of the four different projects it finances which are aimed directly at the promotion of water reclamation. Progress with these projects is reported later in this chapter.

One of the highlights of the year's activities as far as water reclamation is concerned, was (as mentioned in chapter 1) the publication of a manual entitled 'Manual for Water Renovation and Reclamation' which was released jointly by the Commission and the National Institute for Water Research of the CSIR. The manual is based on the experience and results gained over the past six years with the project 'Technological development of water reclamation and pollution control, Daspoort, Pretoria', and therefore serves as a meaningful conclusion to the agreement at the end of 1978.

For the meaningful application of the developed technology in practice, the Commission deemed it wise to compile a supplementary guide to this manual in order to meet the practical needs of planners, design engineers, scientists and operational personnel. The guide with the title: 'A guide for the Planning, Design and Operation of Water Reclamation Plants', is currently being processed and will be released during 1979.

Another event of special significance was South Africa's participation in the debate of the California Water Pollution Control Association on water reclamation and reported on in chapter 1. Several other papers based on results of research projects financed by the Commission were read during the year at various international and local conferences and symposia.

As in the past the reclamation project at Windhoek generated much international interest during the year and a number of overseas visitors, amongst whom was the President of the Water Pollution Control Federation of the USA, visited the plant.

The use of activated carbon in water reclamation is indispensable in the production of a reclaimed water for drinking purposes. Although it is an expensive process it has been found that the production costs of reclaimed water can be considerably decreased if the active adsorption ability of the carbon can be regenerated by heat after it has reached the saturation point. An experiment in this regard was undertaken at the Stander reclamation plant at Daspoort and was successfully completed at the beginning of 1978. Since the studies indicated that the regeneration of the carbon could have considerable economic advantages it was decided in consultation with the CSIR and the City Council of

Windhoek to transfer the regeneration furnace from the Stander reclamation plant to the reclamation plant at Windhoek. In this way the cost-benefit study of the process can be done under practical conditions. Before transfer the operators of the City Council of Windhoek received the necessary training with this process unit. Furthermore the relevant personnel of the CSIR were temporarily made available to the City Council of Windhoek to assist with the construction and commissioning of the furnace at Windhoek. During the negotiations the City Council of Windhoek also agreed to regenerate, at operating costs, carbon from other reclamation projects supported by the Commission in the Republic of South Africa. This will allow a more accurate cost-benefit study of the process.

During regeneration of the first load of carbon from the Windhoek reclamation plant it was established that the carbon unit could be more effectively operated as an integral part of the water reclamation system and, within the operational practice of the City Council, at approximately 40 per cent of the cost of new carbon.

The project concerning the reclamation, storage and abstraction of purified sewage effluents in the Cape Peninsula, being undertaken by the Municipality of Cape Town (with financial support by the Commission) and considered as an integral part of their water supply programme, progressed well during the year. The interim reclamation plant at the Cape Flats has been commissioned and the NIWR uses the reclaimed water for studies in connection with the infiltration of the water into and the abstraction from the sand aquifer. This facet of the project was removed from the original contract during the year and a new agreement between the Commission and the CSIR has been negotiated for research to be undertaken in this regard. The main objective of the new contract is to determine if the infiltrated water can quantitatively be recovered from the sand beds and be mobilised, and if the full scale application of the technique is practically and economically feasible. A further contract has been negotiated with the CSIR according to which the geohydrology of the sand deposits of the Cape Flats will be investigated with the aim of determining the potential storage possibilities of these deposits. It will also be possible to obtain an indication of the quantity of natural groundwater that may be abstracted from the sand beds on a continuous basis for utilization. Both the latter two projects share common ground with a project financed by the Commission at the University of Stellenbosch and which involves the utilization of water from the Eerste River through storage in sand beds. (See Chapter 3.) Reports on the projects are presented later in the chapter.

During March 1978 the City Council of Cape Town, in conjunction with the Commission, arranged an information day to which the Honourable the Minister of Water Affairs, Mr AJ Raubenheimer, the parliamentary Study Groups on Water and other interested parties were invited and during which the Cape Flats reclamation plant was visited.

As far as the health aspects associated with human use of reclaimed water are concerned, monitoring at Windhoek was continued by the various organizations *viz* the NIWR, the Municipality of Windhoek, the South African Institute for Medical Research (SAIMR) and the Department of Water Affairs. The SAIMR is continuing the epidemiological studies on the population receiving reclaimed water in Windhoek.

RESEARCH PROJECTS

Reclamation, storage and abstraction of purified sewage effluents in the Cape Peninsula

(Existing project: Contract with the Municipality of Cape Town)

The main objective of this project is the development of design and operational criteria for the full scale local application of the reclamation of purified sewage effluent of mainly domestic origin (in the case of the water reclamation project at the Athlone Sewage Works, Cape Town, waste water consisting of a large volume of industrial effluents is used).

The current contract with the Municipality of Cape Town was preceded by an original contract with the CSIR for which the construction of a 4,5 Ml/d prototype reclamation plant on the Cape Flats was envisaged. As a result of the fact that the Municipality of Cape Town decided to erect a new sewage purification works based on the latest techniques for the removal of nutrients, the construction of the 4,5 Ml/d reclamation plant has been held in abeyance until such time as the sewage works has been completed and the quality of the effluent can be evaluated in order to modify the design of the reclamation plant accordingly. In the meantime, however, construction of a part of the plant has continued in order to be able to supply water with a suitable quality to NIWR for studies in connection with infiltration in and abstraction from the sand aquifer (see next project report).

During 1978 the interim part of the plant became operational and was operated intermittently to supply

purified water in accordance with the requirements of NIWR.

In the meanwhile construction of the sewage purification works is continuing and it is expected that the first module will be completed during the latter half of 1979. Experiments on the purified sewage effluent will then be done with a view to detailed design of the reclamation plant to allow construction of the complete prototype reclamation plant during 1980.

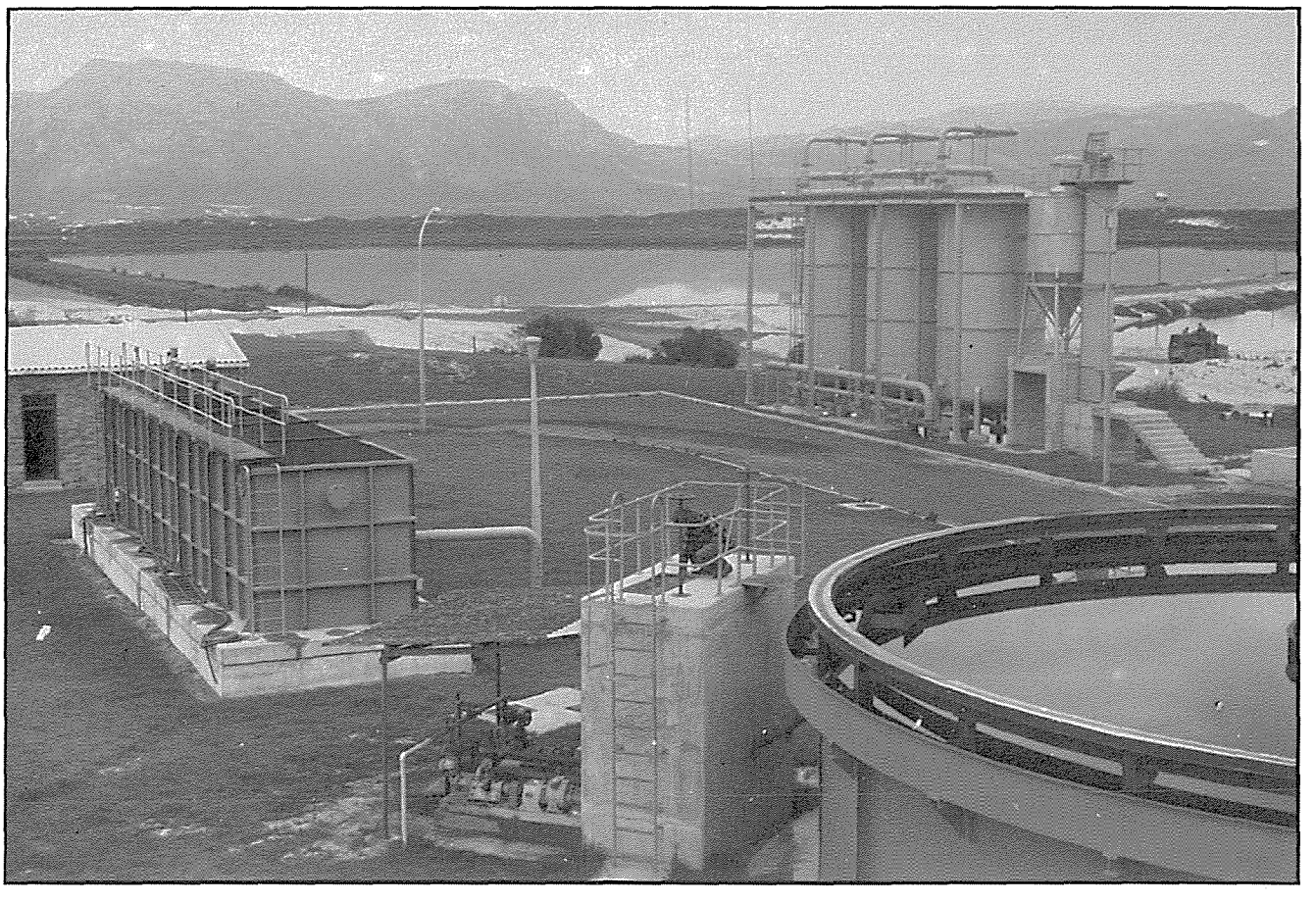
The present contract with the Municipality of Cape Town expires at the end of 1979 and it is envisaged that a new contract will be entered into during 1979. This new contract will provide for the completion of the reclamation plant, the optimisation and operation of the completed plant and for a programme for the utilization of the reclaimed water. Provision will also be made in the proposed research programme for extensive studies of the chemical and microbiological quality of the reclaimed water and for related epidemiological studies, as well as for a meaningful publicity programme to keep the public fully informed of developments.

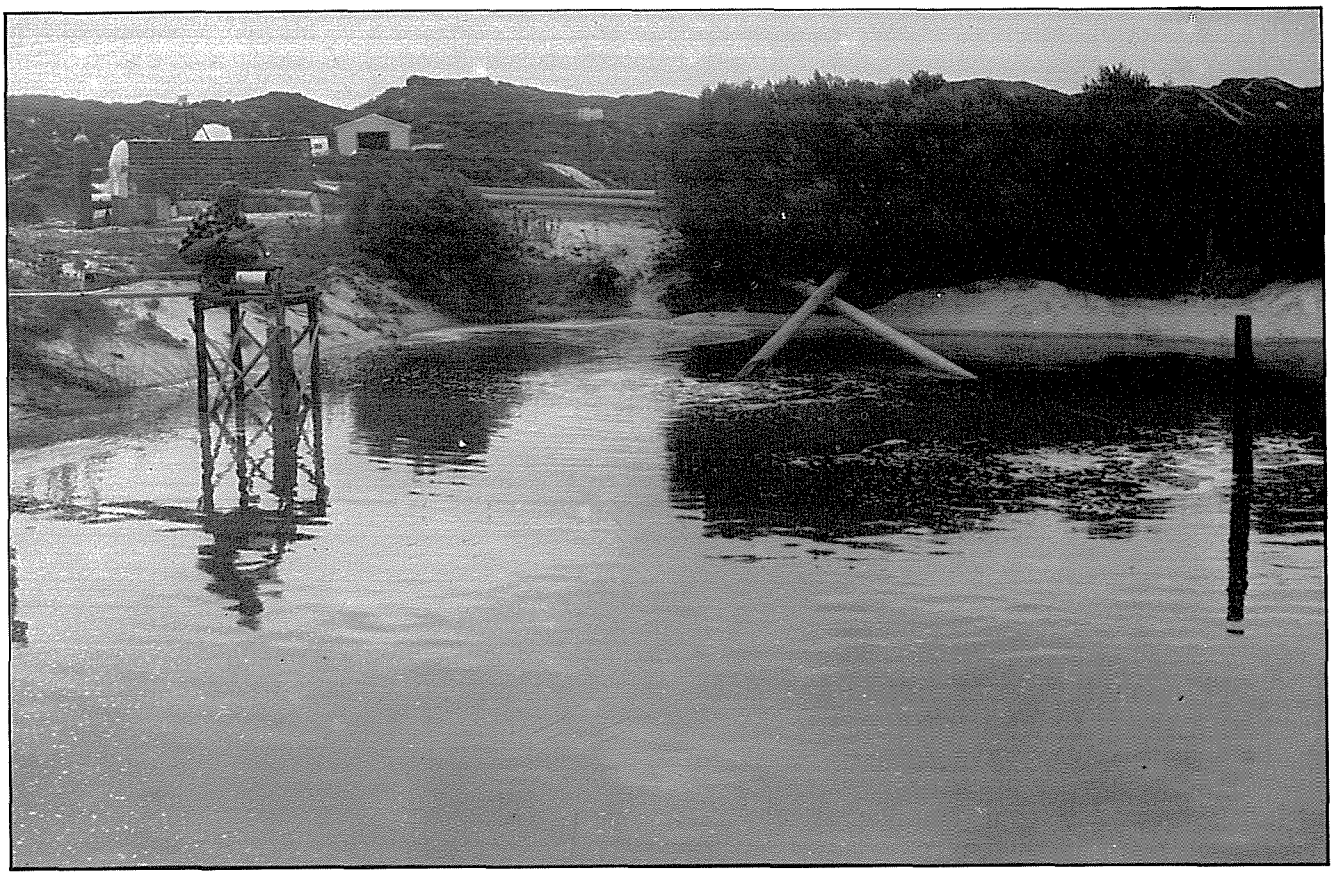
The artificial recharge and abstraction of purified sewage effluent

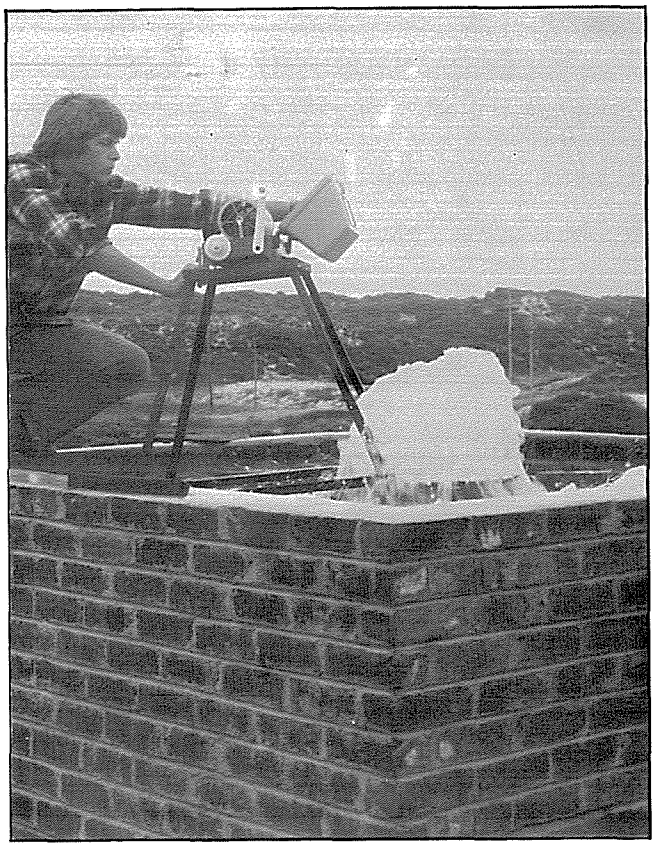
(New project: Contract with the CSIR — National Institute for Water Research)

The exploitation of groundwater in the sand aquifer of the Cape Flats and the possibility of storing reclaimed water during periods of low demand, together with groundwater in the aquifer for later abstraction and use,

A part of the interim water reclamation plant on the Cape Flats. In the right foreground can be seen a clarifier and beyond that the activated carbon columns which will form part of the completed plant.







(Top) An infiltration pond on the Cape Flats. (Left) A close-up picture of the water supply derived from the interim plant on the Cape Flats. This water is discharged to the infiltration pond and the infiltration rate is determined.

offer challenging possibilities for the augmentation of the fresh water supplies of the Cape Peninsula.

In order to obtain background data with a view to the possible application of this method the NIWR during 1978, undertook an intensive investigation in connection with the infiltration and abstraction of purified sewage effluent.

An area west of Strandfontein Road and some one and a half kilometres from the sea was developed for the experimental investigations and a thorough study of the deposits was made with the aid of drilling samples. However, peat and calcrete lenses occur in the area and will probably be a limiting factor on the vertical movement of water.

Sieve analyses of sand revealed the varying nature of the deposit and also that no definite deposit pattern exists, especially with respect to the fine to medium particle fractions in the upper layers of the aquifer. Layers of coarser sand are evident, particularly in the lowest part of the aquifer.

Background studies of the hydraulic nature of this part of the aquifer commenced at the end of 1977 and clearly indicated the complex composition of this part of the aquifer.

In order to determine the maximum infiltration rates for the different ponds, groundwater was initially used for the study of artificial recharge. Typical groundwater infiltration rates lie between 2 and 6 m/d.

Subsequently the interim reclamation plant next to the new Cape Flats Sewage Purification Works became operational and water from this plant was used for the infiltration studies. During the investigation the infiltration rate did not fall below 2 m/d despite partial clogging of the pond beds. It is expected that in the long term clogging will reduce the rate further.

Preliminary experiments with the recharge borehole showed that artificial recharge can, under certain circumstances, occur at a relatively high rate. Differences in quality between reclaimed water and groundwater made it possible to determine the movement of the reclaimed water after recharge. Surveys of the quality of the water throughout the Cape Flats are being continued on a regular basis at certain selected boreholes. This information is essential for subsequent projections for the prediction of the quality of the water in recharge and abstraction schemes.

The geohydrology of the sand deposits in the Cape Flats

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

The investigations in terms of this contract primarily constitute a continuation of the investigation into the establishment of a mathematical simulation model of the aquifer as envisaged in the original project 'Reclamation, storage and abstraction of purified sewage effluents in the Cape Peninsula'.

The value of the model is its ability to investigate applicable alternative systems for the implementation of full scale recharge and abstraction and the concomitant operational aspects that may be prescribed with due consideration of the influence of external factors on the system, including sea water intrusion, water balance, maximum and minimum water levels as well as water quality. Formulation of the basic model is being done with currently available data. Immediate monitoring was continued up to the end of 1978 and provision has been made for a long term observation programme in respect of rainfall, storm water drainage and variations in the water level.

Autographic rain gauges have been installed at seven points on the Flats in order to augment the network of observation points manned by other organizations and in order to obtain adequate coverage of the area. Daily rainfall figures are read from the gauge cards. Detailed information can also be obtained from the cards to determine, for example, the time lapse between rainfall and a rise in the groundwater level at the relevant points. For the calibration of the model it is essential that rainfall intensity be related to the rise in water levels.

The elevation of groundwater surfaces at approximately 100 points was previously determined at monthly intervals, but during the year the frequency was increased to weekly measurements at selected points. A few autographic gauges have already been erected for continuous observations.

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)

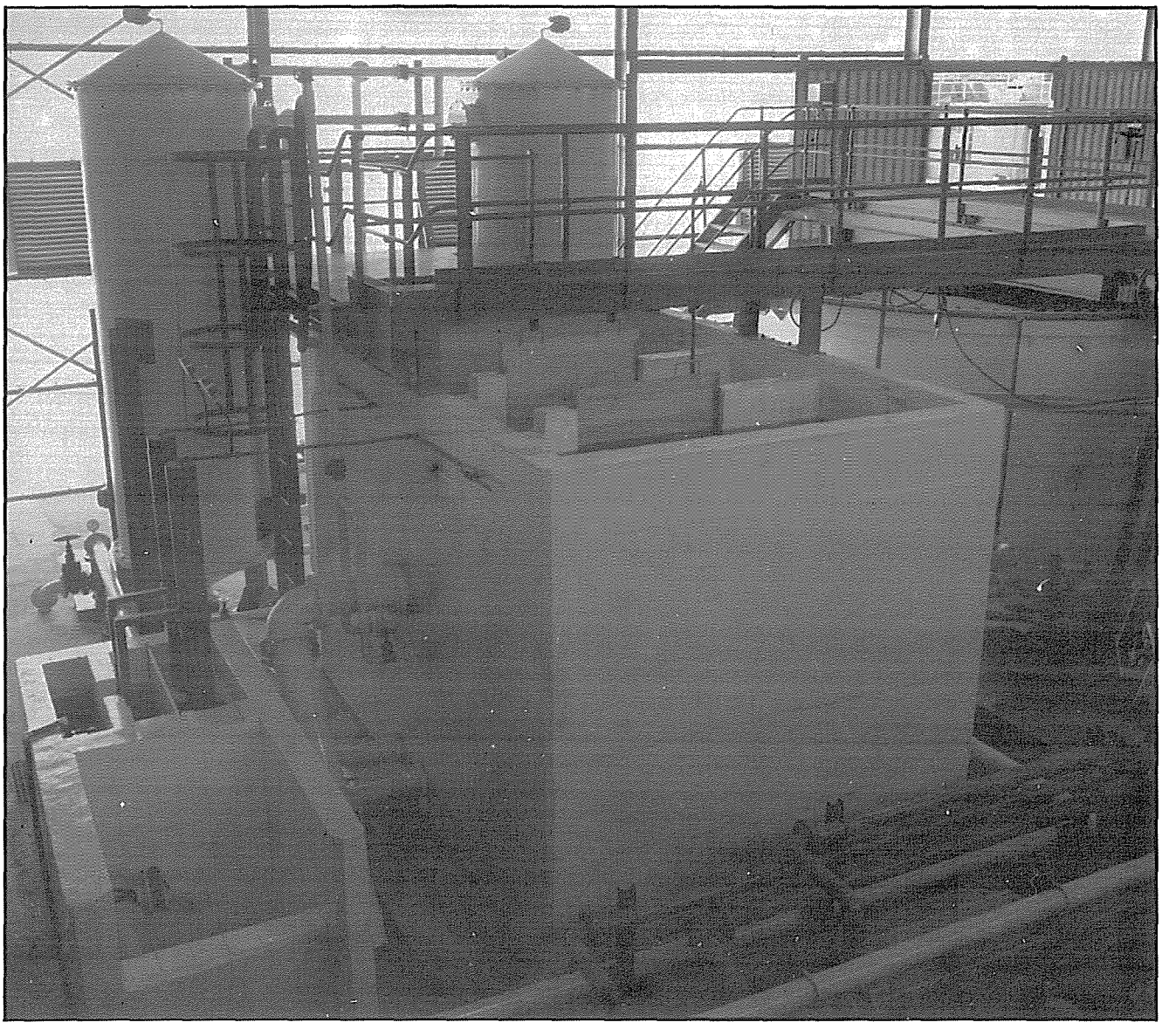
A large proportion of the waste water directed to the Athlone Sewage Purification Plant consists of in-

dustrial effluents with a high salt content and this affords an excellent opportunity of studying the reclamation of such an effluent.

The plant of 300 kl/d consists of a series of physico-chemical treatment processes to rid the water of organic and nitrogenous contaminants, and includes a biologically active aerated basin which performs an important role in the removal of organic matter, oxidation of ammonia and the correction of pH. The final process utilizes activated carbon to produce a good quality water for industrial use.

The plant was commissioned in September 1976 and optimisation reached the stage at the end of 1977 where a full production run of all units was considered possible and indeed necessary for an assessment of running costs for water reclamation. This run was concluded in March 1978 and provided much valuable information on the chemical, staffing, maintenance and monitoring costs of running the plant.

The difficulties of controlling the initial high lime treatment were highlighted and the system was subsequently modified during the planned shutdown from



Equipment at the Athlone Sewage Purification Works includes this sand filter (centre foreground), the activated carbon columns (background) and the primary clarifier (right).

April to July 1978. Various other modifications were carried out during this period while sections of the plant continued to operate to provide a biologically stabilised effluent.

Intensive operation of the plant recommenced in July with the aim of obtaining data on operation under winter conditions thus allowing a more accurate assessment to be made of the economics of continuous production of reclaimed water. This information will be required to assess the viability of large scale reclamation of water for industry. During the year a survey of major water users in industry was initiated with the view of developing a specific research programme aimed at the promotion of the reuse of the reclaimed water by industry.

Technological development of water reclamation and pollution control

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

The agreement for this project between the Commission and the CSIR was entered in 1973 with the primary aim of the development of design and operational criteria for the full scale application of water reclamation in South Africa.

Research in this regard has now been concluded and as mentioned in Chapter 1, a publication entitled 'Manual for Water Renovation and Reclamation' was published during the year. A second publication, 'A Guide for the Planning, Design and Operation of Water Reclamation Plants' is currently being prepared and will be directed mainly at decision makers, planners and managers. The publication contains useful information for research workers and design engineers.

The abovementioned agreement with the CSIR expired on 31 December 1978 after which technological research has been continued by the NIWR on a pilot scale.

During 1978 the Stander Reclamation Plant was operated intermittently for a total period of approximately five and a half months. During this period research was centred mainly on the disinfection of reclaimed water by means of ozone and on the concomitant extension of the life of activated carbon. In this regard promising results were achieved and indications are that the life of active carbon can be considerably extended and which will lead to a reduction in reclamation costs.

The ozonation equipment has been further optimised by placing a water-cooled heat exchanger in front of the ozone generator in order to improve air drying and to stabilise ozone production. Modifications to the ozone water reactor in the form of redistribution baffles in the packed tower have resulted in an increase of more than 95 per cent in the efficiency of ozone utilized in terms of ozone absorbed.

During the last two operational periods which entailed a total of 25 operational days, ferric chloride was used for primary clarification instead of lime whilst the rest of the operational configuration remained unaltered. Indications are that the quality of the final water obtained in this way was equal to that obtained by lime treatment. An important difference is that the treatment cost using ferric chloride is considerably lower than for lime treatment.

It is envisaged that in the near future the Municipality of Pretoria will take over the operation of the Stander Reclamation Plant with a view to demonstrating that a reclamation plant can be operated independently by a local authority. In addition an effort will be made to operate the plant as economically as possible in order to produce reclaimed water of a quality suitable for industrial use at the lowest possible cost. With this in view two operators from the Municipality received training during 1978 in the operation of the plant and the intention is that an employee of the Municipality will also receive training in control aspects and will gain experience with the plant during 1979.

