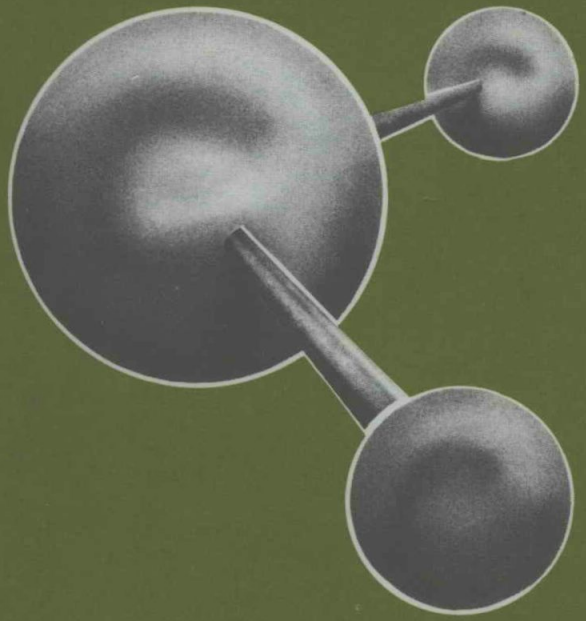

water research commission

ANNUAL REPORT

1 January 1976 to 31 December 1976

WATER RESEARCH COMMISSION

Annual Report

1 January 1976 to 31 December 1976

WATER RESEARCH COMMISSION
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Water Research Commission
P O Box 824
PRETORIA
0001
1 March 1977

Dear Sir

We take pleasure in submitting to you, herewith, the report of the Water Research Commission. This report covers the period 1 January 1976 to 31 December 1976.

Balance sheets and statements of revenue and expenditure for the financial year 1 January 1976 to 31 December 1976, as certified by the Auditor-General, are furnished in chapter 12 of this report.

Yours respectfully

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CHAIRMAN

J P Kriel
VICE CHAIRMAN

The Honourable A J Raubenheimer, MP
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Chapter 1

Review of the year's activities and preview

The Water Research Commission has now been in existence for five years. A retrospective glance shows that the following has been achieved:

- The initiation and operation of some forty water research projects covering a wide range of disciplines.
- The establishment and operation of Study Groups and Co-ordinating Research and Development Committees to consider and co-ordinate research in specific problem areas.
- Publication of an interdisciplinary journal as well as a newsletter on water.
- The establishment and development of the South African Water Information Centre.
- Contracting of specialist consultants from overseas to study specific problem areas locally and to submit reports and recommendations on the status and shortcomings in respect of the national research programme in those fields.
- A survey of existing water research programmes and available research facilities in the country.
- Development of a national master research plan.
- The development of centres of expertise at various South African universities by selectively awarding research contracts, and by making research allocations for work of a more basic scientific nature.

From the foregoing it is clear that the Water Research Commission's activities have already had a considerable impact on water research in South Africa. The Water Research Commission, however, considers itself to be a dynamic organization to which the mere execution of its developed procedures would be insufficient. In order to remain viable, the Commission has to maintain creativity in the alteration or replacement of its procedures in the light of new developments, new requirements and new ideas. It is furthermore true that certain areas have not yet received any attention, and that in these cases procedures will have to be developed *ab initio.*

Against the foregoing as background, some of the most important developments of the year are highlighted and, where applicable, directions for future activities are indicated.

Partnership research

In the past, the Commission's financing of research in most cases entailed an implicit element of partnership – that is to say the contractor is actively involved in the research and provides an input from his own resources by means of related research, facilities, manpower and expert leadership. The Commission is of the opinion that the partnership element should in future be expanded more effectively, because in various ways this would assist the promotion of effective research and its application:

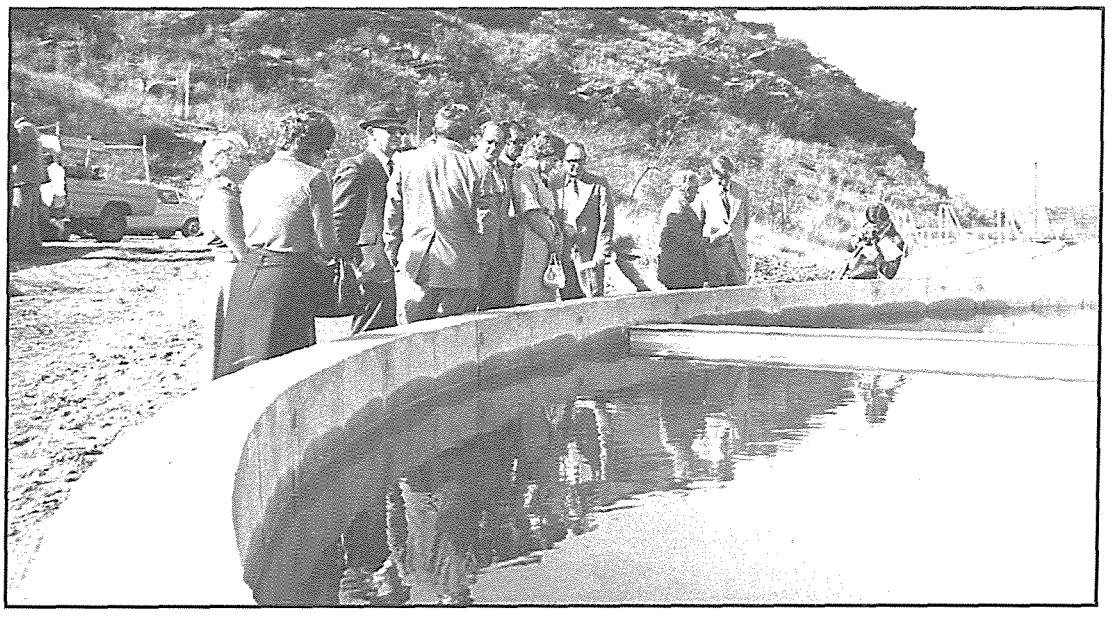
Firstly, this approach should be seen as a method for ensuring that Commission projects be entrusted to organizations which, due to their interest, expertise and facilities, are the most suitably equipped for this purpose. This will obviously assist in maximizing the return on research expenditure.

Secondly, in the case of specific contractors, it would be a strategy for promoting the eventual application of the research results generated. This would apply especially in the case of projects initiated in collaboration with industries, local authorities, and government departments with operational functions.

Thirdly, partnership research promotes better co-ordination of the relevant research. Owing to the fact that the contractors take an active interest in the problems being researched, they will naturally maintain active contact with related research of other organizations, thereby promoting two-way communication.

Examples of partnership research being carried out with financial support from the Commission are the following:

- **Modernizing the Windhoek water reclamation plant in accordance with the latest research information.** The partners in this case are the Windhoek Municipality which



The project in connection with the modified water reclamation plant at Windhoek is a good example of partnership research. In this case the Commission's research partners are the Windhoek Municipality which operates and monitors the plant, the National Institute for Water Research which provides expert advice and specialised quality monitoring, and the South African Institute for Medical Research which is responsible for epidemiological studies and microbiological monitoring. The photograph shows a number of guests at one of the unit installations during the commissioning of the modified plant.

operates the modernized plant – using its own manpower – and monitors performance, the National Institute for Water Research which provides expert advice and specialized quality monitoring, and the SA Institute for Medical Research which undertakes epidemiological studies and microbiological monitoring.

- **Research on the management of tannery effluent.** This project, being carried out by the Leather Industries Research Institute with a test facility situated at a large tannery serves as an example of partnership with industry. As its input, the tannery provides tanning facilities and space for the test plant and also undertakes the operation of the plant.

- **Research on the stimulation of rainfall at Bethlehem.** In this case the Commission has entered into a partnership with a government department, *viz.* the Department of Transport through its Weather Bureau. In addition to specialized manpower, the Weather Bureau's contribution also entails a major capital input by means of equipment and facilities.

More information on the abovementioned projects appears elsewhere in the report.