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)

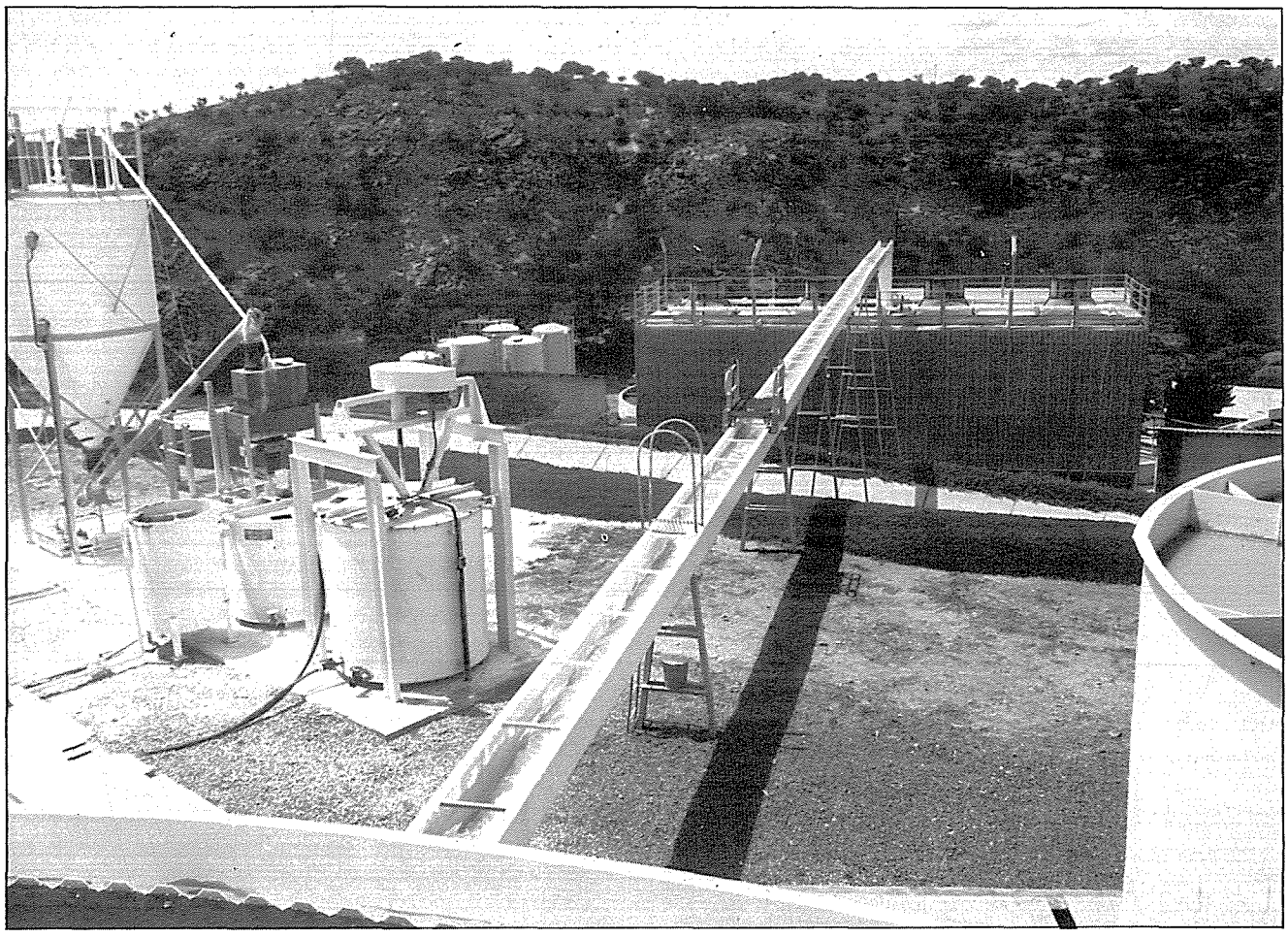
The Windhoek Water Reclamation Plant still plays a very important role in the water supply of the city as is

evident from the fact that during the period January to March 1978 the plant was operated for 56 days and produced 227 660 m^3 of reclaimed water which was incorporated in the conventional supply in the distribution system.

The spent carbon of the Windhoek plant was previously sent to Pretoria for regeneration at the Stander Water Reclamation Plant at Daspoort. However, this was a very expensive procedure as well as time consuming. The Commission and the CSIR therefore mutually agreed to transfer the regeneration furnace to Windhoek where, in May 1978, it was successfully commissioned. It was agreed that subject to certain conditions the spent activated carbon of the Stander plant and of the reclamation plants at Cape Town could be regenerated in Windhoek.

The Windhoek plant continues to enjoy wide local as well as overseas interest since it is still the only water reclamation plant which reclaims water on a production basis for domestic use. Various overseas experts in the field of water visited the plant during 1978.

A paper on the current state of water reclamation at Windhoek was presented in October 1978 during the conference of the Water Pollution Control Federation in Anaheim, USA.



A part of the Windhoek Water Reclamation Plant which continues to play an important role in the city's water supply. The conduit (centre) leads from the primary sedimentation tank to the ammonia stripping tower. To the left (in the far background) the activated carbon columns, and on the extreme left the lime container may be seen.

Microbiological quality and health aspects of drinking water

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

In view of the importance of health aspects of water use, the South African Institute for Medical Research (SAIMR) in terms of an agreement with the Commission, collaborated as in previous years successfully with various parties in monitoring the microbiological quality of reclaimed water in Windhoek and from the Stander Water Reclamation Plant at Daspoort, Pretoria.

The microbiological monitoring of the water produced by the plant at Daspoort was done as a collaborative effort by the National Institute for Water Research (NIWR) the SAIMR, the National Institute for Virology, the Rand Water Board and the Pretoria Municipality.

The water produced by the plant at Windhoek was monitored for its microbiological quality by the NIWR, the Department of Water Affairs (South West Africa branch), the SAIMR and the Windhoek Municipality.

The water was again found to be of a high quality, neither at Daspoort nor at Windhoek did viruses appear in the final product although these were regularly present in the sewage effluent as it entered the reclamation plants. Bacterial standards were on a par with those required of metropolitan water supplies in South Africa and elsewhere.

Only the reclaimed water at Windhoek (and not that at Daspoort) was used for human consumption. Epidemiological studies have thus far not indicated that significant differences in disease incidence have occurred since the inception of direct water re-use.

International interest has been shown in the epidemiological work carried out in South West Africa and a paper based on results, was presented in December 1978 at a symposium sponsored by the Royal Society of Tropical Medicine and Hygiene, the International Association on Water Pollution Research and the Institute of Civil Engineers in London.

Chapter 3

Groundwater research

In order to ensure the optimal utilization of the Republic's limited water resources it is essential that groundwater resources be utilized as an integral part of the water supply. In the dry and semi-arid regions especially, where little or no groundwater exists, local groundwater sources can be utilized at a far lower cost than imported surface water.

However, it is important that the potential of a groundwater source should first be determined quantitatively before it can be considered in any advance planning of water supplies. Quantitative estimates of the groundwater potential have already been made on a regional basis for the Western and Eastern Transvaal by the Water Plan Commission and the Water Planning Committees of the Department of Water Affairs. Similar estimates for a number of groundwater sources have also been made by other organizations and experts. Most of these findings, however, do not meet the accuracy required for the incorporation of these sources in a meaningful way into the more accurate planning of water supplies by the Department of Water Affairs. In spite of this effort, however, most of the sources have not been evaluated at all.

In the light of the abovementioned circumstances the Commission has for some time supported research in connection with groundwater and in this regard collaborates closely with the Department of Water Affairs. The immediate purpose of the research is to make the necessary accurate quantitative evaluation of the most important groundwater sources in the Republic physically possible. Research which will contribute to this aim therefore enjoys priority.

Existing groundwater projects supported by the Commission and reported later in this chapter will be modified whenever necessary, so that they may be incorporated more directly in the operational programme of the Department of Water Affairs. This will lead to the evaluation of groundwater sources which the Department presently wishes to incorporate in its planning of water supplies.

As mentioned in last year's Annual Report the Commission appointed a specialist consultant with a view to recommendations with respect to the meaningful integration of its groundwater projects with the requirements of the Department of Water Affairs, and with a view to the development of a purposeful long term research and development programme. He is Dr JF Enslin, former Director of Geological Survey, Department of Mines.

In compiling the long term programme it was necessary, as a first step, to study the groundwater situation in South Africa in order to identify gaps in the knowledge of the geohydrology and especially to identify the potential of important sources. Furthermore the deficiencies in the techniques and methods currently in use for the evaluation and exploitation of the different types of groundwater occurrences in the Republic had to be determined.

This study has now been completed and a memorandum with guidelines for further research is now being discussed.

The second phase for the compilation of the long term research and development programme involves an intensive study of all existing reports on groundwater investigations done by the Geological Survey (Department of Mines) and the Geohydrological Division (Department of Water Affairs). Furthermore some of the

sites will be visited in order to determine their suitability for the research recommended in the memorandum mentioned above. On this basis specific research projects on selected sites and with respect to suitable sources will be recommended.

The various research projects have progressed well and further details appear in the progress reports. The project on geohydrological studies in the Gamagara catchment by using environmental isotopes and complementary techniques was successfully completed.

RESEARCH PROJECTS

Geohydrological studies in the Gamagara Catchment using environmental isotopes and complementary techniques

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

The Gamagara catchment is part of the Molopo drainage system and lies on the southern edge of the Kalahari Thirstland. The southern part of the catchment is composed of a number of outcropping dolomitic compartments, and rock exposures in the form of hills bound the catchment on the east and the west. The central part consists of a glacial valley which has been filled with the gravels, clays and sands of tertiary Kalahari Beds. The area is important for cattle farming whilst mining development and mineral exploration are rapidly expanding, increasing the demands for water. These have to be met by groundwater and the importation of supplies via the Vaal-Gamagara pipeline.

The largest mine in the area at Sishen, on the downstream side of the dolomitic outcrops, has encountered large supplies of groundwater and is forced to dewater the groundwater compartments to allow for deepening of the open-cast pits.

The environmental isotope study was undertaken to investigate the applicability of the techniques involved in determining the mode of occurrence of the groundwater in this environment and to apply them as a tool, along with standard geohydrological methods, in establishing the hydrogeological characteristics of the aquifer. The isotopes employed are present in nature and, therefore, provides a means whereby the different types of groundwater in the area can readily be identified.

Tritium and radiocarbon, both radioactive with widely differing half-lives, give information on the rate of rainwater recharge to, as well as the residence time of, groundwaters. The nonradioactive heavy isotopes of hydrogen, oxygen and carbon allow for the identification of waters from different origins, as well as the tracing of evaporative and ion exchange processes.

The results of the investigations have been compiled into a final joint report, which constitutes the first account of a comprehensive multi-parameter environmental isotope study of an extensive groundwater system in South Africa. The report was prepared in cooperation with the Division of Geohydrology of the Department of Water Affairs, and also contains the results of their investigations in the area.

Many aspects of the groundwaters in the catchment were investigated and a number of major conclusions could be drawn from this work:

- Regionally, isotopic and chemical observations identified the main areas of recharge and elucidated certain aspects of the chemical evolution of the groundwaters. Direct rapid recharge was furthermore shown to occur at a number of points to Kalahari Beds aquifers and different recharge selection mechanisms were demonstrated.
- At Sishen mine, environmental isotope observations provided valuable original information on the complex groundwater relations which is required for the dewatering planning. The results of studies conducted in cooperation with ISCOR have confirmed conclusions drawn from standard geohydrological observations as well as calculations of the storage capacity of the Sishen groundwater compartment.
- Studies of infiltration of rainwater through the thick Kalahari sand cover were conducted with the aid of nuclear bomb produced tritium. Deep penetration of rainwater appears to have occurred during recent high-rainfall years with a considerable percentage of the rain water being retained in the sand.
- Detailed isotopic and chemical studies of the aquifers occurring in the upper and lower Kalahari beds have shown the feasibility of direct rain recharge through a thick overburden of Kalahari beds. The isotopic differences observed between the aquifers provide a means for the more extensive study of the groundwater in the Kalahari beds than was

hitherto possible by means of the poorly documented boreholes.

The study confirmed that the isotope techniques can be employed usefully as a supplementary method in the execution of operational geohydrological programmes aimed at determining the hydrological parameters of aquifers.

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

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

The ultimate objective of this research project which received much attention during the year under review, is the compilation of computer simulation models by means of which the groundwater potential in a specific area can be calculated. The models are compiled in such a way that a variety of geohydrological parameters may be taken into consideration. Some of these parameters, for example the permeability of the rock and the volume of water stored in the rock, have to be established in the field by means of pump testing. However, it is also important to determine the extent of an aquifer and to this end geological mapping is being done. Additional, information which is also relevant includes, for example, the extent of recharge of the groundwater supply by means of rainfall, and leakage and abstraction from the groundwater system by means of pumping, fountains, evapotranspiration and groundwater movement.

The application of such a computer model can be utilized in two ways in the future. First, and primarily on a short term basis, these models can be used to calculate the hydraulic parameters of the aquifer. Although various analytical techniques exist for calculating the permeability of the rock and the volume of water stored in the rock formations, the equations are not always valid for South African conditions. Equations have been developed overseas for calculating the hydraulic parameters for porous rock but equations do not yet exist for the calculation of the flow of groundwater in broken rock aquifers. It is possible that analytical techniques to determine the hydraulic parameters of the latter types of rock will never be developed because broken formations are too heterogeneous and anisotropic. The numerical models compiled by the Institute, however, can be used to calculate the permeability and the volume of water in the rock formations by means of an iterative process. This technique finds application especially in calculations of potential groundwater yield from dolerite aquifers.

Secondly the model can be used for long term calculations. To achieve this, however, relevant information collected over a number of years for a specific area should be available in order to calibrate the model. When this has been done, predictions with respect to safe yield from such a system may be made. The siting of boreholes can also be optimised and predictions made for quite a number of years in advance of the manner in which the water level will react with respect to certain abstraction systems. This development is important, especially in the following two respects: First, as seen from a water supply viewpoint, the exhaustion of such a system can be carefully monitored. In fact, such a system may be administered in the same way as abstraction from a surface source. Secondly, these models may be used in the dewatering of certain compartments and this application is of special importance to the mining industry, where strip mining techniques are used. Pumping rates, inflow rates, lateral dewatering effects, optimal spacing of dewatering pumps and rehabilitation of the system once the mine has been worked out, can all be calculated.

Groundwater simulation models are currently being generated at a considerable rate overseas and the utilization of such overseas expertise is important. In this regard Dr Peter C Trescott of the United States Geological Survey visited the Institute. He is a world authority on finite difference simulation models and during his visit made a valuable contribution by compiling an algorhythm according to which groundwater flow in dolerite aquifers can be simulated three-dimensionally. He also made available, free of charge, a number of computer models to the Institute.

As this research project of the Institute becomes more widely known, more and more overseas experts are being attracted to visit the Institute, mainly at their own expense. Examples are Prof Gedeon Dagan of the University of Tel Aviv, Glynn Jones of the University College of London and Dr Mike Coward of the University of Leads who have all made valuable contributions with respect to the research project.

All regional geohydrological investigations have already been completed. The intention is that the Institute will, during the coming year, involve itself in the calibration and verification of the computer models. Thereafter alternative areas in the Southern Free State and Northern Cape will be selected to determine the extent of the validity of these models for the whole area.

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

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

The development of techniques for determining the exploitation potential of groundwater resources in the Doornberg fault zone area where it is exposed between Prieska and Koegas and also where it is overlaid by Karoo sediments is being done in terms of this contract.

During the year work centred mainly on a geophysical-geohydrological investigation around the town of Kenhardt. The geology of this area was influenced very strongly by the tectonic occurrence responsible for the Doornberg fault zone. Because there had also been an urgent need to investigate the groundwater supply of Kenhardt, it was decided that such an investigation at Kenhardt would be a logical extension of the project. The work was done in collaboration with the Geohydrology Division of the Department of Water Affairs and entailed the following:

- Geohydrological mapping by the Institute for Groundwater Studies of the University of the OFS, with special reference to linear structures.
- An extensive geophysical investigation by electrical sounding by the CSIR to determine the thickness and distribution of the most important aquifers of the area, *viz* alluvium and weathered gneiss. Attention was specially devoted to the tracing of linear structures by means of both the electric specific resistance method and the electromagnetic method. The latter method was applied by the Geohydrological Division of the Department of Water Affairs.
- A drilling programme by the Geohydrological Division to calibrate the geophysical results with accompanying pump tests to determine the waterbearing properties of the aquifers.

It has been found that the weathered gneiss is the most important aquifer in the area and that the linear structures do not contribute materially to the groundwater supply. The quality of the groundwater in the weathered gneiss is satisfactory for domestic use and the supply would seem to be adequate to meet the town's requirements.

In April 1978 the National Physical Research Laboratory, in collaboration with the Geohydrological Division, also commenced with an investigation into the development and evaluation of geophysical methods for determining the groundwater potential of the Breë River area between Brandvlei Dam and the Wit River Bridge.

The groundwater is stored mainly in the alluvial deposits which are highly permeable in some places and from which groundwater may be abstracted at high pumping rates.

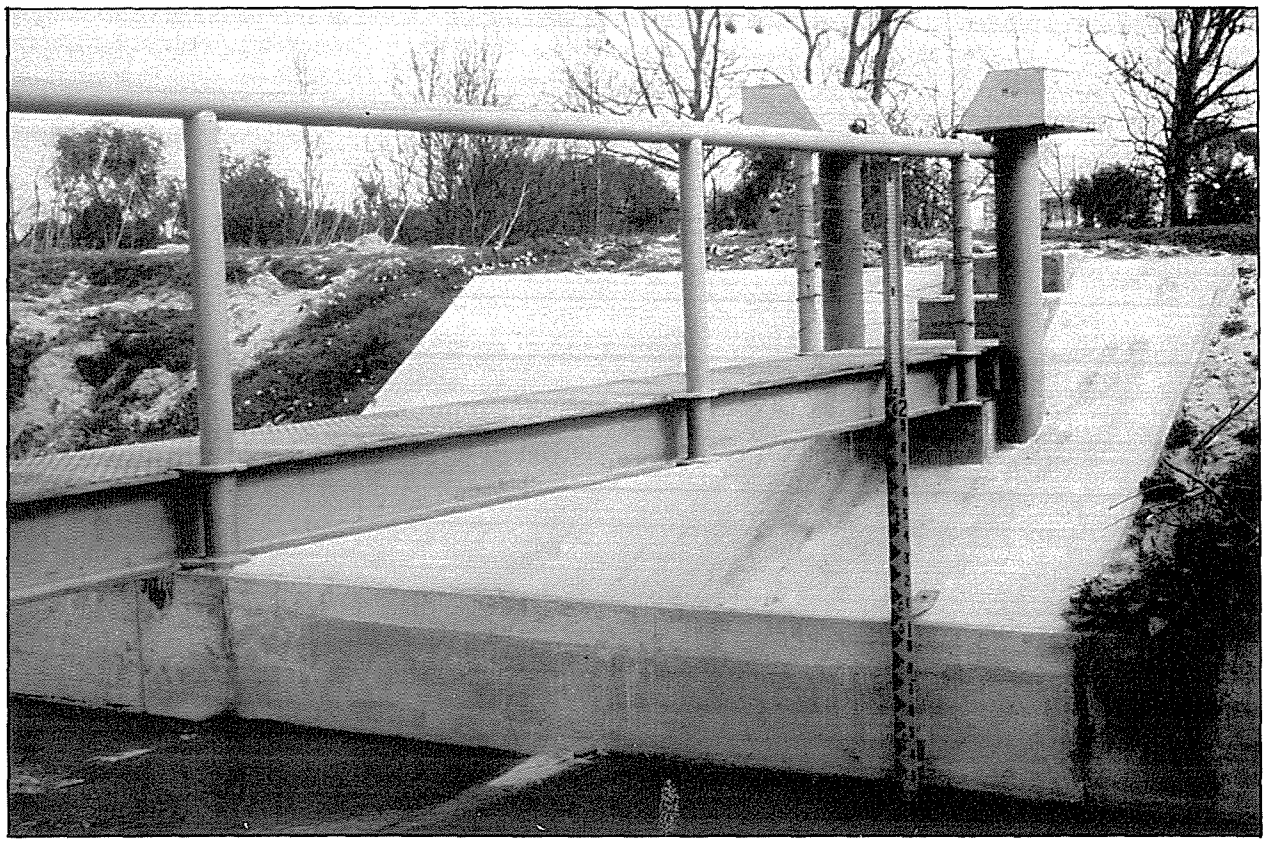
The primary aim of this work is to determine the thickness and specific resistance of the water-saturated alluvium and to study the relationship between the electric and waterbearing properties of the alluvium. If such a correlation exists it could make the proposed future drilling programme much more efficient in that areas with potentially high yields can be selected on the basis of electrical results. The correlation study will comprise pumping tests on selected boreholes which still have to be drilled in order to determine the hydraulic properties of the waterbearing formation.

The geophysical results obtained so far show that the diameter of the alluvium varies considerably and that it consists mainly of a coarser, stony and a finer, sandy fraction.

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)

This project involves an investigation into the practical feasibility of storing water from the Eerste River which, according to existing plans cannot be diverted or stored and made available for use, in the sand deposits in the eastern part of the Cape Flats. The most important factors being investigated to this end are the geohydrological properties of the sand deposits which primarily determine whether the water can permeate readily, whether a sufficient quantity can be stored and whether the water can be economically abstracted. The nature and concentration of dissolved substances in the



A gauging station in the Kuils River which will serve as a valuable control for the estimates of runoff based on rainfall figures for the Kuils River catchment.

groundwater in the sandbeds as well as in the river water are being studied with a view to providing an indication of the water quality which may be expected should a possible scheme be implemented. The volume of water potentially available for infiltration in the sand beds is being studied on a daily basis to allow determination of the divertable quantity as a function of the capacity of the diversion system in terms of the mean annual volume and its variation.

At this stage the boundaries of the sand deposits are reasonably well-known and investigations are now directed at the practical abstraction of water from boreholes in order to determine the storage- and yield capacity of the formation. It has been found that clay and calcrete layers play an important part during the abstraction of water and that they will also strongly influence the infiltration of water. Preliminary results seem to indicate that the south-western part of the area will be more suitable for the large-scale infiltration and abstraction of river water than the north-eastern part where most of the small ponds currently occur. The relatively low groundwater pressures observed in the deepest waterbearing sand beds near the ponds after the extraordinarily dry winter of 1977 seem to indicate further that layers with poor permeability considerably retard the downward movement of water in the latter area.

A gauging station has also now been erected in the Kuils River and the flow measurements at this station will provide a valuable control for the estimates of runoff based on the rainfall records for the catchment. Daily water samples are also being taken at the station with a view to chemical analyses in order to establish the total salinity of this river. In the case of the Eerste River simultaneous observations of the salt concentration and streamflow have been made on a daily basis for more than a year now, so that the salinity of the river may be determined with reasonable accuracy.

The investigations into the geohydrological properties of the relevant sand deposits have now reached the stage where the results can be used as parameters in a mathematical model with which the movement of the groundwater level in the deposit can be quantitatively predicted for a specific system of infiltration and abstraction of water. Results ensuing from this work will be used with the synthetic series of daily divertable water volumes from the Eerste and Kuils Rivers to calculate the water yield of specific schemes and develop operational regulations.

Chapter 4

The water environment

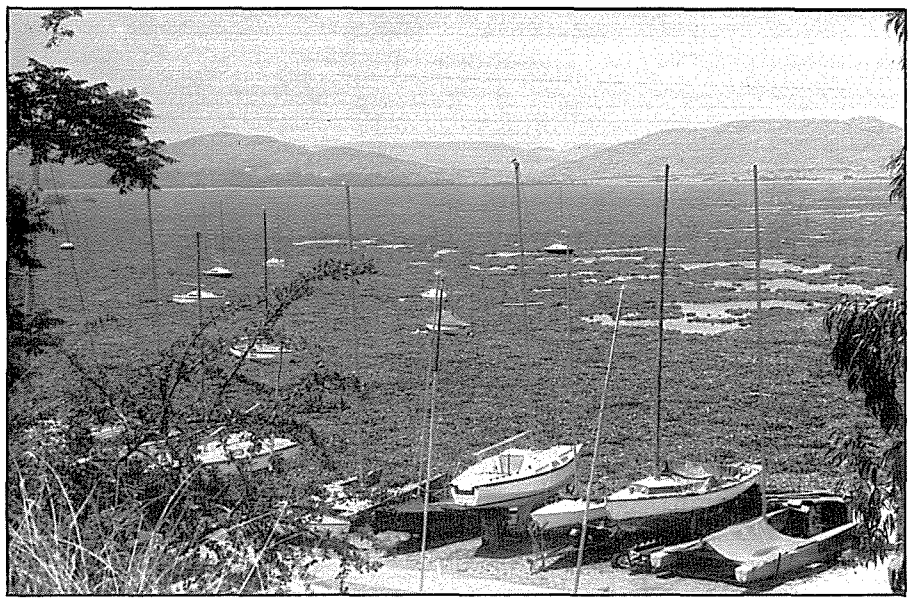
Treated effluents are discharged to the environment (except where direct reuse is practised) and, therefore, research in the field of the water environment is closely related to that of effluent treatment (see next chapter). The former is important to the Commission because in considering the degree of effluent treatment that should be applied it is necessary to establish the impact of different levels of pollutant on the environment. Research regarding the water environment is also of prime importance to authorities such as the Department of Water Affairs, the Department of Health and the SA Bureau of Standards in the setting of regulations governing effluent quality.

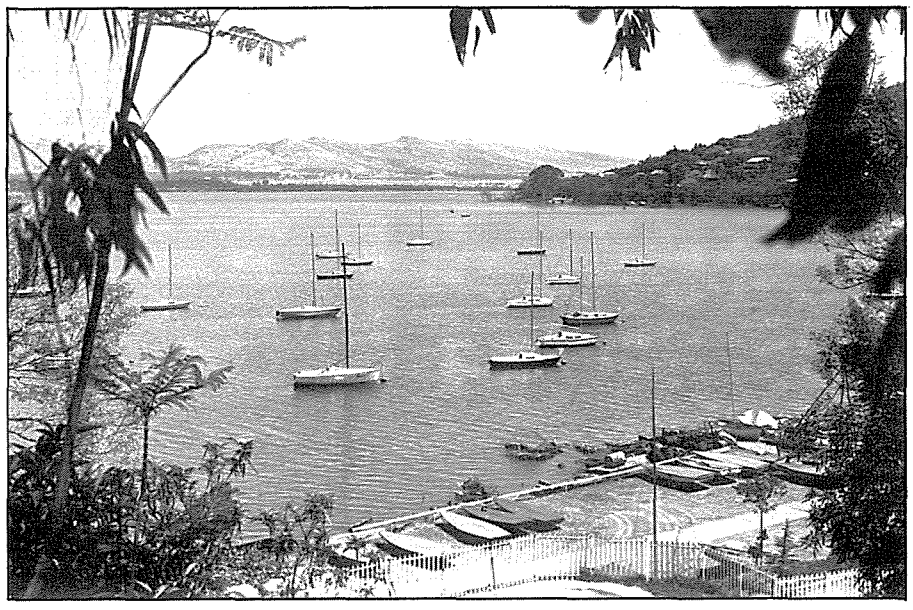
It is also desirable for the Commission to understand the dynamic processes at work in the water environment, in order to be in a better position to predict the impact of pollution discharges and other human activities on water bodies, and to develop processes whereby the effects of pollution can be minimized or controlled.

In the 1977 Annual Report reference was made to the negotiations between the Commission and the CSIR that had taken place, culminating in the recognition of the CSIR's Committee for Inland Water Ecosystems (of the Cooperative Scientific Programmes Unit) as a Coordinating Research and Development Committee for the Commission, for research and environmental problems related to water. During 1978 the Committee assumed the task of evaluating the recommendations made to the Commission during 1977 by Dr AF Bartsch of the US Environmental Protection Agency who had been brought to the Republic by the Commission to advise on the coordination of research on local inland water ecosystems. The Committee decided on the systematic "national plan" for limnological research in South Africa in order to facilitate research coordination and the allocation of priorities to the many important problem areas requiring research. Thus towards the end of the year the Cooperative Scientific Programmes Unit published a report entitled "Research into Inland Water Ecosystems in South Africa". This document has been compiled to clearly pinpoint the priorities for research. It also gives guidance to scientists applying for research funds and also guidance for the planning and execution of research.

The research contract on eutrophication with CSIR (through the National Institute for Water Research), was extended to June 1979 to allow time for the adequate processing and interpretation of data from the Natal dams, which during 1977 were included in the research programme. The final analysis, now under way, will deal with results from the study of some 20 dams in Transvaal, Natal and the Eastern Province in an attempt to correlate levels of nitrogen and phosphorus compounds in the dams with resultant algal growth observed.

The contract with Rhodes University, whereby its Institute for Fresh Water Studies had studied the role of the macrophytes in Swartvlei, was completed at the end of 1978. One of the most important aspects of this work during the year was a study of the response of the natural macrophyte population to artificially increased





During the year the investigation into the large-scale spraying of water hyacinths on Hartbeespoort Dam has been completed. The two photographs on the left (taken exactly one year apart) show the Dam in October 1977 (top) on the day spraying with herbicide took place, and in October 1978 (below)

concentrations of nutrients. For the purposes of the final contract report, the work on Swartvlei is being integrated with closely related studies that were done, also by the Institute for Fresh Water Studies, on the Swartvlei estuary, partly supported by the Department of Planning and the Environment.

In the early part of the year the multidisciplinary programme of monitoring of the effects of large-scale application of herbicide to water hyacinth (*Eichhornia crassipes*) on Hartbeespoort Dam was completed, and the final report has been compiled and published. This investigation was done in collaboration with the Department of Water Affairs, the CSIR's National Institute for Water Research, as well as several other organisations. No ill effects of the spraying could be observed, and the exercise served as a source of valuable information both on the execution of such a weed eradication programme and on the kind of monitoring programme that should be mounted. The worldwide concern about meeting the protein demand of growing populations is felt in South Africa as well. Fish protein is an important resource, and it is increasingly considered that more attention should be given to the potential of South Africa's fresh water bodies for fish production. This concern finds expression in the Commission's sphere of interest in two forms. The first is the project by the Department of Nature Conservation of the Transvaal Provincial Administration, assisted by the Commission, on the production of fish by means of the 'raceway' system (progress is reported on below). The second is the support being given by the Committee for Inland Water Ecosystems in response to a request by the Commission, for research on the productivity of one of the

country's large impoundments. This work is indirectly funded, in part, by the Commission, by means of the grant made towards the research supported by the Committee for Inland Water Ecosystems.

RESEARCH PROJECTS

The role of aquatic plants in maintaining trophic conditions at Swartvlei, Wilderness

(Existing project: Contract with Rhodes University — Institute for Freshwater Studies)

Owing to its unspoiled nature, Swartvlei, one of the six Wilderness lakes, provides an ideal site for a quantitative study of the role played by submerged weed beds in the maintenance of trophic conditions in shallow waters.

During the year under review, the cycling of nutrients, particularly phosphorus, in the macrophyte community in the shallower waters of Swartvlei was studied intensively in an attempt to determine the influence of the plant zone on the trophic studies of the lake. Of particular relevance in this project was the artificial enrichment of a series of isolation columns. Enrichment with phosphorus and nitrogen fertilisers was carried out weekly at four different application rates for four months. All the added nutrients, even at the highest fertiliser application rates, were consistently removed within 2 days of addition, thus confirming the original hypothesis that these beds of aquatic plants are very efficient nutrient filters. However, experimental work with the radioisotope ^{32}P showed that increasing fertiliser loads were taken up by increasing filamentous algal growth rather than by the macrophytes, and that unsightly dense algal mats replaced the macrophyte cover on the water surface.

The implications of this for aquatic ecosystem management are considered in the final report, together with other implications for management of the whole of the Swartvlei system, both lake and estuary, that flow out of the programme of research that has now run to a close. Much of the work that has been done at Swartvlei in terms of the Commission's contract with Rhodes University, will form the basis of further work to be done on the closely related Wilderness vleis, supported by the Committee for Inland Water Ecosystems.

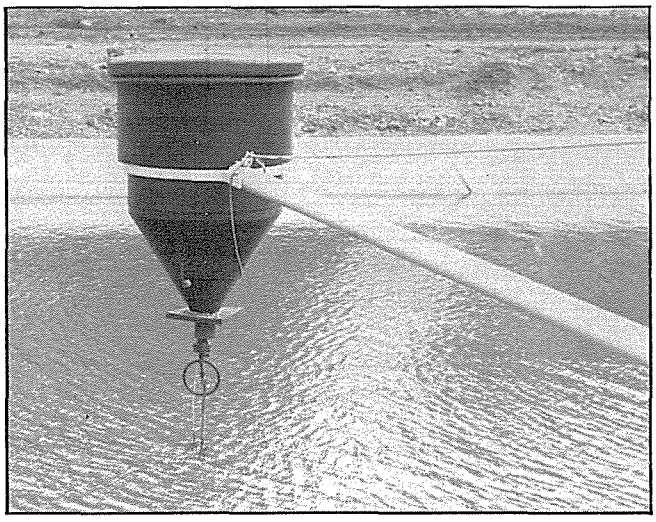
Eutrophication of rivers and dams

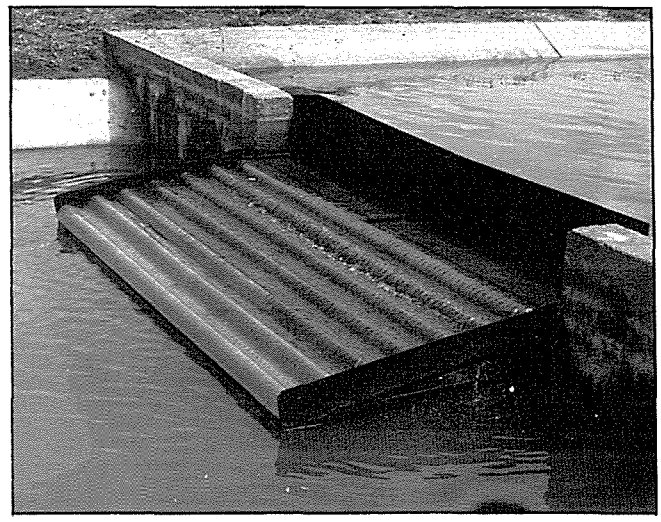
(Existing project: Contract with the CSIR — National Institute for Water Research)

Limnological research carried out under the eutrophication contract has continued towards the goal of obtaining a better understanding of eutrophication and the behaviour of impoundments under local conditions. During the year considerable emphasis has also been placed on the completion of final reports on work carried out during the first phase of the eutrophication contract. These have been released mainly in the form of published scientific articles and include information on the current situation of the Hartbeespoort, Rietvlei, Roodeplaat and Buffelspoort Dams.

The study of Lindleyspoort and Buffelspoort Dams, which was carried out over a period of three years and which involved the artificial enrichment of the two impoundments, has yielded valuable information concerning the mechanisms of eutrophication. Enrichment produced increases in the phytoplankton standing crop of both impoundments, although the response in the extremely turbid Lindleyspoort Dam was not as pronounced as that in the relatively clearer Buffelspoort Dam. This difference was attributed to the effects of suspended clay material on light penetration and photosynthesis. After enrichment had ceased both impoundments appeared to show a rapid recovery since the sizes of phytoplankton populations during the post-enrichment year reverted to conditions encountered prior to enrichment. These observations indicate that silty impoundments can tolerate higher nutrient loading rates than clear water impoundments and that the recovery of systems which have been subjected to decreased loading should be fairly rapid under South African hydrological conditions.

In addition to the previous investigations on the three impoundments in the East London area, studies were initiated on six impoundments in the highveld area and five in the Natal region. It is intended to utilize data from these impoundments in conjunction with data provided by other workers to develop a trophic status classification and a suitable model which can be used to predict eutrophication levels. For this purpose a computerized limnological data base has been created in order to facilitate the efficient storage and retrieval of information by contributors.





Two pieces of equipment used in research on freshwater fish production by means of the raceway system at the Lowveld Fisheries Research Station near Marble Hall. The automatic fish feeder appears on the left and an aerator on the right.

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" for the production of fresh water fish species is currently being investigated by the Lowveld Fisheries Research Station at Marble Hall in the Eastern Transvaal. This method of fish production makes use of running water which forms part of an irrigation scheme with the result that considerable dam surface areas and associated water losses due to evaporation are being limited.

The water is used for a dual purpose, viz., for the production of fish and to irrigate crops; with a resulting increase in the general productivity per unit water available for utilization.

Construction of the 940 m^3 raceway system has been completed and limited pilot-scale tests gave encouraging results. A full series of tests was commenced during the next season. The experimental canal has been populated with 2 000 Aischgrund carp per segment (15 fish per m^3). The fish have been fed intensively with formulated fish food pellets by means of an autofeeder.

Production figures of between 1 387 and 461 kg per segment (10,4—3,4 kg/m^3) have been observed. Water quality in the seven segment canal deteriorated considerably as water flowed through the segments. It has been found that low dissolved oxygen concentrations, often lower than 3 mg/l in the lower segments, has been the chief limiting factor for fish in the canal. Low concentrations of dissolved oxygen has had a definite detrimental effect on the growth and effective food conversion capacity (1:1,7 to 3,3) of the fish.

Mechanical aeration apparatus will now be used and the current fish population figures in use will also be revised. In contrast with the first two canal segments which do not show any limitations to fish growth, the other segments cannot cope with the relevant fish populations. The so-called 'multispecies production principle' can be fruitfully employed in the raceway system, since the production potential can be considerably increased by installing filter feeders, for example, for the kurper and silver carp. A heavy load of suspended organic material have been found in the canal and if this potential source of food is effectively utilised by the fish it will ensure a favourable overall food conversion in the canal.

The economic viability of the system is still uncertain in the light of results obtained so far. However, it is expected that clearer conclusions will result from experiments during the current season.

Chapter 5

Treatment of municipal and industrial effluents

The discharge of municipal and industrial effluents, unless adequately purified, into receiving waters or into the environment can pose a serious problem to the limited water sources of many parts of the Republic, and is a matter which merits high priority of attention. In view of this, the Commission very closely collaborates with local authorities and industries, and supports research aimed at the development of an advanced technology for efficient waste water purification.

The Commission already enjoys good cooperation from municipalities which are prepared to make a significant input to the execution of the research. In addition a Study Group, with representatives of municipalities, has been established to consider problems concerning water supply, and treatment of effluents and of wastes which have water pollution potential. This Study Group then makes recommendations for research to be undertaken.

Liaison with industry regarding research on the treatment of effluents is done through its various National Associations. This is of considerable importance, since any research which is sponsored by the Commission in the industrial field must be for the benefit of the whole industry. Industrial research in water and wastewater management is a very diverse field, and each particular group has to be treated as an entity on its own. In each sector, the guiding control is through a Coordinating Research and Development (CR&D) Committee, on which are representatives of the various National Associations belonging to that group.

During the year considerable progress has been made with the different projects. In the textile industry the existing contract with the University of Natal was amended in 1977 and was based on an agreed Master Plan (developed by the Coordinating Research and Development Committee for Effluent Problems in the Textile Industry) which covered a five year programme in the fields of wool scouring, sizing and desizing, and dyeing and printing. These fields are the three major operations within the textile industry which are highly water consumptive. Detailed surveys have been carried out on the characterisation of the different types of textile effluents in order to provide the background information needed for Codes of Practice, which will be formulated to provide guidelines for 'good housekeeping' and the control of water usage and effluent production within the factory. All pilot plant studies at factory sites, are being carried out on a partnership basis with the individual firms concerned, who are contributing substantially to the work.

In the case of tanneries and fellmongeries the problem of disposal of wastewater emanates from the high organic strength and the high saline content of the wastewaters. Where tanneries or fellmongeries are located at the coast, the disposal of wastewater involves removal of organic matter only, but for inland tanneries successful disposal leading to near zero impact on the water environment requires reduction of the mineral as well as the organic content. A draft set of guidelines, including a Code of Practice, has been prepared and submitted to the relevant CR & D Committee for consideration. When finalized the document will be disseminated to industry as well as to local and central government departments.

The Commission supports research in connection with water pollution and reclamation of effluents in the Pretoria-Witwatersrand-Vereeniging-Sasolburg (PWVS) complex. This complex abstracts much of its

water requirements from the storage basin of the Barrage in the Vaal River. A very substantial section of the mining, industrial and urban complexes are located within the catchment areas of the tributaries that drain back into the Barrage. Consequently large volumes of treated sewage, industrial effluents and stormwater run-off are returned to the Barrage carrying heavy loads of dissolved salts. In the Barrage basin these effluents are mixed with the relatively unpolluted water from the Vaal Dam and after being subjected to conventional water treatment are pumped back into the purified water delivery system of the PWVS complex. Water not abstracted is passed on down the Vaal River which is the source of water for further mining, industrial and urban developments downstream. This cycle is resulting in a rapid increase to unacceptable levels of the concentrations of various pollutants in the Barrage storage basin and downstream in the Vaal River.

The Commission has for a number of years supported research by the NIWR and the University of Cape Town on the biological removal of nitrogenous and phosphorous compounds from effluents. These nutrients are the principle cause of eutrophication and sewage purification plants have been identified as one of the most important point sources contributing nitrogen and phosphorus pollution of the water environment. These two contracts expired at the end of 1978 but in view of the importance of the problem of eutrophication and of the promising results obtained, the Commission has decided to initiate and finance two new projects in this regard. The first is a cooperative project for the optimization of the modified activated sludge process for nutrient removal, to be jointly executed by the City Council of Johannesburg, the NIWR and the University of Cape Town. This project will concentrate on the effective full-scale implementation of existing research results and findings and problem aspects of the process which still require further investigation. The second project involves the removal of phosphorus and nitrogen from biofilter effluents and will entail full-scale studies on chemical phosphorus removal and laboratory and pilot-scale studies on biological processes for the removal of these nutrients.

The agreement between the Commission and the University of the Witwatersrand regarding research on the removal of metal ions from dilute solutions by means of electrolytic precipitation expired at the end of 1978. During the year the work has reached the stage where a pilot plant was erected at an electroplating company and initial results were promising. Indications are that scaling-up of the equipment will not pose any major problems. At the termination of the contract the University will carry on with the work, aiming at reducing the limits of removal of some of the ions and lowering the costs of the process by using several more novel ideas.

The Commission has financed research by the NIWR on the technological application of anaerobic digestion for the purification of spent wine residues. Bench scale and pilot scale research has progressed to such a point that full-scale implementation of research results and findings is now considered justified, and in fact essential, for the full scale exploitation of the process.

RESEARCH PROJECTS

Research on the activated sludge process

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

This project was started at the end of 1973 with the main objective of developing design criteria for the activated sludge process for South African conditions. To date the processes of carbonaceous, nitrogenous and phosphorous matter removal from sewage have been investigated in-depth at the bench scale experimentation level and to a lesser degree at the pilot scale level.

In order to develop a general design approach, applicable under the widely varying conditions encountered in South Africa, research into the basic kinetic behaviour of the aerobic activated sludge process was initiated at the University of Cape Town.

Research on the kinetics of the oxidation of carbonaceous matter and of nitrification progressed considerably during the year under discussion. It is now possible to outline a reliable procedure for designing any type of activated sludge plant, i.e. aerated lagoons, contact stabilization and extended aeration processes. The generalized dynamic mathematical simulation model which was developed at the university and which allows such designs, is applicable to systems consisting of single or a series of reactors and is valid for temperatures between 14° and 20°C, a wide range of sludge ages, and for dynamic loading conditions.

Phosphorus removal in the activated sludge process i.e. biological phosphorus removal, was studied intensively this year. Numerous process configurations were tested in an effort to maximize the process efficiency. It became clear from this investigation that there is apparently an upper limit to the mass of phosphorus which can be removed biologically from sewage with a high phosphorus content. Preliminary work on integrated biological-chemical processes has shown great promise and chemical precipitation of residual phosphorus with lime, alum and iron is most effective.

All the work to date on aerobic activated sludge

treatment has been written up as a comprehensive research report which should be invaluable to research scientists. In fact, the work is of such a high standard that it was received very favourably at the 9th Conference of the International Association on Water Pollution Research, in Stockholm in June 1978. In addition to the aforementioned research report, results of this five year project are currently also being re-worked in the form of a design manual specifically aimed at wastewater-purification-works design engineers at state departments, local authorities and consulting engineering firms.

In order to ensure proper and effective technology transfer from the research sphere to practice, future research will centre on the large scale implementation, evaluation and development of the nutrient removal technology in practice, i.e. at the Goudkoppies Works (150 Ml/d) in Johannesburg. To this end a cooperative project (as explained in the introduction to the Chapter) between the City Council of Johannesburg, the University of Cape Town and the CSIR through the National Institute of Water Research will start early in 1979.

Biological denitrification and phosphate removal

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

This project was launched in 1974 with the primary aim of developing process criteria for the biological removal of nutrients from sewage effluents, with special regard to nitrogen, phosphorus and carbon compounds. Investigations are initially undertaken in the laboratory with the aim of identifying and quantifying operational parameters after which the most promising findings are further evaluated and developed by means of a 100 kl/d pilot plant at Daspoort, Pretoria.

One of the well known problems of biological wastewater purification in practice and which was notably present during the previous year's studies is the reduction in process efficiency during the winter months. As a result of this, special attention was given to a study of the temperature dependency of biological removal of nitrogen and phosphate during the year under review. It was found that the process of nitrogen removal was very dependant on temperature; the lower the temperature the lower the rate of nitrogen removal. In contrast to this it was found that biological phosphate removal reactions were influenced by temperature to a small extent only. The investigation also confirmed literature findings *viz* that nitrogen removal takes place according to two different rates. It has also been found that in many cases existing mathematical simulation models have poorly predicted sludge production, a parameter which plays a highly important role in the process and which consequently is of great importance for design purposes.

Modern requirements for effluent quality demand that the formulation of realistic specifications to which effluents must comply has as its primary aim the protection of the environment, should be very carefully considered.

The pilot plant mentioned above has been operated for a period of one year under simulated full scale conditions with settled sewage by using a fixed design and procedures determined according to the latest research results and experience. The plant not only succeeded in achieving its primary objective, i.e. the confirmation in practice of laboratory findings, but also produced valuable information in connection with the demands that current biological wastewater purification technology can reasonably be expected to meet. A similar investigation using raw sewage is currently being undertaken and has progressed well. The findings to date with both settled and raw sewage indicate that the concentrations of nitrogen and phosphorus compounds in the effluent can be limited to an average of 7 and 2 mg/l respectively. This would seem to indicate a considerable reduction in the concentrations as seen in a comparison with the corresponding feed concentrations of approximately 35 and 6 mg/l for nitrogen and phosphorus compounds respectively.

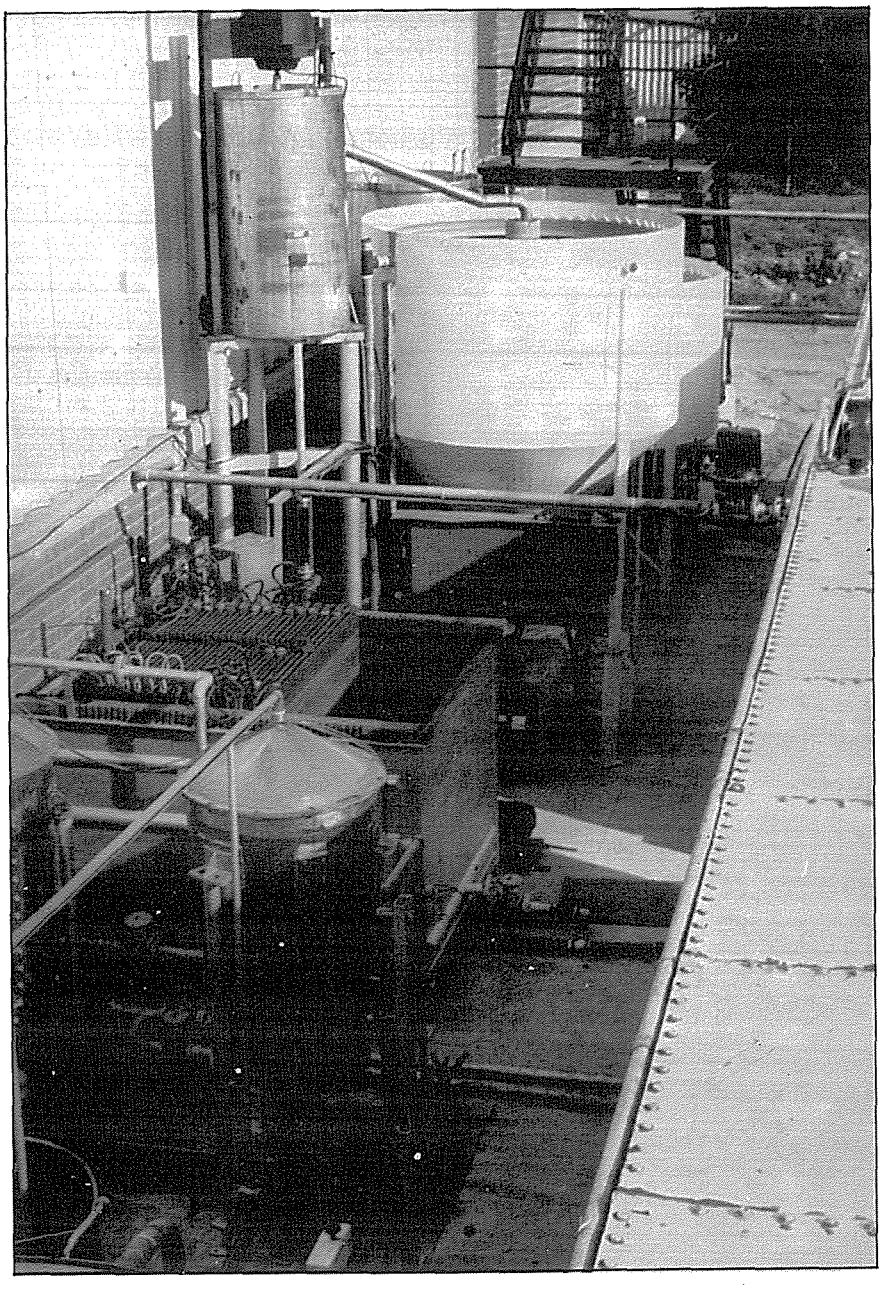
The existing project was completed at the end of 1978. A start has been made with the compilation of a technical manual from the results which have ensued from this project. It is expected that this manual will be of great value to design engineers in government departments, local authorities, and firms of consulting engineers.

Future research in connection with denitrification and phosphate removal will be undertaken in a new project and in collaboration with the Municipality of Johannesburg and the University of Cape Town, as explained in the introduction to this chapter.

Research into water management and effluent treatment in the textile industry

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

The work involves the development of treatment methods for effluents produced by particular manufacturing processes to allow for water reuse. In this respect substantial progress has been made on the closed loop



A pilot plant for the treatment of dyehouse effluent which has been installed at a large worsted manufacturer by the Pollution Research Group of the Chemical Engineering Department of the University of Natal.

recycle systems for the effluents from wool/synthetic fibre dyeing, desizing, cotton/synthetic dyeing and wool scouring. For the semitechnical scale and pilot-plant studies at factory sites, the work is carried out on a partnership basis with individual firms, who are contributing substantially to the work. Associated with this, further work has been carried out on the efficiency of washing/rinsing operations and a conductivity control system for regulating water usage is under test on a range of wet processing operations.

Wool/synthetic fibre dyehouse effluents

A continuously operating pilot plant has been designed and commissioned at the largest worsted mill in the Republic. The treatment system consists of ion exchange for dyeing, auxiliary chemical recovery, electrocoagulation and sedimentation for colour and heavy

metal removal and final filtration. The pilot-plant is operational on the effluent from five production dyeing machines and the reclaimed water is reused by these machines. Tests on the reuse of the recovered dyeing auxiliary chemicals are also being made.