Contracting of overseas scientists for research on the stimulation of rainfall

An important development during the year was an agreement with the Department of Transport in terms of which the Commission would recruit and contract scientists of specific categories from overseas to be seconded to the Weather Bureau for the rainfall stimulation project at Bethlehem mentioned above. Scientists with suitable training were not available in the Republic, and this presented the only route for making this project viable.

Apart from the importance of the research itself, there are two other reasons why this project is of considerable importance to the Commission: Firstly, it showed that it is practically feasible to recruit overseas research scientists on a contract basis for important research which suffers from a shortage of specialized manpower in South Africa. Secondly, this was the first time that the Commission had entered into a partnership with a government department for the execution of a research project.

Rainfall stimulation as a tool for the augmentation of water sources has for many years received serious attention throughout the world. However, it requires long term research, the results of which may be projected only to a limited extent. Realizing furthermore that timely research would have to be initiated before rainfall stimulation could be operationally applied in times of water crisis which must surely come, the Commission decided to support the research at the Weather Bureau. Before entering into the agreement with the Weather Bureau, the Commission acquired the consultation services of two overseas specialists to advise, *inter alia,* on the planning and operation of the project.

In addition to the Weather Bureau, other interested organizations, such as the Department of Water Affairs, the Department of Agricultural Technical Services and the CSIR, are involved in the relevant Steering Committee whereby mutual co-ordination of related research is also promoted.

Prof R Braham (left) and Dr A Gagin (right) visited the Republic during 1976 as specialist consultants on rainfall stimulation. The former is professor of meteorology at the University of Chicago and Dr Gagin is head of the Cloud Physics Laboratory of the Hebrew University of Jerusalem.

Research on behalf of the industrial sector

During 1976 the Commission has considerably expanded its contact with and activities on behalf of the industrial sector. This was achieved mainly by development of the Co-ordinating Research and Development Committees (CRD committees) established by the Commission for specific industrial sectors. Experience thus far has shown that these Committees are important tools for the identification of research requirements and the planning of research programmes.

In the case of the *textile industry* the Commission formed a Study Group during 1976, which was subsequently followed by the establishment of a fully-fledged CRD committee. The committee compiled a situation statement on the water and effluent problems of the industry as well as a master research plan which has already been approved by the Commission. The proposed research will be done at various textile factories by the University of Natal's Chemical Engineering Department. This will constitute an expansion of related research already being done by the University under contract to the Commission.

The interests of the textile industry are catered for by various trade associations. Although these associations have no legal powers in respect of their members, they are in a position to influence their members to some extent. It is therefore envisaged that the support of these associations will be obtained for the research and the implementation of results, by means of suitable agreements.

The CRD committee for the water and effluent problems of the *fruit and vegetable canning industry* also showed satisfactory progress during 1976. The committee nominated a technical subcommittee to prepare a general situation statement on the relevant problems of the industry, and this assignment has progressed well. The committee also recommended to the Commission that the services of an overseas consultant be obtained to investigate the status of the industry in South Africa in the light of overseas practices and experience. This recommendation was accepted by the Commission. It appeared that the United States of America had shown most progress in relevant research and contact was established with its National Canners Association. The Association agreed to make the services of Mr W W Rose, head of its Water and Wastewater Engineering Department, available to the Commission. It was agreed that Mr Rose would visit South Africa early in 1977.

The *meat, hides and skins, leather and related industries* have to cope with exceedingly difficult effluent problems and in some cases local authorities have already refused to accept some of these effluents in their sewerage systems. During the second half of 1975 and on the recommendation of the relevant CRD committee the Commission obtained the services of a specialist from the United Kingdom, Dr A L Downing, former Director of the Water Pollution Research Laboratory and attached to a well-known firm of consultants, to evaluate local conditions against the background of overseas experience and to make recommendations for a suitable research programme. As a result of Dr Downing's recommendations, test facilities were erected at a fellmongery and at a tannery to study methods for treating effluents from these industries. The services of the consulting firm to which Dr Downing belongs will be retained for the duration of the investigations to provide expert supervision of the research and to develop a code of practice for the management of effluents in these industries.