Cotton/synthetic fibre dyehouse effluents

These effluents differ significantly from wool/synthetic fibre dyehouse effluents in that different classes of dyestuffs are used and substantial quantities of salts are needed for the dyeing process.

Preliminary semi-technical scale hyperfiltration (reverse osmosis) tests have been made at several factory sites and the quality of the product water is suitable for process water reuse.

Different membrane modules are being evaluated to find the most suitable for long term industrial application. Laboratory investigations are being carried out on the treatment of the hyperfiltration concentrate, which contains the rejected salts, dyestuffs and dyeing auxiliaries.

Desizing effluent

A semi-technical scale ultrafiltration plant using high temperature membranes has performed well on desizing effluent from a local textile mill. Problems with pre-filtration and fouling of the membranes have been largely overcome.

Large scale mill trials have shown that two types of polymeric sizing agent (polyacrylate and polyvinyl alcohol) can be used successfully for weaving a large range of cotton and cotton-polyester cloths. Recovery of both types of size has been achieved with good membrane fluxes and excellent rejection. Investigations on the reuse of the reclaimed size by the textile mill indicated that the polyvinyl alcohol type was superior to the polyacrylate sizing agent.

In the coming year the techniques developed are to be applied to pilot plant work within the factory, and the industry has been so impressed with the work that several firms have indicated their keenness to have the pilot plant located within their own particular factory.

Wool scouring

Laboratory investigations on the treatment of the highly polluting effluent and the recovery of grease have been completed, and the preliminary factory trials have been accomplished successfully. Ultrafiltration techniques, using conventional membranes and dynamic membraned porous stainless steel tubes have been applied, and results show almost 100 per cent grease and dirt removal after desuinting, with recovery of 90—95 per cent of the wash water. The quality of the product water from the ultrafiltration of the desuinted scouring effluent is suitable for factory re-use. In the coming year this research work will be transferred to the largest wool-scouring factory in the country, where the industry itself will be closely involved in the work.

Removal of metal ions from dilute solutions in an electrolytic precipitator

(Existing project: Contract with the University of the Witwatersrand — Department of Chemical Engineering)

Excessive concentrations of metals in industrial effluents discharged to sewers may adversely affect the performance of sewage purification works. Although technology exists for treating these effluents, it has not found wide application owing to the cost of equipment and chemicals and the absence of sufficient space at most plants.

In this project the efficiency of removing these metals in dilute solutions by electrolytic precipitation using particulate electrodes, is being investigated. This process involves compact equipment and does not require the addition of chemicals.

Preliminary work showed that a cell with a fixed bed cathode of rectangular geometry separated from a plate anode by an anion permeable membrane would be effective and relatively easy to operate in an industrial environment. A survey of the effluent problems in the electroplating industry on the Witwatersrand, indicated that this type of equipment would find wide application if it could successfully treat water containing up to 40 mg/l of heavy metals (mainly copper, nickel, chromium and zinc).

During the year the fundamental physical and chemical processes involved in depositing metals on conducting particles were examined. A mathematical model for the system was derived in terms of the cell geometry, current density and solution flowrate. A computer solution of this model was generated in a form which could be used in the design of full-scale plant for a wide range of applications. To test the model a series of experiments was conducted on a number of laboratory-size cells using copper and nickel wash water from an electroplating plant. The results showed good agreement with theory.

A pilot plant to treat 5 l/min of effluent containing up to 40 mg/l metal has been designed and built, using the information obtained in the laboratory. Tests with this plant at an electroplating company are still in progress but the initial results indicate that scaling-up of the equipment will not pose any major problems.

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

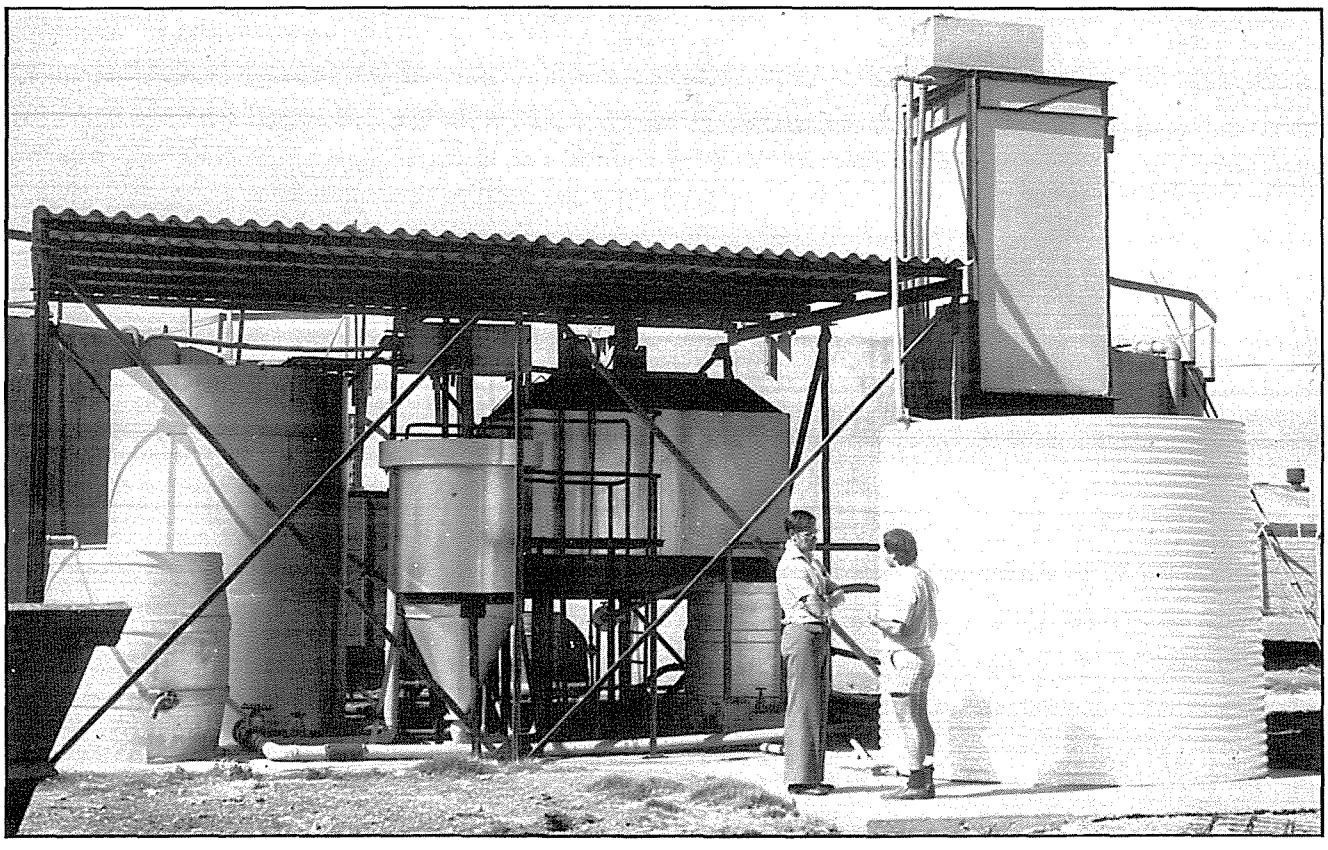
(Existing project: Contract with the CSIR — Leather Industries Research Institute)

This project is a continuation of the research programme arising from a systems study on the present practice regarding water management, the potential for waste water re-use and the possible impact of waste water discharges on the environment.

The research programme has been recommended at regular meetings of the various steering committees and approved by the Coordinating Research and Development Committee for the Meat, Hides and Skins, Leather and Allied Industries. Commencing with pilot plant investigations in Port Elizabeth and King William's Town into the treatment of process waste waters from the fellmongery and tanning industries respectively, additional investigations have commenced during 1978 at tanneries near Pretoria and at Wellington, where conditions vary from those at the first two plants. The impact of liquid waste is recognised as only a part of the environmental problem and, therefore, investigations have been widened to include solid wastes.

Fellmongering

The study on the effect of various loading rates on the activated sludge process of biological oxidation of fellmongery unhairing effluent is nearing completion, and this will enable design criteria to be established for treatment plants to meet a range of standards according to discharge requirements and subsequent treatment costs. The work on fellmongery effluent is being extended to include the remaining effluent liquors of lower oxygen demand, and a comparison with results obtainable from a pilot plant high-rate biofilter which has



A pilot plant for the treatment of effluent derived from a large fellmongery in Port Elizabeth. The column on the right is a high-rate biofilter the results of which are compared with those of the activated sludge process of the pilot plant.

been erected alongside the activated sludge pilot plant. Studies are also being extended to cover the dewatering and disposal of the sludge.

Tanning

Pilot plant tannery beamhouse liquors have proved more difficult to deal with than those from a fellmongery using the activated sludge process. Various possible causes for this are being studied including presence of antiseptics, detergents, higher salinity and type of aerator. A high-rate biofilter has been set up for comparison, to be used either prior or subsequent to the activated sludge system. The study will be extended to include chrome tanning liquors from "wet-blue" plants adjacent to large abattoirs, and also total tannery effluent. A study is nearing completion on the use of unsalted hides as a means for meeting effluent standards required by a large municipality and the degree of aeration and sludge treatment required to meet sulphide and settleable solids standards.

In order to study the elimination of odours from evaporation ponds, a series of pilot plant ponds has been set up.

The problem of sludge dewatering and disposal is also being studied, including a novel method of beamhouse sludge precipitation developed at a Wellington tannery.

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

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

The anaerobic digestion process as applied for the purification of spent wine residues, i.e. the residues remaining after distillation of alcohol from fermented grape juice, has been researched in depth for many years by the National Institute for Water Research (NIWR) of the CSIR. The process is, however, still not being used to any great extent in the major wine producing areas of the Western Cape, primarily because there is a lack of confidence in the process' practical application at full scale. For this reason a joint project was initiated in 1977 with the CSIR (through its NIWR) and the Stellenbosch Municipality to investigate at bench, and at pilot and full scale level, the problems then experienced with full scale anaerobic digester plants.

The experimental results of this two year investigation have overcome many of the doubts which have been aired about the process. Sufficient results have been found to prove that spent wine residues are very amenable to anaerobic digestion and that this biological treatment process based on high volumetric load rates and low hydraulic retention times, results in efficient effluent purification.

Criteria were established for the design of full-scale anaerobic digestion plants, while operational guidelines for optimum performance were devised so as to maximise the biological and physical parameters which affect the process with respect to purification and solids retention in the systems. The results were better than those obtained during the previous years and are now being progressively applied to improve the performance of the present full-scale system.

The limiting factor for increased loadings on the full-scale plant is the inferior settleability of the mixed liquor suspended solids (MLSS). Studies indicated that it is possible to correlate variances in the settling properties of the sludge by means of solids flux curves and microscopic evaluation. Lower sludge concentrations allow for better settling and the factor to be resolved is the selection of maximum solids concentrations which will not prejudice economic biological digestion while still achieving effective solids separation.

This contract expired at the end of 1978. The major findings of the study will be included in a design manual which should be of considerable value to design engineers active in this field. A new tripartite contract agreement is currently being negotiated between the Water Research Commission, the Stellenbosch Municipality and the CSIR. The main incentive for this agreement is to get the research findings obtained in the laboratory and on the pilot plant, implemented at a full-scale works, thereby ensuring that the necessary technology transfer from the research organization to practice takes place.

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 project comprises a detailed study of pollution control and reclamation of effluents in the PWVS complex with particular emphasis on the southern catchments, and it has been successful in attaining the pre-

liminary objectives set for it by the Commission. For the most part, research for the project has been conducted by the Hydrological Research Unit of the University of the Witwatersrand under the direction of a firm of consulting engineers who has been appointed as Project Manager to coordinate the various phases of the research.

A comprehensive mathematical model of the daily variations of mineral salts in the system has been developed and fully tested. The model is capable of predicting for various time horizons, the time series of salinity (TDS) at any point in the southern system including any point within the Barrage storage basin itself. It is also capable of simulating and determining, again for any time horizon, the effect of further industrial developments or of any control or reclamation options that might be proposed.

The model comprises four major components:

- The Vaal System Model. This simulates for any time horizon the behaviour of all storage reservoirs in the system and provides output in the form of a time series of storage states at all the dams (e.g. Sterkfontein, Grootdraai, Vaal and Bloemhof Dams and the Barrage). Use may be made of this model to determine a complete view of the water resources of the Vaal River.

- The Barrage Tributaries Model. This simulates the movements of effluents from various sources (both point and diffuse sources) and of the natural hydrology in each of the tributaries that drain down to the Barrage.

- The Barrage Model. This model can generate the time series of daily salinities in any or all of the 57 cells into which the Barrage has been divided.

- The Usage Model. This simulates the delivery-usage-effluent cycle of the water abstracted from the Barrage and being delivered after conventional water treatment.

The above four models are linked together and are dependant on input only in the form of data on rain, evaporation, various point sources and water demands throughout the system.

Although the model was basically developed for the PWVS complex, it may with relative ease be utilised to analyse similar problems in other catchments, as has already been done in the case of the Fish River. Thus it can be seen that good progress has been made with the project and in the forthcoming year further refining and calibrating of the model will take place. The simulation of various control and reclamation options will also be undertaken.

A study into the cost to industry of high TDS waters will also be initiated during 1979 with a view of establishing a definite level of TDS to be aimed at.

Chapter 6

Irrigation

South Africa currently has 330 government and other irrigation schemes and it is estimated that approximately 30 per cent of the country's food and clothing requirements are cultivated under irrigation at these schemes and at smaller private irrigation systems. It is therefore understandable that the economic value of agricultural production under irrigation is of the utmost importance, especially when the erratic rainfall and rainfall distribution pattern and the regular occurrence of droughts in South Africa are taken into consideration. The maintenance of favourable farming conditions in the irrigation areas is of utmost importance when viewed against this background. Furthermore it is self-evident that such conditions will make a significant contribution to a positive water balance in South Africa.

It would seem that in certain irrigation areas there is a gradual decline in the two most important production factors, namely soil and water and specifically in the form of soil mineralization and deterioration of water quality. This phenomenon, together with possible water shortages, may have the effect that desirable production levels will not be maintained in the future. Even though poor irrigation techniques are often responsible for this state of affairs, it must be borne in mind that it could sometimes be ascribed to natural factors beyond the control of the farmer.

Against this background it is clear that there is a need for extension and research programmes aimed at these problem areas. In this regard the Department of Agricultural Technical Services has during the past few years launched an intensified extension programme in an effort to raise the efficiency of irrigation and thus to limit the problems ensuing from poor irrigation practices. Extension programmes of this nature are based on research results of the Department's national research institutes and it is envisaged that research projects which are undertaken or have already been undertaken with the financial support of the Commission will contribute materially in this regard. In 1978 the first irrigation research project in which the Commission was involved, *viz* 'Investigation of soil compaction at the Vaalharts Irrigation Scheme', was successfully completed and the final report on this investigation will be made available to interested parties during 1979.

The actual water requirement of crops is one of the aspects of irrigation that is stressed in extension programmes. It is also well known that this information is related to location, climate and the soil, with the result that research directed at the water requirements of crops must be done in several regions taking the abovementioned factors into account. As indicated later in this chapter, the Commission supports three projects, amongst others, which concentrate on the water requirements of wheat. One of these projects deals with the influence of internal plant moisture stress on the growth and production of wheat, while the others concentrate on the interaction between atmospheric and plant control mechanisms, and water yield functions of wheat. These projects are therefore complimentary to one another with respect to the different climates, soils and approaches in order to present a global picture for crop involved.

This approach highlights a facet of the Commission's coordinating function, namely, that in the choice of research projects, interaction between projects is promoted whereby each individual project makes a contribution to the solution of the wider problem. This results in research that is purposeful and ensures the optimal utilization of available research manpower and funds. The aim of reliable water consumption data is to place scheduling of irrigation on a scientific basis.

During the year under review a further contract with the University of the OFS was negotiated in terms of which the University's Department of Agro-meteorology will develop a scheduling service which will enable

irrigation farmers to irrigate judiciously with respect to the development stage of crops and rainfall possibilities. The service will initially be limited to the irrigation areas of the OFS but will be expanded to other irrigation areas and other crops in time. For a service of this nature, it is essential that the information obtained from the above-mentioned projects be available. There is therefore a clear interaction between the projects and by which it is assured that the results may be directly and fruitfully applied in irrigation.

Coordination of irrigation research

In the 1977 Annual Report it was stated that the Department of Agricultural Technical Services and the Commission, in collaboration with the Department of Water Affairs, had agreed to establish a Coordinating Committee for Irrigation Research (CCIR).

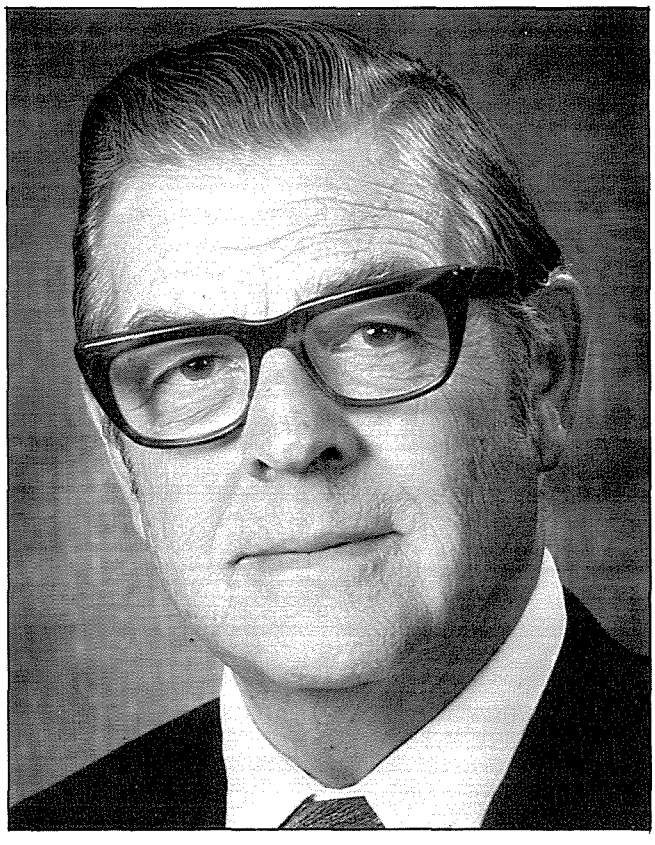
This became a reality during the year and at the inaugural meeting it was agreed *inter alia* that the two member organizations having the greatest interest in irrigation research, *viz* the Departments of Agricultural Technical Services and of Water Affairs, will create internal committees which will assist in the planning of research projects and subsequent evaluation of progress reports. In this way, for example, these functions were assigned to the existing Directorate's Committee for Irrigation Research of the Department of Agricultural Technical Services, and the Water Research Commission, in 1978, utilized this coordinating mechanism. It is envisaged that this *modus operandi* will contribute greatly to the effective coordination of irrigation research.

The first tasks of the CCIR will be the compilation of a register of all current irrigation research in South Africa and the development of a master and priority research plan for irrigation. A description of task areas for irrigation research and which will form the basis of the master research plan is at present under consideration. It is expected that optimal utilization of the available manpower and funds will be ensured in this way and particularly by the adoption of the priority research plan.

Overseas consultant

As early as 1976 the Commission voted funds for the purpose of obtaining the services of an overseas research scientist which would assist the Agricultural Engineering Division of the Department of Agricultural Technical Services in the development of a research programme for instrumentation and automation on irrigation farms. Apart from labour savings associated with automation, it usually has the additional advantage that, by eliminating the human element to a large extent, the efficiency of flood irrigation is increased if the remainder of the irrigation system meets the requirements in respect of irrigation stream size and bed geometry.

The Commission managed to obtain, for a period of three months, the services of Dr Howard Haise, an authority in the field of automation of flood irrigation and previously associated with the Western Branch, Research Division, Soil Conservation Service of the United States Department of Agriculture. On arrival in South Africa in September 1978 he visited several irrigation schemes in order to become acquainted with the current state of affairs. As a result of these visits he built certain equipment in conjunction with the Agricultural Engineering Division and which was tested with a view to its use locally. On completion of his period of service in South Africa Dr Haise compiled a report in which the potential for automation of flood irrigation in South Africa is discussed and in which recommendations are made with respect to other research projects which should be launched.



Dr Howard Haise, previously of the Soil Conservation Service of the USA's Department of Agriculture visited South Africa as a specialist consultant to advise the Commission on the automation of flood irrigation.

RESEARCH PROJECTS

Investigations of soil compaction under irrigation at the Vaalharts Irrigation Scheme

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

Research on the effect of soil compaction on the soil-plant-system, the causes of and the solution to the soil compaction problem and the use of synthetic soil improvers to limit soil compaction has been completed to the extent that final reports are now being compiled. Results obtained with this project, which lasted four years, together with the experience gained during this time, will allow a number of significant conclusions and recommendations to be made.

Laboratory studies, field tests and observations during the field investigations and pot tests have made it clear that compacted layers in the soil have a significant effect on plant growth. The length of roots per unit volume of soil of all agronomic crops decreases drastically with an increase in the degree of compaction. Furthermore the depth of root development of summer crops in particular is limited by the occurrence of compacted layers to the top soil only. These limitations resulted in a decrease in the degree of utilization of the soil in respect of available plant nutrients, especially potassium, phosphorus and manganese. The effect of these limitations on the effective utilization of available and applied soil moisture has not been determined intentionally since this would complicate current research considerably. Available data, however, makes it possible by means of a follow-up project to determine the efficiency with which the different root systems abstract soil moisture considering the effects of soil compaction. The influence of soil compaction on the hydraulic properties of fine sandy apedal soils, namely moisture retention, saturated and unsaturated hydraulic conductivity capacity, has been incorporated in multivariable regression equations. These equations, together with the multivariable regression equations which indicate the relationship between penetrometer resistance, degree and compaction, moisture content and texture, make an important practical contribution with respect to future research in these fields and physical-hydrological calibration studies.

The field investigation and field tests also showed that there is no difference in the degree of compaction caused by sprinkler and flood irrigation. The compaction caused by irrigation is considerably less than that caused by implement traffic plus irrigation, especially the compaction effect of the tractor wheel. The main causes of soil compaction and the creation of compacted layers are the high fine sand fraction of problem soils together with the compaction effect of the tractor wheel in the furrow as well as the compaction of loose topsoil as a result of uncontrolled implement traffic during secondary soil cultivation. A system of controlled implement traffic (CIT) has been tested and is recommended to decrease the detrimental effect of soil compaction on crop growth.

The reduction of the detrimental effect of soil compaction by means of the application of CIT only and CIT combined with the planting of row crops on embankments and irrigation in furrows, did not lead to an increase in harvest yield per unit of soil area for all crops. A sizeable difference is expected with respect to water abstraction and therefore harvest yield per unit of water abstracted or applied. However, this aspect still requires further investigation.

The creation of an apedal soil structure in fine sandy soils by means of synthetic soil improvers has also been investigated. It was possible to create a good fine structure by treating the soil with a solution of polyvinyl alcohol but the solution to the soil compaction problem by means of synthetic structuring would seem to be unsuccessful for a variety of reasons on the basis of results at hand.

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

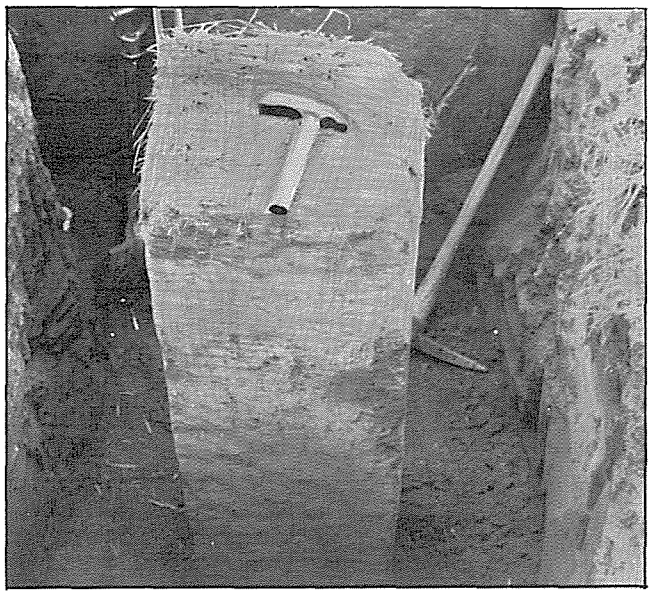
(Existing project: Contract with the University of Fort Hare — Department of Soil Science)

Due to the problems associated with dry land crop production, irrigation is of great importance in the Black States, since a considerable portion of the agricultural products required by these states can be produced under irrigation.

Studies on two main aspects were continued:

- **Determination of the quantity of water which can be stored in a certain soil for a specific crop under specific climatic conditions**

Determination of the profile available water capacity (PAWC) of a deep Jozini soil at Alice was repeated, but with winter wheat instead as test crop. PAWC determinations were only made at advanced growth stages of wheat planted at different dates. The early plan-



These two photographs illustrate the manner in which a soil profile sample is obtained during the project on the utilization of irrigation water in Black States. The project is being undertaken by the University of Fort Hare under contract to the Commission.

ted wheat, which did not suffer from rust infestations, showed remarkably consistent results, with an average of 144 mm. Despite regular spraying, late planted wheat suffered from rust infestations and PAWC values varied considerably. The average was remarkably similar to that for the early planted plots. These averages are also very close to the average obtained with maize the previous summer (148 mm).

It would appear as if the soil factor is the main factor determining PAWC on this deep soil, which allows good root ramification and which has such a high PAWC that it takes several weeks to extract all available water. The soil factor appears to overshadow crop and local climatic factors under such conditions. It will be important to determine the situation on soils with low PAWC's, where the extraction cycles will be short.

A simplified method for the determination of the PAWC was tested and gave very promising results. It could be very useful to collect data in less developed areas by means of this method.

- **Determination of physical and chemical soil parameters in relation to irrigation and drainage**

Comparisons of field and laboratory determinations of hydraulic conductivity curves were made. The purpose is to find a suitable technique with which data can be obtained on a routine basis for use in predicting infiltration with time during a flood irrigation event. Two field methods wre tested on one soil of the Jozini series, viz the drainage method, and the evaporation method. In both cases measurements were made with a neutron probe and with tensiometers.

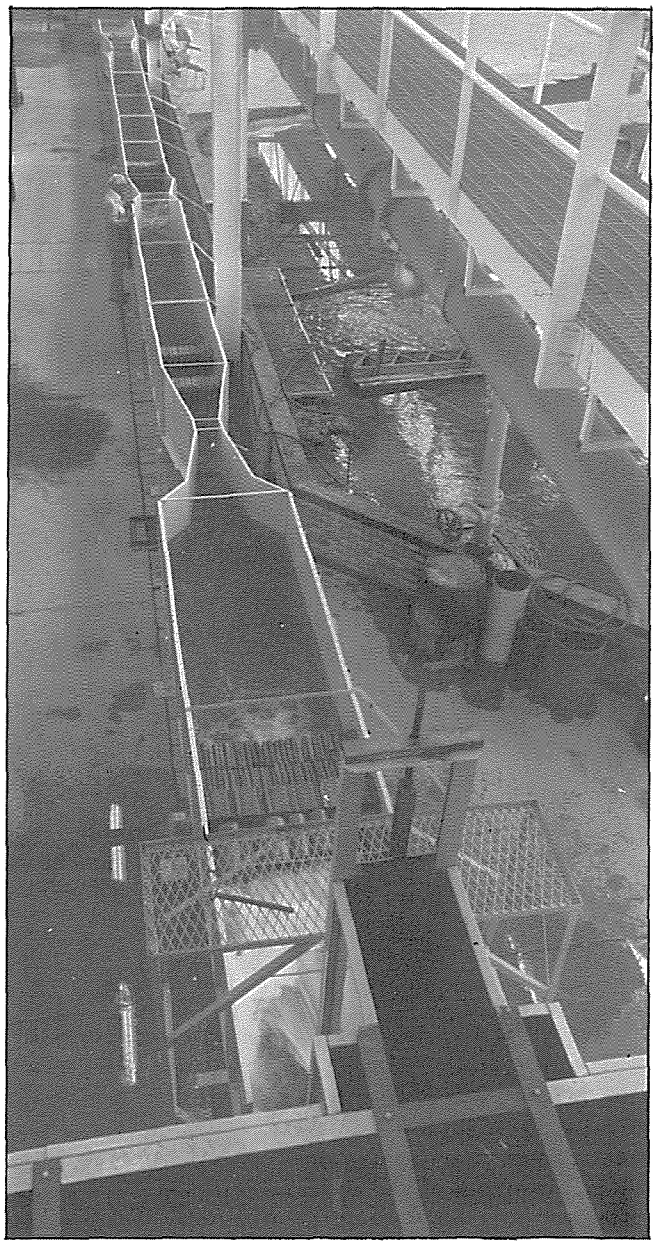
Two laboratory methods were used, *viz* an adapted Millington-Quirk method using desorption curves and a core evaporation technique.

The different methods yielded data which seem to agree reasonably well, except possibly results from the neutron probe. It seems that the Millington-Quirk laboratory method gives good results and a matching factor which may easily be obtained in the field.

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

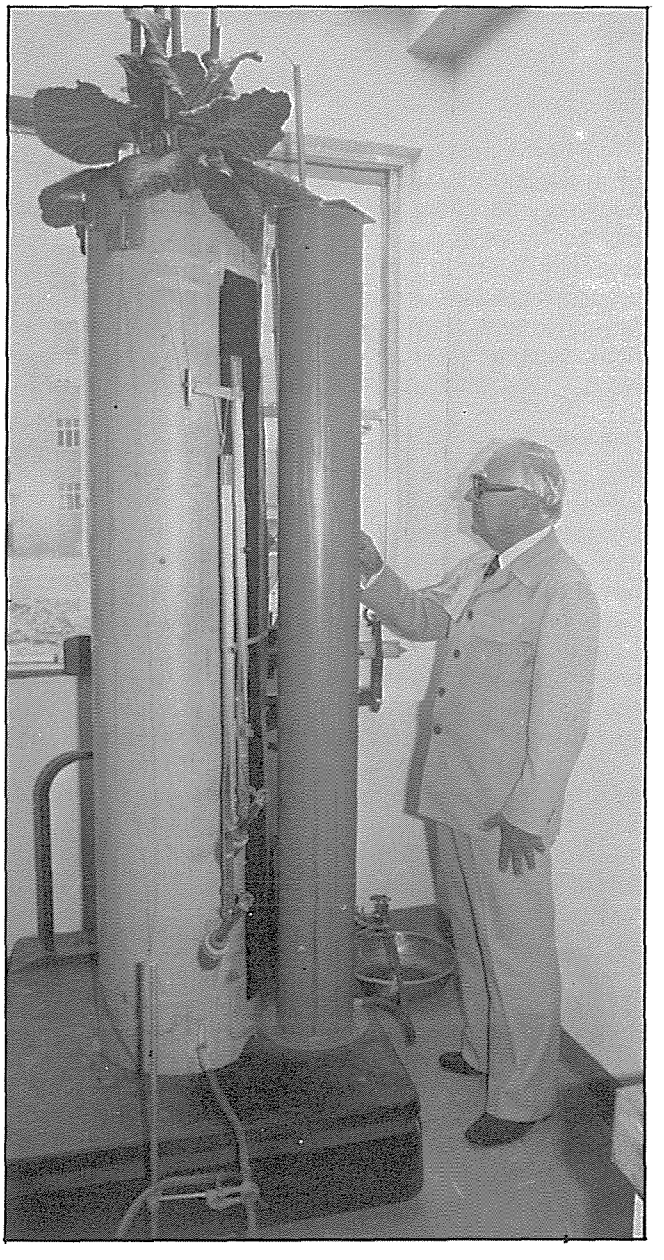
(Existing project: Contract with the University of Stellenbosch — Department of Civil Engineering, Chair of Irrigation Engineering)

Steep lands occur fairly generally along the proposed canals of the Western Cape Water Project and their irrigation has to be evaluated against two other uses of the canal water, *viz* urban water supply and irrigation of lower-lying less steep and more remote lands. In fact, the final aim of this project is to provide coordinated information and design codes for water supply systems and irrigation on steep lands in the



(Left) A variety of flumes in an open conduit at the Hydraulics Laboratory of the Department of Civil Engineering of the University of Stellenbosch. This equipment forms part of a project on the irrigation of steep lands.

The photograph below shows Prof O Wipplinger, Head of the Civil Engineering Department, with a cabbage plant on a soil column which was used in preliminary crop tests and soil moisture observations relating to the project.



Western Cape to the relevant responsible authorities. The project will also develop scheduling systems, easily handled instrumentation for observation and as much automation as possible.

A site has been selected on the experimental farm Welgevallen where the soil quality and topography are typical of much of the steep lands which will become irrigable from the Boland canal systems. The application of irrigation will take place on parts of the plot in accordance with four methods, *viz* sprinkler, microjet, trickle and micro-furrows.

Because good coordination should exist between the water supply systems for irrigation farms and the irrigation systems on the farms, a part of the research for this project will be done in the Hydraulic Laboratory of the Department of Civil Engineering on gauging and control equipment in closed conduits and open canals.

Planning of the model conduits and model equipment has been done and its construction has commenced.

Preliminary tests with crops and instrumentation for soil moisture observations have been done and the four experimental application systems have been planned. The next step will be construction and experimentation.

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)

For the best use of available water supplies as part of a scientifically motivated irrigation programme it is necessary to know when agronomic crops will react best to the application of water. During the year the collection of data on the reaction of certain agronomic crops to moisture stress conditions prevalent during different growth stages was continued. To this end various irrigation tests with wheat, cotton and maize were done at the Vaalharts Agricultural Research Station.

Wheat was cultivated under fourteen different levels of moisture supply — three irrigation treatments were applied during four growth stages, while two control treatments were applied in such a way that moisture stress was eliminated for the whole of the season without introducing conditions of waterlogging. Grain yields were mainly affected by moisture stress during the flowering stage and grain filling. In contrast to this, early and late moisture stresses had very little effect whilst the highest significant yields were obtained with control treatments. The same tendency is experienced with thousand kernel mass whilst hectolitre mass only benefited by the total absence of moisture stress. The greatest number of grains per ear of wheat was produced where no moisture stress existed and also where moisture stress occurred late during the season. The highest hay yields were obtained where no moisture stress occurred during the whole of the season, whilst moisture stress after the flowering stage showed very little effect on hay yield. The greatest number of stalks per unit area was produced where either no stress occurred during the season or moisture stress occurred during or after the flowering stage. In analysing the leaf index it became clear that the leaf surface of the flag and other leaves were detrimentally affected throughout the season by moisture shortages during the tillering stage.

In order to study the drought sensitivity and water requirements of wheat fully and accurately, a similar successful test will have to be done for at least another season. As far as cotton and mealies are concerned, rain during the summer months repeatedly eliminated planned moisture stress conditions with the result that very few differences between yields under different treatments were observed. However, the summer season was not totally lost to this research since different moisture stress conditions, each with its own set of data in respect of growth and yield, were compiled for both crops. Rain did in fact often thwart moisture stress investigations with the result that considerably fewer different levels of moisture supply occurred than had been planned. Moisture stress conditions which did in fact prevail will only be determined later when the Et/Eo ratio (in other words the Class A pan factor) of both crops and the discrimination curve which distinguishes between stress days and days of no stress in cotton are known.

Considerable data which will be required for the second phase of this project namely to convert each irrigation level for each season for the relevant crop to daily values of internal plant moisture stress and plant water potential have already been collected. Soil moisture observations for determining the Et/Eo ratio of the crops under test conditions have already been done and can be presented after proper calibration of the neutron moisture meter. Pressure bomb readings (Scholander readings) have also been obtained for calibration of moisture stress days which will be done towards the end of phase two. It has already been found that these values are more dependable than psychometer readings.

In the final phase, which will only commence after the second phase, drought sensitivity of the crops will be expressed on a day-to-day basis for the growth season by means of correlation coefficients between moisture stress and yield data.

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 Agricultural Technical Services — Soil and Irrigation Research Institute)

The accurate assessment of the water requirements of the crop is essential for any efficient irrigation venture. Field experiments have over the years provided

the necessary answers for many different crops but under very specific conditions. To extrapolate these answers to the wide range of soil and climatic conditions in South Africa, a better quantitative understanding of the movement of water through the soil-plant-atmosphere system must be sought. The roles of soil water and climate are important in this respect. So also is the behaviour of the crop, e.g. how fast it grows and develops, under what conditions it will enter into a state of moisture stress and how it responds to stress. All these factors must necessarily be taken into account in assessing the adequacy of crop water balance models and adapting them for general use in irrigation planning and management.

During the year under review a serious attempt was made to research all the aspects of importance as identified above. Four weighing lysimeters, recording every ten minutes and resolving a mass equivalent to 0,04 mm of water, provided the absolute measure of evapotranspiration rates. Lysimeter data, together with other necessary environmental data, were digitised and recorded on casette magnetic tape whereafter they were read and processed by a programmable calculator. Several published crop water balance models were adapted for use on the computer.

Wheat was sown during the winter of 1977 before the lysimeters became fully operational in August 1977. Subsequently, a detailed evapotranspiration record was obtained which was compared favourably with predictions of the Ritchie model for row crops. The wheat evapotranspiration record also yielded well-defined values of the total and readily available soil water contents in the lysimeter profile.

Soybeans followed the wheat in December, 1977. A much more intensive research programme than for the wheat had been planned, but many of the intended investigations and all the treatments had to be abandoned because of heavy rain and flood conditions. Many useful data were nevertheless obtained and valuable experience with the application of several techniques gained. Detailed leaf growth and leaf area index curves will serve as useful reference data for zero-stress conditions in future years. Measurements of leaf water potential, diffusion resistance, and carbon dioxide uptake were successfully made and related to hourly evapotranspiration rates and solar radiation on a day around about the time of maximum leaf area index. As with the wheat, the lysimeter records provided values of the total available water in each of the four lysimeters. Values for wheat and soybeans were in good agreement.

Now that techniques have been adequately tested, investigations are being intensified. The planned construction of a moveable rain shelter should help to make summer experimentation less vulnerable to rainfall conditions than in the past.

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

(New project: Contract with the University of the Orange Free State — Department of Agro-meteorology)

The ultimate aim of this project is to develop an information service which will be used to ensure maximum wheat production per unit of irrigation water. Initially this service relates to the irrigation schemes at Vaalharts and Jacobsdal and adjacent areas but will be extended later on to other irrigation areas of South Africa.

The implementation of this service requires a sound knowledge of the groundwater-plant-atmosphere system for wheat, as well as development of a model to mathematically simulate water consumption. This model will then be applied to advise the farming industry on a weekly basis on the daily consumption of water by wheat during the previous week, the immediate groundwater status and the probability of rain occurring and moisture stress during the following five days.

The project is being undertaken primarily at the Agro-meteorological Observatory of the University of the Orange Free State and mainly involves determination of the hydraulic conductivity of wheat.

For the establishment of such a prediction service it is essential to obtain climatological data such as wind velocity, air moisture, solar radiation flux, temperature and rainfall for the areas mentioned; such data can be used as input in the mathematical model.

The hydraulic conductivity is a plant physiological factor which is independent of the soil type but a factor of the leaf water potential and crop evaporation rate. Half a hectare of wheat has been planted on a plot at the Observatory to determine the nature and extent of this parameter and in order to measure the soil and leaf water contents under varying evaporation conditions. These measurements are done on wheat cultivated in soil in containers and which are placed in the soil on the plot. The wheat in the various containers is subjected to soil moisture stress. The surrounding wheat creates the necessary climatological atmosphere for the cultivar in the containers. With the aid of this information and the climatological data from the two areas it will be possible to establish a relationship between hydraulic conductivity, meteorological conditions and soil moisture content.

This relationship will be implemented in the mathematical model in order to determine the leaf water po-

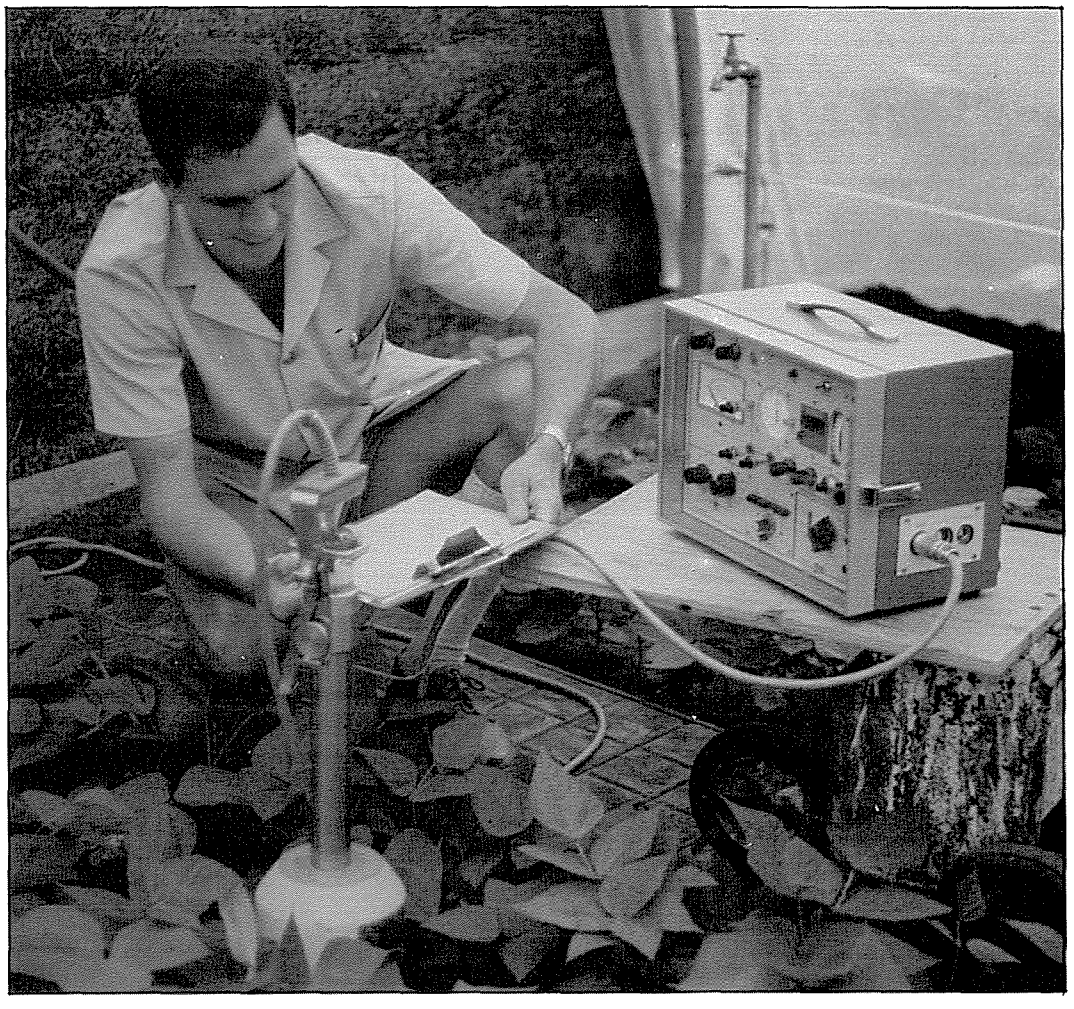
tential and therefore the diffusion resistance of the stomata to the exchange of CO_2 with the atmosphere (photosynthesis). When diffusion resistance starts to increase it will be an indication that irrigation has become necessary.

The mathematical model will determine daily crop evaporation, soil moisture balance and wheat crop growth conditions for the previous week. This information, together with an estimate of the risk of plant moisture stress during the following five days will immediately be made available to the industry. The risk of moisture stress is determined statistically by using rainfall figures for these areas over a period of at least the preceding 30 years.

Water requirements of agronomic and vegetable crops

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

The purpose of this project is to systematically investigate the water requirements of crops with a view to the planning and refining of irrigation programmes. The research results will be used to compile guidelines for modifying irrigation programmes in order to apply a



A neutron moisture meter used by the Plant Production Department of the University of Pretoria for soil moisture determination. This work relates to a project on the water requirements of agronomic and vegetable crops.

given volume of irrigation water in the most effective way. A further important facet of the project is the implementation of research results by the farmer.

The water requirements of wheat in winter and dwarf beans in summer have been investigated and during the year under review several tests were done on field plots, model plots and in a plastic tunnel.

Preliminary results for wheat indicate that crop factors used in the manual on irrigation requirements of crops in South Africa are close to the truth. However, it would seem that the abstraction volumes can safely be put at large quantities which will lead to longer irrigation cycles with considerable advantages. This aspect will enjoy more attention in subsequent tests.

Reasonably serious moisture stresses apparently have to develop before the wheat plant shows visible symptoms. It is therefore essential to determine the extent to which production is hampered by internal plant moisture stresses which are outwardly invisible.

In the case of dwarf beans preliminary results showed that root depth and therefore abstraction quantity have in the past been underestimated. Active soil moisture abstraction occurred up to a depth of 1 m and deeper from sand, loam and clay soils in model plots. Here, too, a larger abstraction quantity will have advantages and facilitate the irrigation programme.

Results further indicated that dwarf beans with respect to yield and soil moisture abstraction, reacted very similarly to the three soil types in model plots.

It is known that leaf temperatures react to internal plant moisture stresses. The possibility of relating leaf temperature to atmospheric evaporation potential and the internal plant moisture potential and to use this as a criterion in determining the water requirements of dwarf beans is being investigated. Test work in this regard was done during the year and is being continued.

Cooperation with farmers in the Groblersdal area has led to their increased interest in the possibilities of the evaporation pan for determining irrigation requirements of crops. The soil moisture studies which were done, however, showed deficiencies in the application efficiency of the sprinkler systems. During further cooperative work an endeavour will be made to eliminate such problems and to put irrigation programming on the relevant units on a scientific basis.

Chapter 7

Surface hydrology

Hydrology is a basic science in the study, development and utilization of a country's water resources and it is essential that hydrological research and the collection of hydrological data should proceed in a continuous and sustained manner in order to meet the problems and challenges of the future.

As a result of the high costs associated with hydrological research, its long term nature and the important role played by water in the national economy of the country, it is a matter which should of necessity rest as a responsibility of government. In accepting this responsibility various government organisations, such as the Departments of Water Affairs, Forestry, and, to a lesser extent, Agricultural Technical Services and the CSIR are involved in different aspects of hydrology.

It has been said that the main constraints in hydrological research in South Africa are the shortage of expertise and to a lesser extent the shortage of funds and that government institutions especially are hampered by this state of affairs. According to its terms of reference the Commission has a responsibility in respect of hydrological research, but it has followed a policy of non-interference, non-appropriation and non-duplication of the functions of the government departments and to this end concentrates on lessening constraints and supplements the functions of government departments.

With this objective in view the Commission has, over the past few years, had considerable success with regard to the mobilization of available expertise outside of government departments. By means of research agreements with the Universities of the Witwatersrand, Natal, Rhodes, Zululand and the Orange Free State the Commission has managed to create highly developed centres of expertise in hydrology with well-trained, motivated and devoted personnel. These centres of expertise and personnel are now capable and available to tackle almost any research problem in hydrology on instruction from and with the financing of the Commission or a government agency.

Such developed centres of expertise also provide, by means of the facilities for post-graduate studies, an extremely important by-product, *viz* the training of hydrologists. It is of great importance that hydrologists should be trained, for example for the Black States, and in this regard the research agreement with the University of Zululand has already stirred considerable interest amongst students.

Since some of the current research agreements with the universities have already terminated during the year under review or will terminate early in the new year, the Commission, in consultation with relevant government departments, has begun negotiations for new agreements with the universities mentioned above in order to maintain and further utilize the centres of expertise advantageously. It may be expected that such units, except in terms of specific research contracts, will undertake projects on their own initiative and will generate new knowledge and information especially through the work of post-graduate students.

As part of a new agreement with Rhodes University some of the techniques for mathematical modelling of rainfall-runoff relationships developed in terms of the current contracts with Rhodes University and Natal University will be applied in determining the hydrology of the catchments of the Wilderness Lakes. This information is required in a study of the ecology of the lakes area which may have an important effect on the future planning and development of the area.

In terms of the new agreement with the University of Natal all rainfall data for the area will be converted to a depth-duration frequency format, which will be of

great value to engineers for determination of flood peaks. In addition certain hydrological data, which is of great agricultural importance, for example the probabilities of a given rainfall and consequent soil moisture conditions on a five-day basis, will receive attention. Relationships between hydrology and soil losses will also be investigated.

In the execution of the Commission's co-ordinating function the Co-ordinating Research Committee for the Hydrological Cycle (CRCHC) consisting of representatives of the Departments of Water Affairs, Forestry, Agricultural Technical Services and Transport, the CSIR and the Commission started operating during the year under review. This Committee has already compiled a master research plan and a priority research programme of which specific aspects will now be further developed in detail by the relevant Co-ordinating Research and Development Committees of the Commission.

RESEARCH PROJECTS

Hydrological research in selected catchments

Since the Republic's water supplies are derived mainly from rivers it is of the utmost importance that rainfall-runoff relationships should be intensively studied. It is of particular importance to be able to determine the water yields as a result of a given rainfall in the various types of catchment of the country.

Since it would be uneconomical and impractical to gauge the runoff of all types of catchments and since it would take too long to collect sufficient statistically meaningful data, designers of schemes have to rely primarily on runoff simulation techniques. This approach is currently being applied successfully worldwide.

For the past five years the Universities of Natal, Rhodes and Zululand have been doing research under contract to the Commission on rainfall-runoff relationships in experimental catchments with varying mean rainfall, soil types, vegetation, topography and soil utilisation. The purpose of this research is to obtain data on which mathematical models for the simulation of flood volumes and peaks can be based and against which different models, existing as well as new ones, may be tested.

This work has progressed considerably; the current contracts are approaching completion and reports containing a considerable amount of new information in connection with rainfall-runoff relationships will soon become available.

Investigations in the Grahamstown area

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

The hydrological research programme initiated in the Ecca Catchment near Grahamstown during 1974, terminated at the end of 1978. The Ecca Catchment was monitored to obtain reliable rainfall, runoff and evaporation data at small time intervals for the purpose of meeting the main aims of the research programme, *viz*:

- To test a variety of conceptual simulation models in semi-arid catchments and to modify the models to make them more applicable to South African conditions.
- To improve the performance of the modified models within various use categories with the objective of obtaining guidelines for the selection of suitable models for various engineering applications.
- To develop a simple model that can produce output at a level of accuracy that is competitive with the complex models but which will provide marked savings in computer cost and user time.
- To investigate the feasibility of transferring model parameter values from the gauged catchments to similar ungauged catchments.

The research which concentrates on methods for further investigations has now been completed and the results obtained will be submitted in the final report. It is envisaged that the report will provide the practicing engineer and hydrologist with a variety of conceptual simulation models in the form of nine computer programs, together with guidelines to the selection of models for various applications. The results of the research have indicated that complex models do not necessarily give better results than simple models for a wide range of applications. Consequently, the judicious choice of model is of particular importance to the model user who does not have unlimited access to a computer and who has to pay commercial rates for computer time.

The research programme has also highlighted the need for accurate rainfall, runoff and evaporation data for the testing and development of simulation models. In semi-arid catchments, models tend to be more sensitive to errors in the rainfall data. As the greater part of South Africa has a semi-arid climate, it is envisaged that the high density data network in the Ecca Catchment will provide an invaluable source of data for future model development as well as other forms of hydrological research.