In the case of the CRD committee for the *mining industry,* the interested parties represented on the committee prepared situation statements and submitted research proposals. Several of these proposals are currently being followed up by sub-committees which are collecting the necessary background information before proceeding with the formulation of specific research projects.

Research on behalf of local authorities

Local authorities can make an important contribution towards optimizing water utilization in the country, and for this reason a large proportion of the Commission's activities are of direct importance to local authorities. This research relates to: water purification, water reclamation, the treatment of effluents to combat pollution, eutrophication and water saving measures.

As a first formal contact with local authorities the Commission, shortly after its inception, undertook a survey of water supply and effluent treatment practice at local authorities and of the problems they experience in this regard. In April 1972 the Chairman read a paper at the biennial congress of the Institution of Municipal Engineers in which he reported briefly on the functions and working programme of the Commission. At the 1976 congress of the Institution the Chairman and two of the Commission's advisers presented a paper on the task of the Water Research Commission in respect of local authorities and industries. The purpose of the paper was to bring the activities of the Commission more prominently to the attention of the local authorities and to invite authorities to come forward with problems which would possibly require research.

In spite of the extensive research programme already instituted in the direct interest of local authorities, and in spite of the opportunities utilized for establishing contact with local authorities, the Commission is aware of a lack of regular contact with municipalities. As a result, the Commission intends organizing a meeting early in 1977 of municipal engineers where specific problem areas can be discussed and recommendations formulated for research which could be done with support from the Commission. The establishment of a CRD committee which would be responsible for the water research interests of local authorities will also be considered.

Co-ordination of research

In the Commission's annual report for 1974 it was reported that the establishment of Co-ordinating Research and Development Committees (CRD committees) had commenced as a strategy for promoting its co-ordinating functions. It was mentioned that these committees were instituted for specific problem areas to co-ordinate relevant research of co-operating organizations, to plan research programmes, to consider progress reports, to initiate new projects and to submit research proposals to the Commission.

The system of CRD committees is now fully operational and experience has shown that, in conjunction with the Commission's steering committees and the partnership principle (as mentioned earlier in this chapter), it is a particularly effective method for promoting co-ordination and for bridging communication gaps.

The Commission has repeatedly asserted that the establishment of CRD committees will be handled with circumspection and only for priority task areas in order to limit unhealthy multiplication of committees. It is, furthermore, the policy of the Commission not to interfere with committees operated by other organizations for co-ordination in the water field. The Commission desires, as far as possible, to incorporate the activities of such committees in its own programme of co-ordination and regards these as important segments in the global framework of co-ordination which is now gradually emerging.

In this regard a positive development during 1976 was the establishment of a standing Liaison Committee between the Commission and the National Committee for Environmental Sciences (NCES) operated by the CSIR. Two committees of the NCES are fulfilling co-ordinating functions in areas of interest to the Commission, *viz.* the Committee for Inland Waters and the Committee for Solid Wastes. The activities of the Liaison Committee are mainly directed at the mutual interests of the Commission and the NCES with regard to the study areas of the Committees mentioned above.

A further arrangement for promoting the co-ordination of the activities of the Commission and the NCES has been that the Commission has made R50 000 available to the NCES during the year for the financing of projects with practical implications which are of interest to the Commission.

The Commission also envisages close liaison with the interdepartmental Co-ordinating Committee for Hydrological Research which will probably be functioning in a new form during 1977.

Financing of research

The Commission grants research appropriations in terms of section 3(1)(c) of the Water Research Act by way of formal contracts, previously approved by the Honourable the Minister of Water Affairs. Each project is carried out under supervision of a Steering Committee representing the Commission, other interested organizations and personal expertise. Steering Committees have, *inter alia,* to consider working programmes, progress reports and budgets and make recommendations to the Commission.

Five new contracts were awarded during the year under review, bringing the total number of research projects initiated by the Commission to 39.

The following projects were completed during the year:

- Research on dry cooling (CSIR – National Mechanical Engineering Research Institute).
- Recycling of water and recovery of chemicals in the textile industry (University of Natal – Department of Chemical Engineering).
- Desalination of brackish water (CSIR – National Institute for Water Research).
- The WAT process for the desalination of sea water (CSIR – National Institute for Water Research).