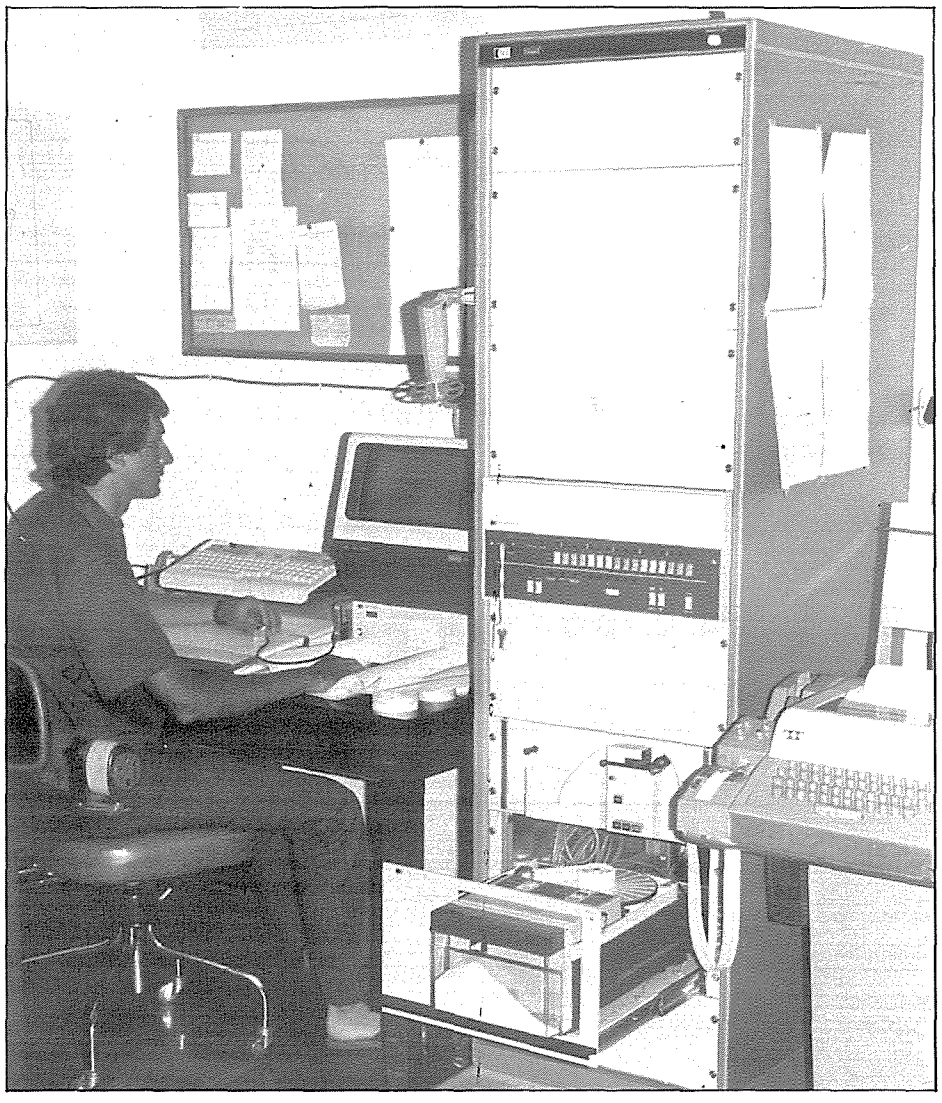
Investigations in the Natal midlands

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

The aim of this research programme is to acquire, digitize and use rainfall and runoff data from small (i.e. less than 50 km^2) rural catchments in order to optimise input parameters used in computer simulation models which estimate and predict flood peaks, flood volumes and water yield. Such information is particularly pertinent to the economic design of culverts, drainage systems, small dams and to the estimation of soil losses. To this end five research catchments, together with a network of autographic rain-stations, were established at Cedara in the Natal Midlands in 1976 and the recording of hydrological parameters was re-instituted at De Hoek, near Estcourt in the same year.

Using data from the above and other small catchments, research is concentrated on improving the SCS hydrograph generating technique. This SCS Model is a physically based user model for estimating flood volumes and peaks in small catchments. It uses as inputs the rainfall in conjunction with a so-called "curve number", which ranges from 0 to 100 and which relates to soil type, land use, the moisture status of the catchment and other catchment characteristics like area and steepness. It is also a model being used more and more in hydrologically oriented soil loss models.

An important variable in soil loss models is the estimation of the kinetic energy of rainfall. These estimations can be obtained by break-point digitizing of rainfall charts. Using data from the catchments and from the Weather Bureau, seasonal and regional variations of ki-



A part of the computer equipment used by the Department of Agricultural Engineering of the University of Natal in a project on rainfall and runoff data in small (up to 50 km^2) rural catchments.

netic energy have been determined for a number of locations in the Republic and more particularly in Natal.

To this day one of the fundamental research problems of hydrologists remains the estimation of catchment mean values of rainfall and plotting rainfall distributions. One of the more promising automated techniques to solve this problem is trend surface analysis, and in this project research has been done in this regard to improve the technique for use in small research catchments as well as on a regional scale.

Finally, in the survey of one, two and seven day extreme rains and other potential flood producing storm events in Natal (using data from over 200 stations each with 20 or more years of daily rainfall records), the seasonal patterns of such rains and association of extreme 2:1 day, 7:1 day and 7:2 day rains have been established. This survey should prove valuable to hydrological design in larger catchments.

Investigation in the Natal coastal area

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

With the completion of the hydrological network of the Zululand catchments in 1977, the early research in 1978 concentrated on testing the adequacy of the raingauge network, determining the nature of the distribution of rainfall over the study area and relating this to variables such as altitude and distance from the sea. The results from these investigations are presently being applied in a Trend Surface Analysis model for the estimation of total rainfall input into the catchments.

The production of a Hydrological Response Unit map is complete. This map is based on land use, soil type and slope and aims at reflecting units of land area that respond similarly throughout when subjected to a given precipitation event. As part of this approach, soil moisture monitoring and infiltration studies are being conducted. These maps and results are providing the basic catchment data for testing the Shanholtz model on the Zululand catchments.

A wide range of measures exists to numerically express the geometry and physiography of a catchment area. An investigation into some twenty-five possible measures has been made and are incorporated in the general investigation of the relationship of geomorphology to the rainfall-runoff process. More specifically, this work has been extended to determine what effect these variables have on the storage component of this process.

The existence of the Hydrological Unit at the University of Zululand has provided a framework in which students have been able to develop an interest in hydrology and gain a grounding and experience in this field. This is vitally important to South Africa and KwaZulu when one considers that every major river in Natal passes through KwaZulu (or flows along its borders) on its way to the sea.

Research on Water Resources

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

Many facets of water research require a background of stream flow history or of stream behaviour prediction or of interplay of complex water supply and demand systems, against which to interpret results. Simulation of the behaviour of a system in relation to any change that may be envisaged is a highly desirable means of evaluating the effects of that change.

During the year under review basic inputs were provided to hydrological and hydraulic models that have been developed for a wide variety of studies and research projects, by means of which hydrographs of monthly (and sometimes daily and even hourly) streamflow were generated for places where no streamgaugings exist.

Because of the complex effects of water abstractions and changing upstream land use, it is sometimes difficult to reconcile modelled river flows with observed flows, and it can take many months of patient research to establish satisfactory model calibrations before acceptable hydrology can be generated. Work has been proceeding throughout the whole of the Vaal catchment upstream of Bloemhof Dam, in South West Africa, in the Mfolozi and St. Lucia catchments and in the Hartbeespoort drainage area.

Modifications of the catchment models have been successfully effected to account for upstream vlei-type storages.

Publications by members of the Unit, particularly on the work at St. Lucia and on the influence of streamflow of changing upstream land use, have attracted widespread overseas interest.

Development of the concept of the runhydrograph in the analysis of flood hydrographs

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

The runhydrograph is a concept based on the mathematical and statistical processing of existing hydrographs. These hydrographs may make it possible to identify important parameters in the runhydrograph for gauged catchments and to develop synthetic runhydrographs for ungauged catchments. The results could be useful to civil engineers and those concerned with floods.

During the year the runhydrograph concept was successfully developed on the basis of continuous instantaneous records on most of the major gauged streams in the Republic of South Africa.

It was found that for the majority of streams the frequency of occurrence of both the flood peaks and flood volumes can be described by the 2-parameter lognormal probability distribution. Furthermore, a strong correlation existed between flood peaks and flood volumes for each of the catchments. The correlation coefficient was also nearly constant for all catchments so that an assumption for the correlation coefficient equal to 0,80 seems to be in order. This assumption simplifies the practical application of the theory and allows extension of the theory to ungauged catchments. Should errors arise due to this assumption, they would be mostly on the conservative side which will result in a slight overprediction of floods. A single bivariate lognormal probability distribution function on standardized flood peaks and flood volumes, therefore, describes the flood behaviour of all the rivers in the Republic.

In practical applications, it is now possible to extract the families of flood hydrographs for each desired return period. This can be done without the help of the computer by simple reference to a few equations and graphs.

Excellent cooperation from the Department of Water Affairs was again enjoyed during the year, without their help the large volume of data could not have been processed and checked against errors.

Chapter 8

Flood occurrences and flood damage

As a result of the variability of rainfall and the physical characteristics of the catchments and rivers in South Africa, the flow regimes of some of the most important rivers are very unstable and can vary between extremes of low flow to flood conditions. Consequently disastrous floods are not uncommon in certain river stretches and, in fact, the Department of Water Affairs has data at its disposal which seem to indicate that in various parts of the country disastrous floods can occur approximately once in every two years.

As a result of the ever increasing utilization of land for agricultural, industrial and domestic purposes in the flood plains of rivers, it is to be expected that financial losses as a result of floods may show a considerable increase in the future, while the disruption of communication and transport facilities as well as essential services may have serious consequences. Consequently it has become essential for the authorities to consider the true extent of flood damage, the justification of flood control measures and the planning of the utilization of flood plains.

Following a request by the Department of Water Affairs, the Commission entered into agreements in 1975 with the Institute for Social and Economic Research (ISER) and the Bureau for Economic Research (BER) of the Universities of the OFS and Stellenbosch respectively, according to which investigations would be made into the damage as a result of the 1974 floods in certain stretches of the Orange, Vaal, Riet, Seekoei, Hartbees, Sondags, Fish and Sak Rivers. The objectives of the investigations are as follows:

- Development of a survey technique and methodology which can be used to determine or to predict damage already effected and possible future damage.
- Identification of different categories of flood damage.
- Determination of the relationship between the extent and duration of a flood and the resulting damage.
- Investigation of the extent to which expenditure for flood control measures is justified by the advantages of the measures.

During 1977 the agreement with the ISER was extended to include an investigation of the flood damage as a result of the flood of 1975 in the Vaal River, where the nature of the damage has differed considerably from that in other rivers.

The total investigation into flood damage has now reached an advanced stage and four parts of the final report entitled "Vloedskade in sekere riviertrajekte van die Republiek van Suid-Afrika" (English: Flood damage in certain river stretches of the Republic of South Africa) is currently available under the following subtitles:

Part I — A methodology for determining flood damage — compiled jointly by the BER and ISER.

Part II — Findings with regard to flood damage in three river valleys in the North Western and Eastern Cape Province — compiled by the BER.

Part III — Findings with regard to the 1974 flood damage for different river stretches of the Orange, Vaal, Riet, Seekoei and Hartbees Rivers — two volumes compiled by ISER.

Part IV An evaluation of the problems surrounding the determination of flood damage in the Republic of South Africa — compiled jointly by the BER and the ISER.

Part I contains the methodology for the determination of flood damage, and its application by the BER and the ISER in the various allotted river stretches is described in Part II and III. On completion of Part II the BER concluded its research in 1977, but during 1978 was responsible for the compilation of Part IV in conjunction with the ISER.

Part IV contains an evaluation of the problems surrounding the determination of flood damage as encountered during the course of the research effort. It also contains valuable information concerning the fundamental logic in connection with flood damage, the extent of flood damage as a phenomenon of regional and national importance, guidelines in respect of flood damage prevention and flood control, determination of flood damage relationships and guidelines for future determination of flood damage and important recommendations in this regard. These reports are now being brought to the attention of interested government departments such as Water Affairs, Agricultural Technical Services, Agricultural Credit and Land Tenure, and Planning and the Environment.

This chapter also contains a report on a research project on flood occurrences which is being done in terms of an agreement with the University of the Witwatersrand. The Commission also has a contract with the University of Natal for the development of the concept of the runhydrograph, and both these projects are related to the flood damage investigations in so far as techniques for the determination of the hydrological aspects of floods are made available.

RESEARCH PROJECTS

Research on flood damage

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

During the year the ISER completed Part III of the report which has been mentioned in the introduction of this chapter, and entitled "Bevindings rakende die 1974-vloedskade vir verskillende riviertrajekte van die Oranje-, Vaal, Riet-, Seekoei- en Hartbeesrivier" (English "Findings with regard to the 1974 flood damage for different river stretches of the Orange, Vaal, Riet, Seekoei and Hartbees Rivers").

In order to present the picture as broadly as possible the damage has been treated under three broad headings *viz* damage to farming, urban damage and damage suffered by authorities and other institutions. The latter have been approached on a broader basis in order to cover, as fully as possible, the total involvement of the central government in particular during periods of flood.

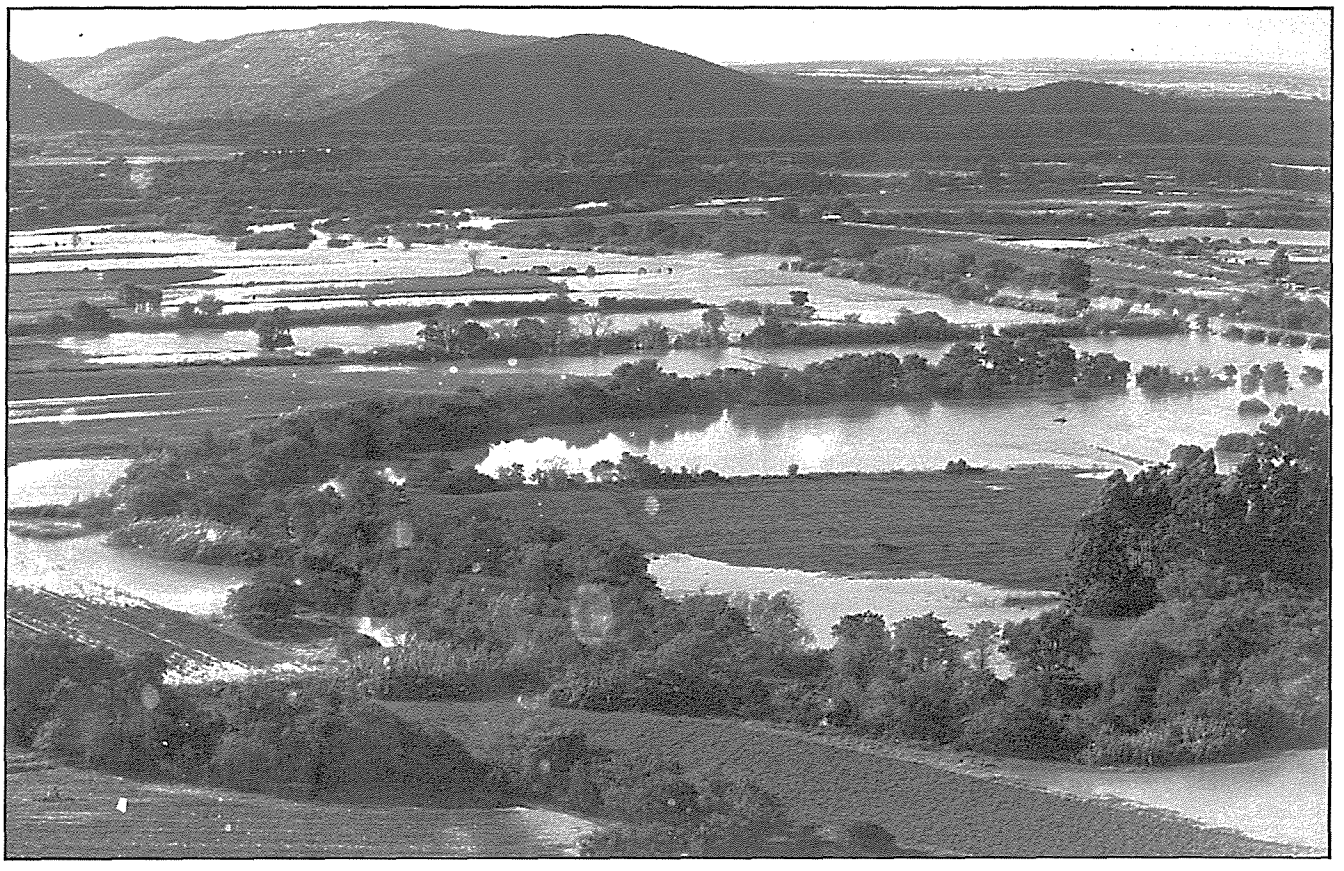
In order to make the presentation and interpretation of the data as meaningful as possible damage is categorised differently for the three headings. In the case of farming it has been presented according to the type of damage, e.g. damage to soil, crops, yields, fixed improvements, etc. For towns it has been indicated according to functional use (residential, commercial, public services, etc) and in respect of government and other institutions according to the institution.

Total damage for all the stretches amounted to R42,4 million, of which 72,2 per cent was damage to farms, 22,1 per cent government and other institutions and 5,7 per cent damage to towns. In the case of farming concerns the greatest flood losses occurred in crops and yields, namely 48,6 per cent, followed by soil losses with 36,5 per cent. In towns the greatest losses have been agricultural in nature, namely 43,4 per cent whilst losses in respect of White dwellings represented 38,2 per cent. In the group of government and other institutions central authorities dominate with 60,1 per cent of the total. The land utilization pattern, is naturally the main deciding factor which determines the composition of damages and considerable differences usually occur between stretches.

Although the total figure for damage is not directly comparable between river stretches, on the one hand, as a result of differences in the probability of flood occurrence, and, on the other, differences in length of river stretches, it should be noted that damage in the stretch between Boegoeberg Dam and Augrabies dominated the picture with 69,5 per cent of the total damage. This is followed by the stretches Riet River (13,6 per cent) and Augrabies to the mouth of the Orange River (9,8 per cent).

A more meaningful figure for comparison (which too does not take probability of flood occurrence into account) is damage per kilometre of river stretch. In this regard the stretch between Boegoeberg Dam to the Augrabies again leads with R101 994 per kilometre, followed by the Riet River with R24 308 and the stretch between the confluence of the Vaal and Riet Rivers and the confluence of the Vaal and Orange Rivers with R12 689.

The evaluation of the problems surrounding the determination of flood damage in the Republic of South Africa (Part IV of the report) concludes the joint research effort by the ISER and the BER. This report deals with the fundamental and practical problems which underlie research of this nature and also attempts to evaluate the usefulness of the results. Briefly, it amounts to an evaluation of the extent to which the original objectives have been achieved.



A typical flood scene after a river has burst its banks and flooded adjacent farmlands. The occurrence of floods and the resulting damage are studied in terms of two projects financed by the Commission.

As mentioned in the introduction, the agreement with the ISER was extended in 1977 in order to investigate the flood damage of the 1975 flood in the Vaal River as well. Part IV of the report is a final report but the guidelines it contains can probably be extended after completion of the research on the 1975 flood in the Vaal River.

Research on Flood Occurrences

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

The objective of this project is, briefly, to provide the facilities for routing the runoff resulting from significant precipitation on a catchment through the river system and through the downstream flood plain, in such a way as to minimize damage.

The Unit's Report No 1/78 "Flood forecasting for reservoir operation by deterministic hydrological modelling", based on a Ph.D. thesis was released during the year. Although developed with specific reference to Vaal Dam, the procedures and computer programs devised can readily be adapted for use with any reservoir system. Provided adequate precipitation data can be promptly fed to the computer, the model can predict the hydrograph approaching the reservoir well in advance. It can also calculate on a continuous basis the necessary pre-releases and subsequent gate operations, such as to minimize downstream damage while ensuring a full reservoir after the flood.

Economic studies confirmed that, for Vaal Dam, benefits in the way of reduced flood damages would far outweigh the cost of installing either a weather radar monitoring or a rainfall telemetering system to reduce the time lapse between precipitation and receipt of reports at the computer. Work is proceeding in the Hartbeespoort catchment on development of procedures for

hooking a weather radar to a gate operation model. Downstream flood damage surveys are also being conducted to provide information for the economic study.

Precipitation and runoff data for South West Africa have been assembled and checked. Work is now proceeding on extending the storm studies of a report on the arid areas of Southern Africa.

The flood plain model developed for the Mfolozi flats has been improved and integrated with the estuary model developed for St. Lucia. The comprehensive model with improved hydrological input is now being used to test the design and to predict the behaviour of the proposed link channel between Mfolozi and St. Lucia. The models will be generalised for application to similar problems in the other estuarine areas.

Chapter 9

Rainfall stimulation

In view of South Africa's reasonably low, variable and poorly distributed rainfall and of indications that a water shortage will exist by the turn of the century, it is essential that all possible routes should be investigated for the elimination of these constraints. One of the routes followed by the Commission in order to solve these problems is the financing of research on rainfall stimulation.

Rainfall stimulation is one of the most important facets of the concept of 'weather modification'; others are hail suppression, fog dissipation and hurricane moderation. As a result of the nature of its terms of reference the Commission is involved mainly in rainfall stimulation and to a lesser extent in an investigation into the effect of hail suppression on the normal rainfall pattern of a given area.

In various parts of the world large sums of money have been invested in operational rainfall stimulation without the necessary scientific background for rainfall stimulation in the specific area being available. These actions have often been precipitated by drought conditions but when the cost aspect of rainfall stimulation is taken into account it would seem that this is not the most desirable approach to the problem.

For successful rainfall stimulation, it is essential that the basic requirements of the physical properties of clouds which show seeding potential, as well as the factors leading to cloud formation must be available. Although mathematical modelling and laboratory studies are valuable they cannot be regarded as complete substitutes for experimental observations in the cloud, mainly because of the complex dynamics of real clouds. Apart from the microphysics of clouds, the interaction between clouds and the influence of the environment also have to be investigated. For large-scale operational rainfall stimulation it is also necessary for its environmental, economic and social impact to be known well in advance. In other parts of the world investigations into rainfall stimulation have generated much information but it has also become clear that the transferability of data from one country to another, and more specifically from one area to another, is a subject which requires an extremely careful approach. Consequently the Commission in 1976 decided to support the rainfall stimulation project of the Department of Transport (Weather Bureau) and in 1978 further extended its involvement with research of this nature by entering into an agreement with the Laeveldse Koöperasie in Nelspruit. In the case of the Weather Bureau's project at Bethlehem and in conjunction with the Department of Water Affairs, meticulous attention is being paid to the hydrological effects of rainfall stimulation. It must be borne in mind that although rainfall stimulation will probably lead to an increase in the surface runoff (as a result of higher intensity), this need not necessarily be the case since there is a strong possibility that stimulation can lead to changes in rainfall characteristics, e.g. a lower intensity of precipitation. However, increased rainfall at a lower intensity will be of great value from an agricultural point of view.

South Africa is to experience an increasing water shortage and the successful application of rainfall stimulation may be an important step to overcome this shortage. It is therefore essential that research of this

nature should be done now in order to obtain the necessary information and develop the necessary technology with a view to its future application.

RESEARCH PROJECTS

Research on the artificial stimulation of rainfall at Bethlehem

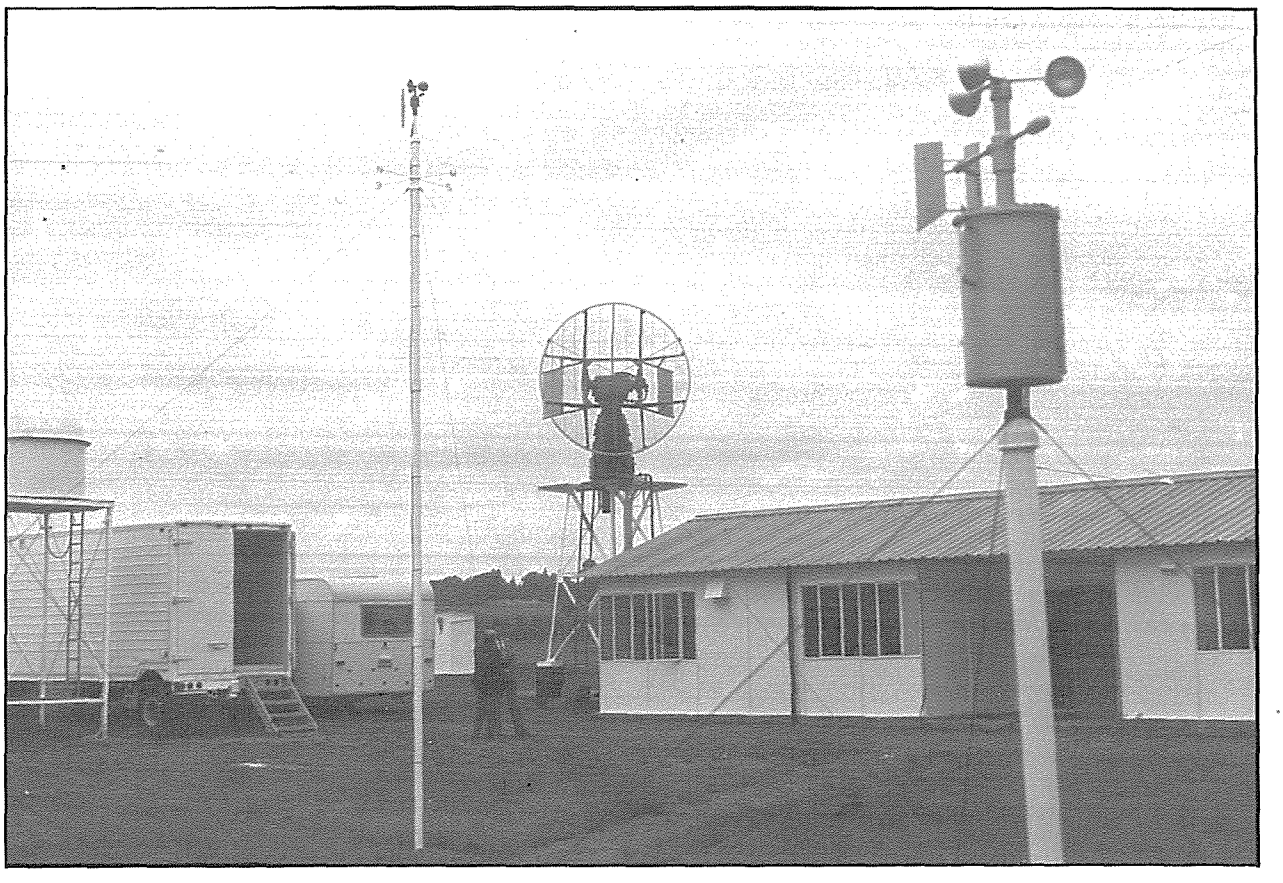
(Existing project: Contract with the Department of Transport — Weather Bureau)

The aim of this project is to determine the possibility of increasing rainfall by means of cloud seeding and, if so, to what extent and at what cost. The project has been established in the vicinity of Bethlehem since this area falls within the Vaal Dam catchment. During the summer months field work is done in this area.

In terms of the agreement the Commission has committed itself to supply specialist personnel to the Weather Bureau for the execution of the project. Equipment used includes three radar sets, four aeroplanes, three minicomputers, as well as a large variety of additional equipment such as automatic weather station equipment and radio transmitting and receiving equipment.

The existing network of rain gauges of the Weather Bureau has been supplemented to such an extent that there are currently more than 220 reliable observation points within the project area and within a radius of 100 km of Bethlehem and which hopefully will be extended even further.

Historic rainfall data for the previous 15 years have been analysed and stratified. This has enabled a distinction to be made between "good" years and "bad" years of rainfall on the basis of the quantity of precipitation which reaches the earth in the form of general rain, while the quantity of precipitation and, interestingly enough, the frequency with which it occurs in the form of showers (scattered or isolated), remain approximately constant, irrespective of whether it is a "good" or a



The Weather Bureau's station at Bethlehem where research on the stimulation of rainfall is undertaken in terms of a contract with the Commission.

"bad" year. Should it be found, as in some other countries, that shower conditions are more susceptible to artificial stimulation of precipitation, then it is considered that valuable information has already been obtained. The reason for this is that there would then be an indication that the opportunities for increasing precipitation remain approximately constant from year to year.

Another facet in the research process is the occurrence of supercooled liquid water. In the highveld area the process which dominates the formation of precipitation by far is the so-called Beigeron-Findeisen-process which is based on the differential vapour pressure over water and ice surfaces at the same temperature. If artificial ice crystals can be produced in the vicinity of supercooled water drops, the ice crystals will grow extremely quickly to precipitation size at the expense of the drops of water. A prerequisite for a successful cloud seeding project is the occurrence of supercooled drops of water.

In a relatively large number of cases measurements showed that in the Bethlehem area extremely high concentrations of liquid water occur at heights where the temperature is approximately $-10°C$. Prof A Gagin of the Hebrew University in Jerusalem who is acting as a consultant to the Commission and who visited the project, has been very pleased with this preliminary result and is on record as saying that the concentrations observed in the Bethlehem area are of the highest ever encountered by him.

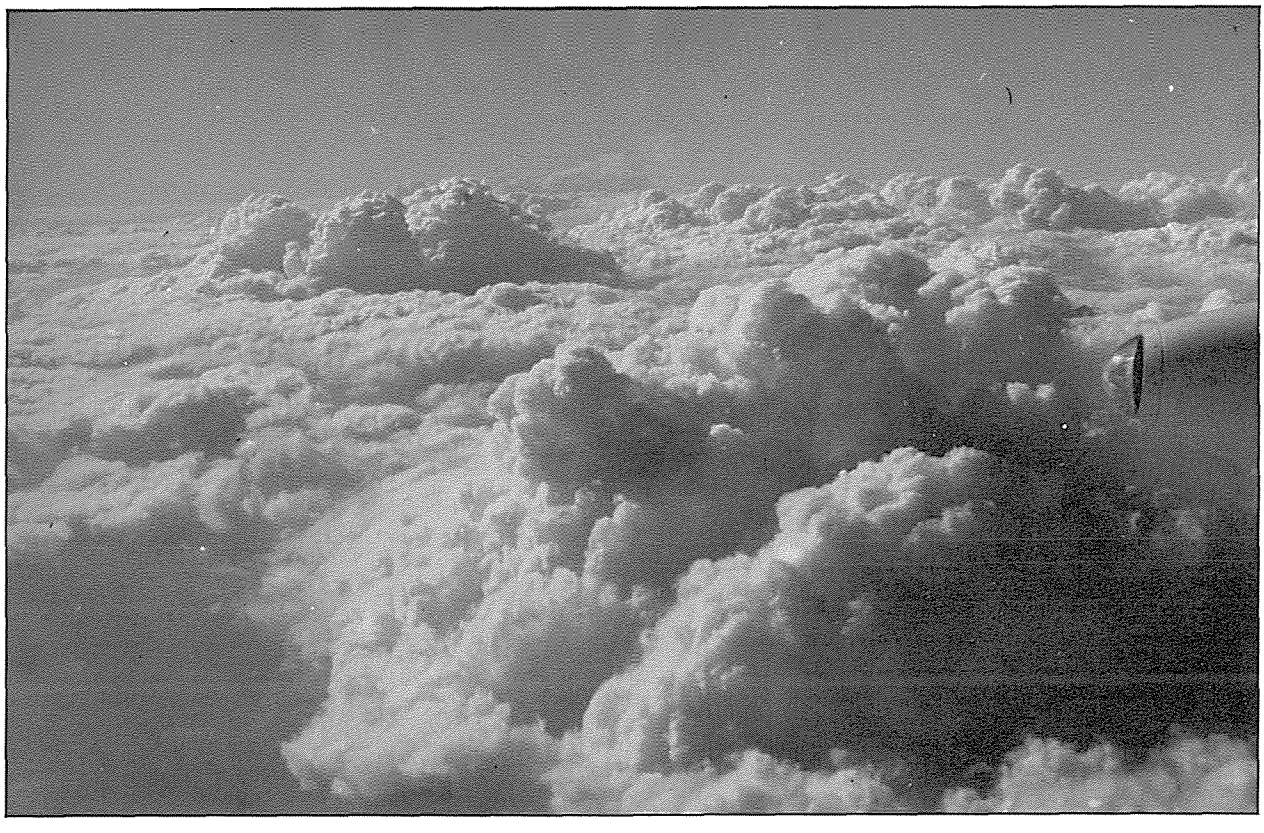
A large quantity of collected data has still to be analysed and at this stage it is too early to predict whether a successful increase in precipitation can be achieved. On the whole, however, progress has been good.

Research on the stimulation of rainfall at Nelspruit

(New project: Contract with the Laeveldse Koöperasie Beperk)

In June 1978 the Commission entered into an agreement with the Laeveldse Koöperasie, in terms of which the latter would conduct a three year research programme, aimed at determining the effects on the regional rainfall of their existing cloud seeding programme for hail suppression.

The weather modification activities centred at Nel-



The Laeveldse Koöperasie uses Lear jets in the execution of its programme of hail suppression. The photograph shows the cloud scene from the jet at high altitude above the Lowveld.

spruit in the Eastern Transvaal are primarily designed to reduce the hail damage to the sensitive crops (tobacco, citrus, etc.) in the region. Seeding operations commenced in December 1971, so to date there have been six full years of cloud seeding. Of local concern is the effect of the hail suppression seeding on the rainfall. Preliminary studies have indicated a slight increase in the rainfall since seeding began. If this increase is related to the cloud seeding activities, then it is imperative in a water-stress country such as South Africa, to attempt to gain an understanding of the technology that has led to the augmented rainfall. The primary research responsibility has been subcontracted to Simpson Weather Associates in the United States, where two well known scientists in the field of weather modification, Professors Joanne Simpson and Michael Garstang, are to act as the principal investigators.

The purpose of the study will be to place rain augmentation experiments as well as existing hail suppression operations in the context of three atmospheric scales — large or synoptic, local or mesoscale and cloud or convective scale. An instrumentation system is being installed on one of the project Learjets which will be capable of examining the microphysical structure of the clouds which are the dominant rainfall producers in the region. These same clouds will be carefully scanned and recorded by the project radar, thus building up a cloud climatology of the region which will enable the investigators to assess the potential for future augmentation in the Nelspruit area.

Another objective of the proposed study is to investigate the transferability of rain augmentation technology to and from other areas. Successful techniques used elsewhere in the world cannot be transferred to South Africa unless similar opportunities for application of the imported technology can be identified.

The success of this project will depend heavily on the efficient co-ordination of the current operations with the planned research activities. Much of the critical support such as the aircraft and radar will be provided by the Co-operative.

Chapter 10

Desalination

The important role of desalination in South Africa's future water economy was repeatedly stressed in previous annual reports. The Commission still awards high priority to coordination and financing of research on desalination in order to achieve optimal use and reuse of saline waters and effluents.

The programme originally commenced with the establishment of a Study Group for Desalination Research and the appointment of a specialist consultant who prepared a master plan. This plan was later endorsed by a Coordinated Research and Development Committee which also recommended a priority programme for implementing the research.

During the year the emphasis was directed at ion exchange and reverse osmosis as the two main practical desalination processes available under present conditions, and considerable progress can be reported in these fields. Practical experience in the operation of several pilot plants, has been gained.

Work conducted on the ion exchange process at the University of Cape Town has allowed extensive experience to be gained in the operation of a 5 kl/d pilot plant using treated sewage derived from the Milnerton and Athlone sewage works. The process is showing considerable potential since it is possible to remove both inorganic and organic matter from the treated sewage effluents. The quality of the final product closely resembles that of domestic fresh water supplies and the cost of water production is attractive enough to warrant further investigation.

In view of this, the Commission has decided to extend the project and to negotiate a new agreement with the University of Cape Town and an industrial concern involved in desalination, with the objective of establishing a pilot plant of 100 kl/day capacity to develop design and operation criteria for the full scale application of the process. Laboratory scale investigations by the University such as the comparison of an alternative regeneration system using lime and sulphuric acid (resulting in the formation and recovery of gypsum) with the present system using ammonia and nitric acid (with ammonium nitrate to be recovered) will be continued. In order to study the use of thermally regenerable resins as a process capable of using waste heat as the regenerant rather than chemicals, the Commission sponsored the visit of a scientist of the National Institute for Water Research to Australia and Japan to assess the potential of the system under South African conditions. From the report received from the Institute it appears that the method has much merit but that it requires further developmental work before consideration can be given to its possible practical application. A watching brief will be maintained on the further developments in this field.

As far as the reverse osmosis process is concerned, the direct application of membrane processes to particular situations has reached the stage where a pilot plant for the desalination of seawater was commissioned at Swakopmund, South West Africa, by the Department of Water Affairs in partnership with the Commission, in August 1978. This Department is responsible for the operation of the unit while the National Institute for Water Research of the CSIR, financially supported by the Commission, undertakes the evaluation of the unit. The main objective of this study is to develop design and operating criteria for the full-scale application of the reverse osmosis process in the production of potable water to supplement the existing fresh water supplies for the Swakopmund-Walvis Bay environment. In the studies it was found that the pretreatment of the seawater is extremely important and due to the variability in the quality of the seawater alternative pretreatment processes are being studied.

Studies on the treatment of purified sewage water by reverse osmosis have continued both in the case of purified domestic and purified mineralised industrial waste water. Water of acceptable quality is being produced but problems regarding the fouling of membranes and of clearing fouled membranes are still receiving attention. Sufficient data have, however, been accumulated by which it is possible to prepare a manual

covering the selection of membranes and correct modes of operation for specific waters and effluents. This manual is currently being prepared and will be published in due course to serve as a guide to those interested in the desalination of purified sewage effluents and mineralized industrial waste waters.

Throughout the world the use of the reverse osmosis and ultrafiltration processes for the desalination of sea water, mineralized groundwater, and industrial effluents with subsequent recovery of industrial process chemicals, is giving promising results. In view of this the Commission entered into an agreement with the CSIR through its National Institute for Water Research whereby the Institute undertook to carry out the required research and development work for the production of proto-type membrane modules based on formulations developed locally. The research work is being carried out by the University of Stellenbosch in collaboration with the Institute. Good progress has been made during the year, particularly in the formulation of new types of membranes and in the design and construction of the prototype membrane modules. It is envisaged to produce tailor-made proto-type units for field tests within the ensuing year.

RESEARCH PROJECTS

Treatment of wastewater by ion exchange

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

In the reclamation process of wastewater the salinity increases with each pass the water makes through the 'use' cycle. In order to provide a treatment system for this saline, organic contaminated water presently being discharged from sewage works, the ion exchange research programme was started. The aim of the research has been to develop a process which will simultaneously remove both the organic and inorganic components of a sewage plant discharge and thus provide a complete tertiary treatment.

Following laboratory test work in which the technical feasibility of the process was proved and information provided for preliminary cost estimates and design details, a five column, 5 000 l/d laboratory pilot plant was constructed. The programme of research on the pilot plant was initially aimed at establishing operating and control strategy and equipment reliability prior to the test programme on actual sewage plant waste streams.

During the year a detailed investigation of the feasibility of the process has been conducted on water from the Milnerton and Athlone sewage works. The aim has been to provide a water of potable quality at the minimum cost, and simultaneously to establish design criteria for eventual construction of a full-scale facility.

The test programme has proved the technical feasibility of the ion exchange process on water that has received an adequate biological treatment in a sewage works. The laboratory scale ion exchange plant, during a year of continuous operation, has removed both the organic and inorganic contaminants of the water, including toxic heavy metals and undesirable nutrient chemicals. It has produced a clear, colourless treated water with a chemical composition equivalent to present domestic fresh water supplies.

Simultaneous life tests on the ion exchange resins has shown that prolonged contact with purified sewage water does not cause any loss of resin capacity. Resins have been subjected so far to an equivalent of three years of full-scale plant operation without any deterioration in performance capabilities.

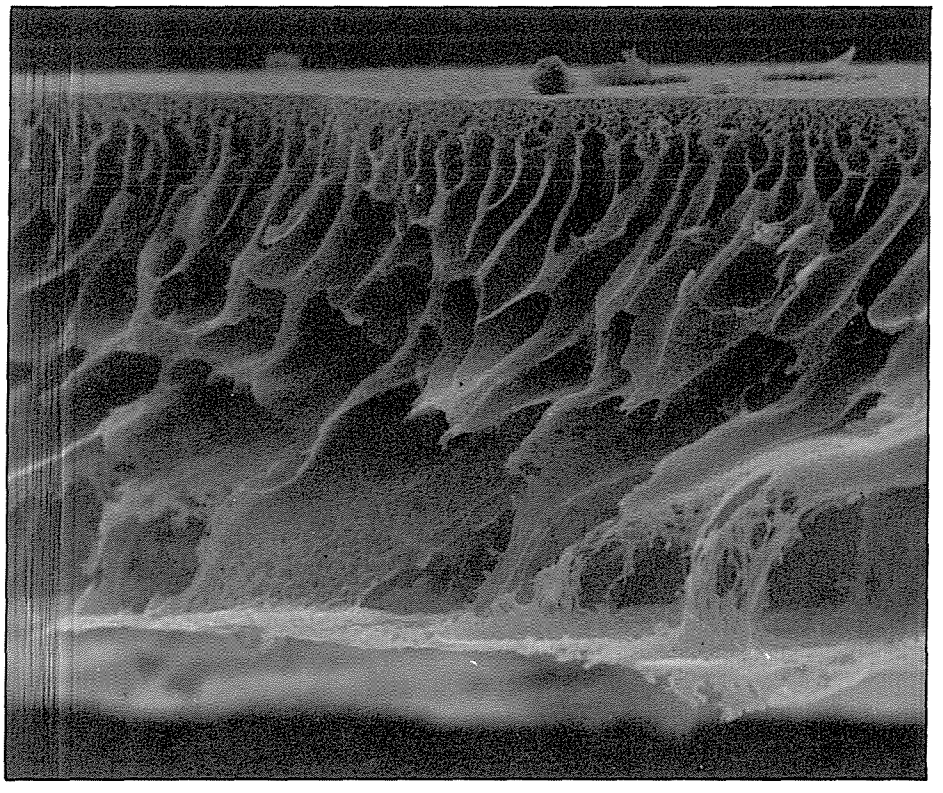
Research during the coming year will aim at testing a new heavy resin which is about to be manufactured by a South African company. This resin, if satisfactory, will result in a further cost reduction of the already low plant operating costs. Simultaneously, tests on alternative plant configurations more suited to operation in others parts of South Africa will be conducted.

Research on the Development of Membrane Support Systems and Modules

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

The reverse osmosis and ultrafiltration test rigs which were designed during 1977 have been brought into service and are being used to evaluate tubular membranes produced by the research team.

The performance of the tube winding machine which forms tubular membrane supports from paper ribbon, has been very satisfactory and cellulose acetate and polysulphone membranes have been cast inside tubes produced by the winding machine. Problems were experienced with the original equipment used to heat seal the seam, but these have been largely over-



Sectional picture (x450) of an ultrafiltration membrane (polysulphone/sulphonated polysulphone) cast by the Institute for Polymer Science of the University of Stellenbosch. The actual thickness of the membrane is only 0,254 mm.

come by the installation of an ultrasonic seam welder. The machine has been modified to facilitate the continuous casting of membranes inside tubes immediately after the latter have been formed.

The tubular cellulose acetate reverse osmosis membranes so far made, have desalting properties similar to those of commercial membranes which have been produced by the batch casting technique. A number of composite membranes with very promising desalting properties have also been produced.

The desalting properties of substandard cellulose acetate membranes have been improved by coating them with a solution of a commercial water soluble polymer. The film which is formed on the membrane is then insolubilized by chemical treatment. This very inexpensive technique can be applied in the field to damaged membranes without stopping the plant. It holds promise of extending the useful life of cellulose acetate membranes with an attendant decrease in the cost of desalination.

Another machine has been designed for the continuous casting of flat sheet membranes on suitable backing materials. This machine is expected to come into operation early in 1979 and the reverse osmosis and ultrafiltration membranes produced in this manner will be wound into a spiral configuration and evaluated on the existing test rigs.

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)

The purpose of the reverse osmosis pilot plant at Swakopmund is to obtain information and experience which will facilitate the design and operation of a full-scale desalination plant, providing a major increment to the water supply system of the Central Namib State

Water Scheme near Swakopmund. Special attention is given to the evaluation of the performance and lifetime of commercial sea water reverse osmosis (RO) membrane systems under practical operating conditions, and to research on and development of a simple and inexpensive pretreatment method.

In order to achieve the required quality standard for reverse osmosis plant feed water various couplings of the different units can be done. In this respect the sea water is pretreated in either a sludge blanket sedimentation and granular media filtration installation or a dissolved air flotation installation, each of 480 kl/d capacity. Either can be coupled to a diatomaceous earth filter for final polishing of the pretreated sea water. This polished water is fed to the desalination equipment now comprising two skid-mounted RO plants, one being a two-pass and the other a single pass system. Both plants operate at 55 to 60 bar, and convert between 30 and 50 per cent of the feed sea water to fresh product water.

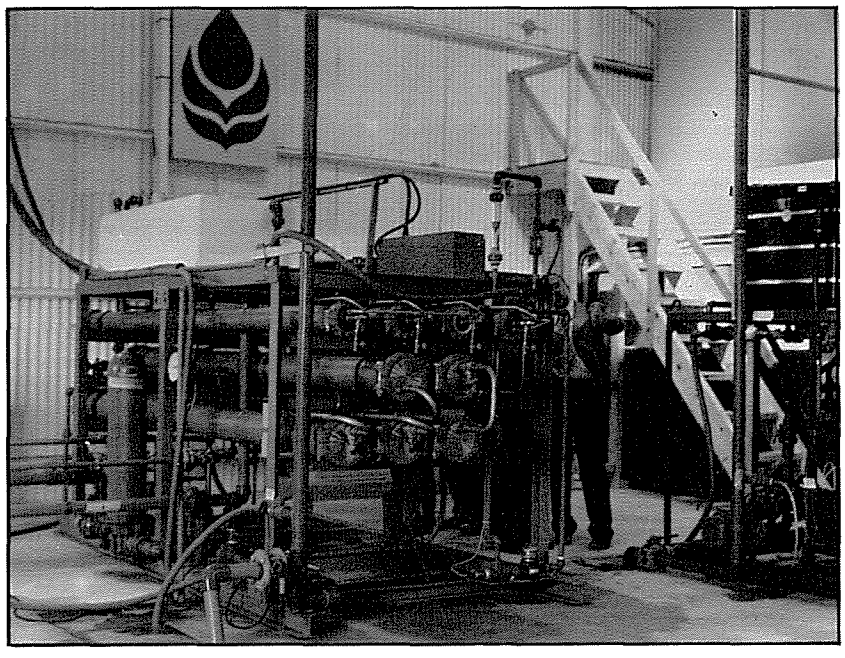
The pretreatment section was commissioned during May and June, 1978 and tested for approximately two months before the desalination section was started up. Chemical treatment for the coagulation of plankton, and other suspended solids, in the water encompasses a dosage of 3 to 5 mg/l of chlorine, 15 to 25 mg/l of alum and 0,1 to 0,25 mg/l of a polymer to promote floc growth. It has been found that the sedimentation installation functions very satisfactorily at a rise rate of 2 m/h producing effluent turbidities typically below 1,0 NTU. Sand filtration without polishing has so far not produced water of satisfactory quality to serve as a feed for the RO process.

The required quality is a "plugging index" of less than 45%, which is determined by measuring the extent to which flow through a 0,45 micron millipore filter is reduced during a standard time interval.

This is a much more stringent specification than is commonly applied to drinking water purification plants. Standard turbidity measurement techniques are normally not sensitive enough to serve as a measure of the colloidal material remaining in water after filtration. Present work on the sand filters is concerned with optimizing the granular media size range and type to improve overall performance.

The dissolved air flotation process has been found to give effluent turbidities typically below 0,5 NTU with a retention time of 20 min for flocculation and 12 min for flotation using a 5 per cent recycle of product water saturated with air at 400 kPa. This installation is expected to give lower turbidities if improvements can be made to the air injection system. Experience has shown that diatomaceous earth filtration of the flotator or of the settler effluent can produce the required RO feed water quality consistently. Optimization of the sand and diatomaceous filter operation is in progress in order to reduce filter runs and consumption of the expensive filtration material.

Further pretreatment after filtration consists of pH adjustment with sulphuric acid, dechlorination using



Reverse osmosis equipment used for the desalination of sea water at Swakopmund.

sodium bisulphite and addition of sodium hexametaphosphate as a precipitation inhibitor.

The reverse osmosis units were operated intermittently from the end of July 1978 while alterations to the pretreatment section were completed. During these runs the total dissolved solids of the final product water averaged 350 mg/l while the combined output of the two units was approximately 70 kl/d.

Research on the desalination of treated sewage

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

Processes for the reclamation of sewage effluents all suffer from one disability, namely that inorganic salts present in the sewage effluents are not removed and tend to build up within the cycle of use, reclamation and re-use. In this way multiple re-use potential is restricted. The National Institute for Water Research, in terms of a contract between the CSIR and the Commission, is evaluating the application of the pressure-driven membrane processes of reverse osmosis and ultrafiltration for the desalination and concurrent improvement of purified and reclaimed sewage effluents.

Results achieved to date with the reverse osmosis process on secondary purified sewage effluent have been very satisfactory and excellent quality product water is obtained. Salts present in the water are reduced to about 10 per cent of their initial level and chemical oxygen demands of less than 5 mg l^{-1} are consistently achieved. In addition, the bacteriological quality, colour and turbidity of the water are significantly improved. Promising preliminary results have been obtained with regard to the life of the membranes used in the process. Methods for the prevention of membrane fouling and for membrane cleaning are receiving serious attention.

Ultrafiltration, although promising initially, has not come up to expectations and work in this area has been suspended pending the development of local membranes with better salt and low molecular mass organic molecule rejection characteristics.

Chapter 11

Transfer of information and technology

Information and technology transfer forms an essential and very important part of the Commission's activities. It includes a wide variety of activities which contribute singly or complementarily to assist in the application of research results, and in last year's annual report full details are given on the methods developed by the Commission in this regard. Some of the relevant activities of the Commission during 1978 are reported below.

Publications

Of all methods applied for the promotion of information and technology transfer the most general one is the dissemination of information by means of publications. Publication usually occurs on three levels, *viz* pure scientific (scientific magazines), popularly scientific (newsletters, bulletins, etc) and practical-scientific (manuals and reports in which results are packaged specially to promote their application). In promoting information and technology transfer by means of publications the Commission utilizes all three of these levels in publishing *Water SA, SA Waterbulletin* and manuals respectively.

Water SA

Water SA is a scientific journal which contains original research articles and review articles on all aspects of water science. The journal appears quarterly and was launched by the Commission in April 1975. Currently there are approximately 1 300 subscribers of whom more than 300 are located overseas. Applications to be placed on the mailing list are received regularly.

Water SA also enjoys world-wide coverage by means of abstracting services. These services publish resumes of articles appearing in *Water SA*. During the year this coverage was extended and 12 abstracting services now include *Water SA* in their coverage.

SA Waterbulletin

The *SA Waterbulletin* is a bilingual newsletter, published by the Commission since 1975. It was launched to promote 'water consciousness' at all levels of the community. The bulletin contains articles, news snippets and items of interest on local as well as overseas aspects of water. Emphasis is placed on information on the activities of various institutions in the field of water in South Africa. The bulletin is published quarterly and the distribution list is steadily growing; currently there are approximately 1 300 subscribers.

Manuals and reports

When a project is concluded and also whilst research is being done, results are evaluated in respect of application possibilities 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.

In the previous annual report reference was made to a technical report on the control of eutrophication. As mentioned in Chapter 1 of this report, a manual entitled 'Manual for Water Renovation and Reclamation' appeared during the year. It is a joint publication of the National Institute for Water Research (NIWR) and the Commission and is based on research of the past decade by the NIWR and in which the Commission has been involved for the past five years by way of contract financing. The publication is aimed mainly at informing the design engineer, research worker and organization about the feasibility of water reclamation and provides detailed information on all relevant unit processes. A second publication, 'A Guide for Planning, Design, and

Operation of Water Reclamation Plants' is in preparation and will be aimed mainly at the policy maker and decision taker.

During the year many of the research results ensuing from projects financed by the Commission were also published in *Water SA* and other scientific journals.

The South African Water Information Centre

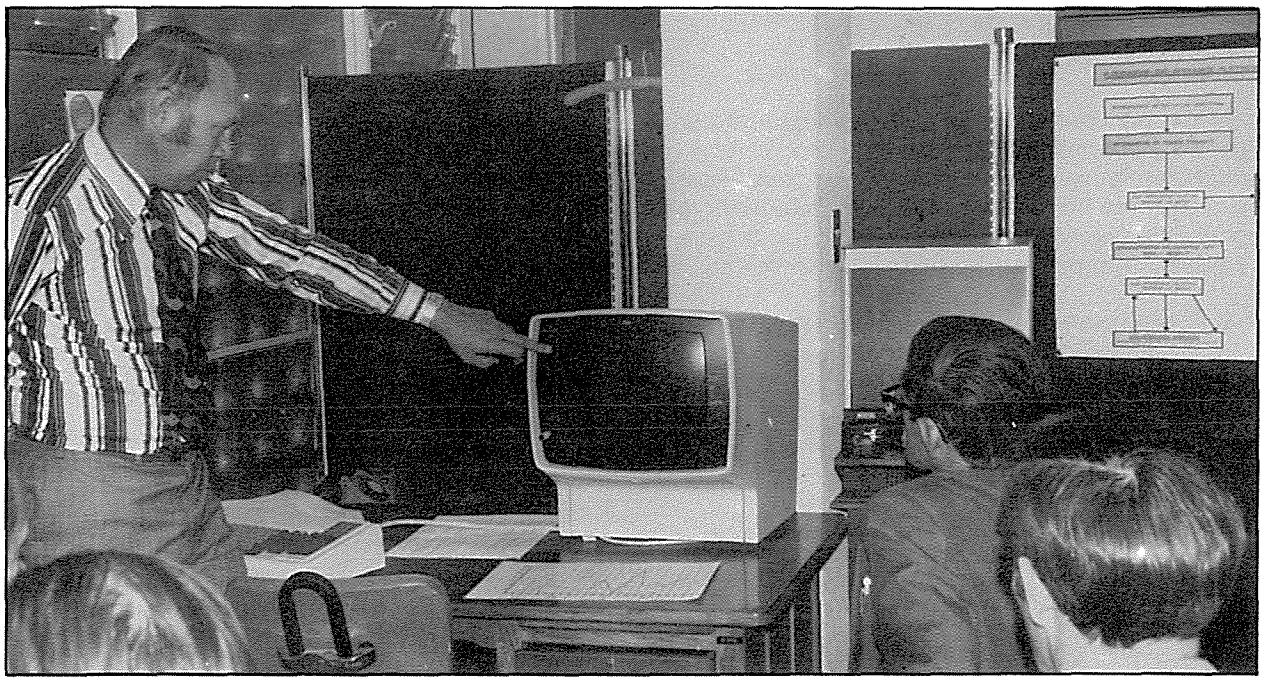
One of the most important activities for promoting the transfer of information and technology by the Commission commenced in 1974 when the South African Water Information Centre was established. This Centre is operated on behalf of the Commission by the CSIR as an independent unit and under contract.

During the previous year the development of the Centre's computerized bibliographic data base, *Waterlit,* was completed and since then additions take place on a continuous basis. The base contains information of articles on water and related sciences which appeared in local and overseas journals and reports and which are available in South Africa. On the data base *Waterlit* the Centre offers a selective dissemination of information (SDI) service and retrospective search services and in addition the Centre publishes various publications as part of its current awareness services.

The year has been characterised in particular by the close liaison between the Centre and the scientists and engineers in the field of water. In the meantime the Centre has been able to contribute positively to water research.

There has been a large increase in the number of users of the different services. This can be ascribed mainly to the fact that the Centre followed an active 'marketing programme' and widely advertised the services. As part of this promotion campaign officials of the Centre, in conjunction with the Commission, visited water scientists and engineers in several centres in the country. During these visits interested groups were addressed after which followed individual consultation with relevant persons with a view to the compilation of personal literature profiles or retrospective searches. During visits to the Eastern and Western Cape, Natal and the Free State, for example, a number of lectures were held and more than 150 persons attached to universities, municipalities and provincial councils were informed about the services the Centre has to offer. A large percentage of these people now make use of these services. Lectures were also held during conferences, symposia and similar occasions and poster presentations were held at four national conferences. More than 200 visitors were received by the Centre and informed on the activities.

During the year more than 8 000 items from approximately 500 journals were included in the *Waterlit* base. Most of these articles were indexed by the Centre's own staff, but ISCOR, the Department of Water Affairs and the Department of Planning and the En-



The Head of the South African Water Information Centre, Dr PJ Aucamp, explains the method for carrying out a retrospective search on the Waterlit *data base by means of a computer terminal.*

vironment also contributed. Although the monthly input varies greatly due to the irregular receipt of journals in South Africa the Centre nevertheless maintained a mean input of more than 720 items per month during the last few months.

By using *Waterlit* the Centre, during the year, undertook almost 300 retrospective literature searches and during the last few months 31 searches per month were done on average. Most enquiries were in connection with wastewater treatment, groundwater, biology and water treatment and came from universities, the Department of Water Affairs, the National Institute for Water Research, the Water Research Commission and civil engineering consultants.

By the end of the year the Centre maintained 108 interest profiles on the monthly input to *Waterlit.* This represents double the number of profiles of the previous year. In this regard the universities and the National Institute for Water Research are also the most important users and water and wastewater treatment are the subjects which enjoy the greatest attention.

The current awareness services of the Centre are well patronised and current awareness magazines, namely *Water Patent Bulletin* with 84 subscribers, *Selected Journals on Water* with 152 subscribers and *SA Waterabstracts* with 556 subscribers, are generally popular.

The Centre has established good liaison with similar organizations abroad and negotiations are currently in progress to sell the *Waterlit* bibliographic data base to at least four large international networks or make it available on an exchange basis.

Partnership research

In the previous annual report two important principles for promoting the eventual application of research results were mentioned. Firstly, the research projects have to be directed at well-defined needs, and secondly the potential users of research results have to be involved on a partnership basis in the research.

The extent to which the Commission has succeeded, by developing its working procedures such as the establishment and operation of Coordinating Research and Development Committees for specific problem areas and the expansion of its current manpower, in implementing these two principles in its financing of research has been discussed in Chapter 1.

Symposia and seminars

The Commission has also taken the initial steps to utilize symposia and seminars as a means for promoting technology transfer.

In South Africa chlorination is traditionally applied as the exclusive method for the disinfection of water. However, with the recent world-wide controversy about the possible detrimental effects of chlorinated hydrocarbons it has become necessary to take cognisance of other disinfection techniques such as ozonation especially and the application of chlorine dioxide which has become general practice in Europe. The Commission therefore financed the visit by Dr WJ Masschelein, a noted Belgian expert in the field of these two techniques, to South Africa to participate in the annual one-day symposium on new developments in water research.

This symposium, which dealt with the disinfection of water, was held on 16 November 1978 in Pretoria and presented by the National Institute for Water Research and the Institute of Water Pollution Control.

A technology transfer seminar is being planned in conjunction with the Institute of Water Pollution Control, the Institution of Municipal Engineers of Southern Africa and the South African Institute of Civil Engineers (Division of Municipal Engineering) for 17 May 1979 and will deal with nutrient removal from municipal effluents. This theme has now become of great importance to local authorities since the Department of Water Affairs has indicated that effluent standards for phosphorus will be instituted in certain sensitive catchments.

Where the Commission has, for the past few years, financed important research at the NIWR and at the Department of Civil Engineering of the University of Cape Town on the biological removal of phosphorus from sewage effluent, the seminar will offer an important opportunity for making the results available to local authorities and consultants. The seminar will deal with practical aspects and the Department of Water Affairs, the NIWR, the University of Cape Town, the Johannesburg Municipality and the Water Research Commission will participate.

Exchange of publications between the Commission and overseas institutions

The exchange of publications between the Commission and overseas organizations has been in progress for several years. In addition the Commission is a member of the Water Research Centre in the United Kingdom as well as the American Water Works Association Research Foundation's information coordination programme on water reuse, in terms of which the Commission regularly receives recent information on water research. During the year arrangements were also made with overseas organizations to mutually exchange publications. These actions and arrangements contribute greatly to the Commission's effort to remain abreast of the latest developments in the water field.

Chapter 12

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 1978 to 31 December 1978.

The Commission derives its income from rates and charges on water usage. In terms of section 11 of the Water Research Act, the Minister of Water Affairs has announced the following rates and charges for the Republic in respect of the 1978 financial year in Government Notice No 464 of 10 March 1978:

"(a) Forty (40) cents in respect of each hectare of land scheduled in terms of section 63(7) or, where applicable, section 88 of the Water Act, 1956 (Act 54 of 1956), or in respect of which an allocation has been made in terms of section 56(3) of the said Water Act, 1956, to be irrigated at any time during the period 1 January 1978 to 31 December 1978 with water supplied or made available from a Government dam and distributed by means of an aqueduct, irrespective of whether or not such aqueduct belongs to or is controlled by the Government, an irrigation board or other statutory body. This rate shall be recovered by or by direction of the Secretary for Water Affairs simultaneously with any rate or charge which I may levy in respect of land concerned during the said period in terms of section 66 of the said Water Act, or, if no such rate or charge is levied, the rate levied hereby shall be payable to the Secretary for Water Affairs upon demand.

"(b) Twenty (20) cents in respect of each hectare of land scheduled as in paragraph (a), but where the water supplied or made available is not distributed by means of an aqueduct. This rate shall be recovered in the manner described in paragraph (a).

"(c) Twenty (20) cents in respect of each hectare of land scheduled in terms of section 88 of the aforementioned Water Act, to be irrigated, at any time during the 1978/79 or, as the case may be, the 1978 financial year of any irrigation board or other statutory body, with water supplied or made available from a water work belonging to such irrigation board or other statutory body. This rate shall be recovered by the irrigation board or other statutory body concerned and shall be remitted to the Secretary for Water Affairs within thirty (30) days of the close of the financial year of the said irrigation board or other body.

"(d) Two tenths of a cent (0,2c) per cubic metre in respect of metered water supplied or made available during the period 1 January 1978 to 31 December 1978 from a Government water work for purposes other than the irrigation of land. This charge shall be recovered by the Secretary for Water Affairs simultaneously with any charge I may levy in terms of section 66 of the Water Act during the said period.

"(e) Two tenths of a cent (0,2c) per cubic metre in respect of the quantity of water supplied or made available for use for urban, industrial or domestic purposes during the period 1 January 1978 to 31 December 1978 by the Rand Water Board, by any regional water supply corporation established in terms of the Water Supply Ordinance, 1945 (Ordinance 21 of 1945), of Natal, by the Western Transvaal Regional Water Company (Pty) Ltd, by any water board or irrigation board established in terms of the aforementioned Water Act and by any local authority serving a White population in excess of 2 000 according to Report 02-05-01, published by the Secretary for Statistics: Provided that there shall be deducted from the total quantity of water used, supplied or made available by an abovementioned public supplier during the said period the quantity of water supplied or made available from the Government water work in terms of paragraph (d) or the quantity obtained from any other such public supplier during that period. The total amount payable in terms of this paragraph in respect of water used, supplied or made available shall

be remitted by the supplier concerned to the Secretary for Water Affairs, Private Bag X313, Pretoria, as follows:

i) In respect of the period 1 January 1978 to 30 June 1978, not later than 30 September 1978; and

ii) in respect of the period 1 July 1978 to 31 December 1978, not later than 31 March 1979.

"The audited statements prescribed under section 11(3)(b) of the said Water Research Act shall be submitted together with the payment mentioned in subparagraph (ii).

"If such rates and charges remain wholly or partly unpaid after the due date interest at a rate which at the due date applied in respect of loans under section 26(1) of the Exchequer and Audit Act, 1975 (Act 66 of 1975) will be charged in respect of the amount outstanding as from that date."

For the purposes of this notice one cubic metre shall be equal to one kilolitre.

In terms of section 11 of the Water Research Act as amended, the Administrator-General for the Territory of S.W.A. has announced the following rates and charges for South West Africa in respect of the 1978/79 financial year in Government Notice No AG25 of 1978:

"1. Forty (40) cents in respect of each hectare of land to be irrigated at any time during the period 1 July 1978 to 30 June 1979 with water supplied or made available from a Government water work. This rate, recoverable by the Secretary for Water Affairs, shall be payable simultaneously with any other rate which may be levied in respect of the supply of such water.

"2. Two tenths of a cent (0,2c) per cubic metre in respect of metered water supplied or made available during the period 1 July 1978 to 30 June 1979 from a Government water work for purposes other than the irrigation of land. This charge, recoverable by the Secretary for Water Affairs, shall be payable simultaneously with any other charge that may be levied in respect of such water supplied.

"3. Two tenths of a cent (0,2c) per cubic metre in respect of the quantity of water, excluding water referred to in paragraph (2), supplied or made available for urban, industrial or domestic purposes during the period 1 July 1978 to 30 June 1979 by the Municipalities of Windhoek and Tsumeb. The rates recoverable by the said Municipalities shall be paid over to the Secretary for Water Affairs, c/o the Director of Water Affairs, Private Bag 13193, Windhoek, 9100 —

a) in respect of the period 1 July 1978 to 31 December 1978 not later than 31 March 1979; and

b) in respect of the period 1 January 1979 to 30 June 1979 not later than 30 September 1979.

"The audited statements prescribed under section 11(3)(b) of the said Water Research Act shall be submitted to the Secretary for Water Affairs, as aforesaid, together with the payment for the period mentioned in subparagraph (b).

"For the purposes of this notice one cubic metre shall be equal to one kilolitre.

"In respect of any rates and charges which are due and payable but unpaid, interest shall be charged as from the date fixed for payment thereof under subsection (5) of section 11 of the Water Research Act, 1971, as inserted by section 1 of the Water Research Amendment Act, 1977 (Act 106 of 1977), at the standard interest rate which at that date applies in respect of loans granted by the State out of the State Revenue Fund under section 26(1) of the Exchequer and Audit Act, 1975 (Act 66 of 1975)."

WATER RESEARCH COMMISSION

STATEMENT 1

BALANCE SHEET AS AT 31 DECEMBER 1978

1977	Liabilities	1978		1977	Assets		1978	
R		R	R	R		R	R	R
	Sundry creditors				*Capital assets			
47 958	Revenue paid in advance		133 945,67	5 000	Land (Cost)		5 000,00	
	Fund account				Motor vehicles	10 272,75		
5 377 163	Balance at 31/12/77	5 377 163,16		5 227	*Less:* Depreciation	3 846,93	6 425,82	
	Less: Excess of expenditure over income 1978	82 468,14			Office equipment	32 935,50		
			5 294 695,02	28 380	*Less:* Depreciation	1 646,78	31 288,72	
					Office furniture	30 879,57		
				23 653	*Less:* Depreciation	1 543,98	29 335,59	
								72 050,13
				3 695 459	Investments			3 970 981,26
					Current assets —			
					Sundry debtors			
					Outstanding revenue			
					Prior to 1978	20 543,81		
					1978	405 248,82		
					In transit	116 673,38		
				305 707			542 466,01	
				1 162 327	Project advances (Statement 3)	748 491,63		
				5 800	Subsistence and transport advances	11 964,00		
				50	Deposits	250,00		
							760 705,63	
				50	Cash on hand		150,00	
				193 468	Cash in bank		82 287,66	
								1 385 609,30
R5 425 121			R5 428 640,69	R5 425 121				R5 428 640,69

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

Pretoria, 5 April, 1979

G.J. STANDER
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, as 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.

Department of the Auditor-General
Cape Town, 23 April, 1979

(Sgd) WG Schickerling
Auditor-General

WATER RESEARCH COMMISSION

STATEMENT 2

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD 1 JANUARY 1978 TO 31 DECEMBER 1978

1977	Expenditure		1978
R			R
371 330	Salaries and allowances		474 303,32
16 193	Subsistence		13 643,73
3 370	Motor transport		4 977,98
56 502	General transport		121 274,73
737	Commission members' allowances		475,00
3 769	Postal and telegraph services		4 111,46
10 235	Telephone services		11 109,00
7 879	Printing and stationery		9 706,34
2 096	Advertisements		2 840,94
49 840	Publications and Information		25 456,67
7 797	*Lease and maintenance of office equipment*		8 688,08
3 773	Entertainment		6 740,15
21 715	Office rental		25 915,17
251	Maintenance of and alterations to offices		3 197,25
1 166	Electricity		1 491,81
40	Typing services		1 978,00
3 575	Insurances and licences		4 942,36
34 004	Collection fees		34 884,27
763	Audit fees		844,00
91	Legal costs		165,50
7 549	Registration and subscriptions		7 328,54
2 430	Miscellaneous petty expenses		2 402,42
5 538	Depreciation		7 037,69
2 782 697	Research projects (Statement 3)		2 622 946,79
	Contracting of overseas researchers and expertise	R	
140 986	Weather modification at Bethlehem	168 258,90	
11 244	Evapotranspiration and water use studies by means of weighing lysimeters	16 477,09	
—	Instrumentation and automation of flood irrigation systems	7 865,91	
			192 601,90
146 301	Research and other grants		178 728,32
133 421	Specialist and consultation services		220 098,86
R3 825 292			R3 987 890,28

1977	Revenue			1978
R		R	R	R
	Rates			
	Government irrigation Schemes with canal systems			
	Received	25 867,82		
	Plus: Adjustment in respect of previous years	445,45	26 313,27	
	Plus: Outstanding 1978		47 160,93	
65 053				73 474,20
	Government irrigation schemes without canal systems			
	Received	984,72		
	Plus: Adjustment in respect of previous years	89,70	1 074,42	
	Plus: Outstanding 1978		2 231,28	
3 193				3 305,70
	Irrigation Board Schemes			
	Received	23 454,86		
	Less: Adjustment in respect of previous years	739,06	22 715,80	
	Plus: Outstanding 1978		4 039,97	
14 400				26 755,77
	Charges			
	Metered water from Government Schemes			
	Received	2 159 398,34		
	Less: Adjustment in respect of previous years	4 861,43	2 154 536,91	
	Plus: Outstanding 1978		314 594,67	
2 251 575				2 469 131,58
	Municipalities			
	Received	959 723,28		
	Less: Adjustment in respect of previous years	310,18	959 413,10	
	Plus: Outstanding 1978		12 384,53	
939 289				971 797,63
	S.W.A.:			
	Received		48 373,39	
	Plus: Outstanding 1978		24 837,44	
58 543				73 210,83
—	Interest on rates and charges in arrear			1 396,88
306 200	Interest on investments			286 149,04
178	Sundry revenue			200,51
186 861	Excess of expenditure over income			82 468,14
R3 825 292				R3 987 890,28

WATER RESEARCH COMMISSION

STATEMENT 3

STATEMENT OF PROJECT EXPENDITURE AND ADVANCES FOR THE YEAR 1978

Project	Expenditure		Total advances outstanding as at 31/12/78
	1977	1978	
Development of research on the reclamation of water at the Athlone Sewage Works, Cape Town	50 799	41 935,30	45 563,86
Technological development of water reclamation on the basis of the Windhoek plant	70 665	19 465,15	6 901,05
Eutrophication of rivers and dams	123 160	134 914,00	6 039,59
Technological development of water reclamation and pollution control — Daspoort	270 803	122 212,00	4 633,29
Reclamation, storage and abstraction of purified sewage effluents in the Cape Peninsula	552 923	372 040,61	61 934,70
Natural draught dry cooling heat exchangers	192	—	—
Financial support of the University of the Witwatersrand Hydrological Research Unit	60 000	—	—
Research on recycling of water and recovery of chemicals in the textile industry	34 150	—	—
Research on the treatment of waste water by ion exchange	60 615	75 604,35	*(26 997,17)
Research on the activated sludge process	61 678	64 754,51	*(19 221,48)
The removal of metal ions from dilute solutions in an electrolytic precipitator	6 168	38 919,19	*(293,12)
The role of aquatic macrophytes in Swartvlei, Wilderness, in maintaining trophic conditions	54 120	46 105,00	23 500,08
Hydrological investigation of small catchments in the Grahamstown area	40 899	—	22 273,95
Hydrological investigation of small rural catchments with specific reference to flood events	117 122	43 343,99	2 043,91
Hydrological investigation of small catchments in the Mtunzini district	42 513	34 547,86	27 800,00
Biological denitrification and the removal of phosphate	69 736	75 205,00	2 769,88
An investigation on the optimal utilization of water in the Eerste River by storage in sandbeds or by other means	89 445	—	79 394,99
Development of the WAT-process for the desalination of sea water	6 451	3 918,00	6 861,34
South African Water Information Centre	—	206 861,17	*(24 606,97)
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	111 567	140 845,89	22 736,93
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	196 034	276 456,45	*(7 453,47)
Research on water consumption patterns in urban areas	32 652	—	18 270,37
Research on the removal of sludge and wash water at water purification installations	28 341	—	6 953,17
Research on water losses in pipe networks	21 623	—	3 418,23
Geohydrological studies in the Gamagara catchment using environmental isotope and complementary techniques	58 187	129 757,48	16 023,28
The development of the concept of the runhydrograph in the analysis of flood hydrographs	58 245	11 263,98	705,58
Research on flood damage — Bureau for Economic Research	13 463	—	477,55
An investigation into soil compaction under irrigation at the Vaalharts State Irrigation Scheme	18 010	9 374,19	2 002,83
An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	9 162	11 358,22	*(965,16)
Research on flood damage — Institute for Social and Economic Research	37 018	56 255,41	17 881,76
Research on the microbiological quality and health aspects of water for re-use	79 008	—	206 667,35

Research on the soil factors effecting the optimal utilization of irrigation water in the Black States	7 460	22 691,57	25 946,96
Research on water requirements of certain agronomic and vegetable crops	25 351	—	25 200,80
Research on the purification and re-use of effluents from the hides and skins, curing, fellmongery and tanning industries	65 656	62 831,20	2 404,68
Research on and development of desalination of sea water by reverse osmosis on the pilot plant at Swakopmund	25 356	31 521,00	8 923,00
Research on desalination of treated sewage	42 804	48 426,00	1 083,42
Research on the development of membrane support systems and modules	16 608	39 947,00	4 345,00
Research on the technological application of the anaerobic digestion process for the purification of spent wine residue	5 069	5 924,00	5 007,00
Water management and effluent treatment in the Textile industry	117 456	151 242,01	1 357,99
Research on the development of effective irrigation methods for application on steep lands, with special reference to micro-methods	—	—	14 330,00
Research on flood occurences	—	54 704,18	*(3 794,18)
Research on water resources	—	52 571,01	*(3 741,01)
Research programme for studying conditions in Hartbeespoort dam before and after full scale spraying of the water hyacinths	11 080	10 709,00	18 211,00
Water pollution and effluent reclamation in the Pretoria-Witwatersrand-Vereeniging-Sasolburg Complex	91 108	145 761,47	53 981,25
Research on the scheduling of irrigation of wheat in the irrigation area of the Orange Free State	—	9 790,60	17 209,40
The artificial replenishment and abstraction of purified sewage effluent in the Cape Flats	—	57 833,00	3 567,00
Research on rainfall stimulation at Nelspruit	—	—	60 900,00
The geohydrology of the sand deposits in the Cape Flats	—	13 857,00	8 243,00
	R2 782 697	R2 622 946,79	R748 491,63

*Excess expenditure over advances for projects

WATER RESEARCH COMMISSION
STATEMENT 4
BUDGET 1979

	R	R
ESTIMATED INCOME		
Rates and charges in terms of Section 11 of the Water Research Act		3 362 500
Interest on Investment		200 000
		3 562 500
Appropriation from accumulated funds		1 235 140
TOTAL ESTIMATED INCOME		4 797 640
ESTIMATED EXPENDITURE		
Administrative expenses:		
Salaries and allowances	600 000	
Subsistence and travelling expenses	127 000	
Postal, telegraph and telephone	19 000	
Printing, stationery, advertisements and publications	59 000	
General expenditure	115 900	
		920 900
Research Projects:		
Approved projects		
Development of research on the reclamation of water at the Athlone Sewage Works, Cape Town	34 000	
Technological development of water reclamation on the basis of the Windhoek plant	34 000	
Eutrophication of rivers and dams	53 000	
Reclamation, storage and abstraction of purified sewage effluents in the Cape Peninsula	100 000	
Research on the activated sludge process	65 000	
Hydrological investigation of small rural catchments with specific reference to flood events	23 900	
Hydrological investigation of small catchments in the Mtunzini district	13 000	
Biological denitrification and the removal of phosphate	4 600	
An investigation on the optimal utilization of water from the Eerste River by means of storage in sand beds or other methods	50 000	
South African Water Information Centre	148 500	
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	173 700	
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	100 000	
An investigation into soil compaction under irrigation at the Vaalharts State Irrigation Scheme	2 500	
An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	7 500	
Research on flood damage — Institute for Social and Economics Research	61 000	
Research on the microbiological quality and health aspects of water for re-use	188 000	
Research on the soil factors effecting the optimal utilization of irrigation water in the Bantu homelands	32 000	
Research on water requirements of certain agronomic and vegetable crops	22 500	
Research on the purification and re-use of effluents from the hides and skin curing, fellmongery and tanning industries	47 000	
Research on and development of desalination of seawater by reverse osmosis on the pilot plant at Swakopmund	28 000	
Research on desalination of treated sewage	52 000	
Research on development of membrane support systems and modules	37 500	
Water management and effluent treatment in the Textile Industry: Dyeing and printing effluent	73 500	
Water management and effluent treatment in the Textile Industry: Sizing and desizing effluent	105 500	
Water management and effluent treatment in the Textile Industry: Wool scouring effluent	47 000	
Research on the development of effective irrigation methods for application on steep lands, with special reference to micro-methods	13 650	
Research on flood occurrences	53 400	
Research on water resources	33 800	
Water pollution and effluent reclamation in the Pretoria-Witwatersrand-Vereeniging-Sasolburg Complex	130 000	
Research on the scheduling of irrigation of wheat in the irrigation area of the Orange Free State	31 000	
The artificial replenishment and abstraction of purified sewage effluent in the Cape Flats	72 640	
Research on rainfall stimulation at Nelspruit	73 600	
The geohydrology of the sand deposits in the Cape Flats	15 050	
Research related to the purification and reuse of tannery effluent	10 000	
	1 936 840	
Other possible projects		
Proposed	1 023 400	
Tentative	200 000	
		3 160 240
Contracting of overseas researchers and expertise		241 500
Research and other grants		250 000
Specialist and Consultation Services		225 000
TOTAL ESTIMATED EXPENDITURE		4 797 640