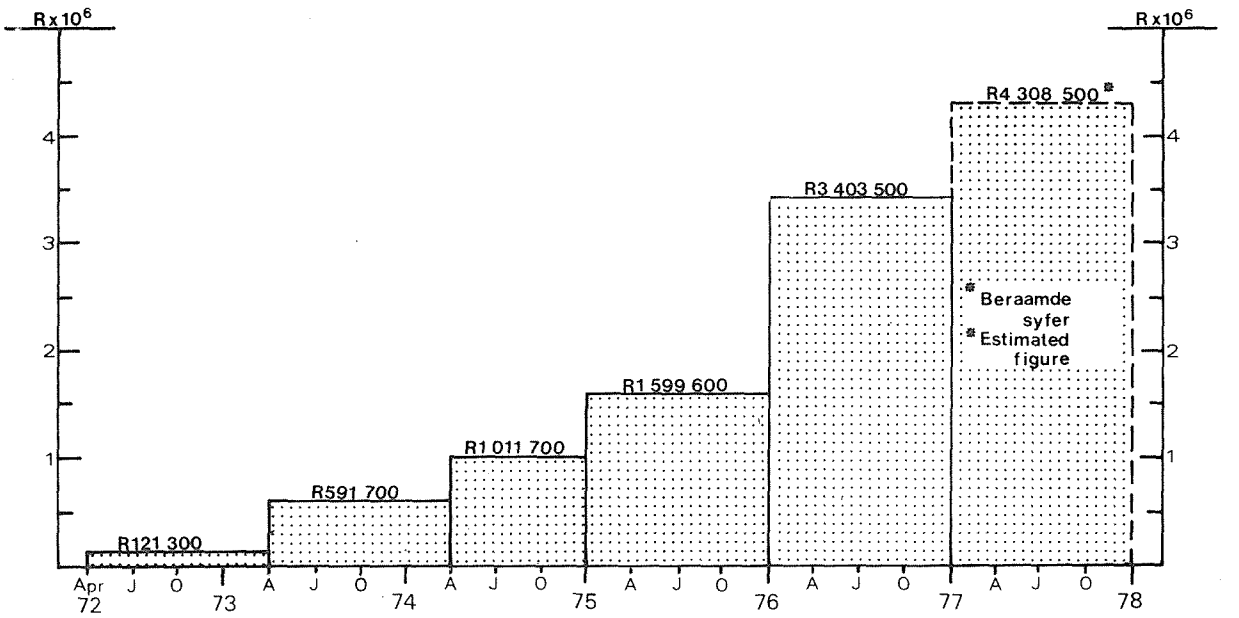


Figure 1
Growth in Commission expenditure on research and consultation services.

In the case of the project on the textile industry, research in 1977 will be consolidated by means of a new contract to provide for a considerable expansion of the programme and for direct co-operation with industry. Similarly, the two desalination projects will be consolidated in a single new contract. A further five new projects have already been approved in principle for the coming financial year.

Figure 1 shows growth in Commission expenditure on research and consultation services since its establishment. It must be pointed out that the expenditure for 1976, as well as the estimated expenditure for 1977, are considerably in excess of the Commission's total income for these years. This is made possible by the fact that the Commission was able in its first years, when its activities and procedures had to be developed, to build up a stabilization fund for the purpose of withstanding the financial pressures of priority projects involving large capital expenditures.

Briefly

Liaison with the International Association on Water Pollution Research (IAWPR)

The Chairman's term as President of the IAWPR terminated at the Eighth Conference of the Association in Sydney, October 1976, when he was not available for re-election. At that stage he had served as President for an uninterrupted period of eight years, having been elected for four consecutive two-year terms.

Technology transfer

Although various of its activities are already promoting the transfer of technology, the Commission is fully aware of a need to initiate a purposeful and systematic programme of action in this regard. As a result, one of the Commission's advisers made an overseas tour in 1976 to obtain knowledge on this matter and to formulate proposals for possible implementation by the Commission in 1977.

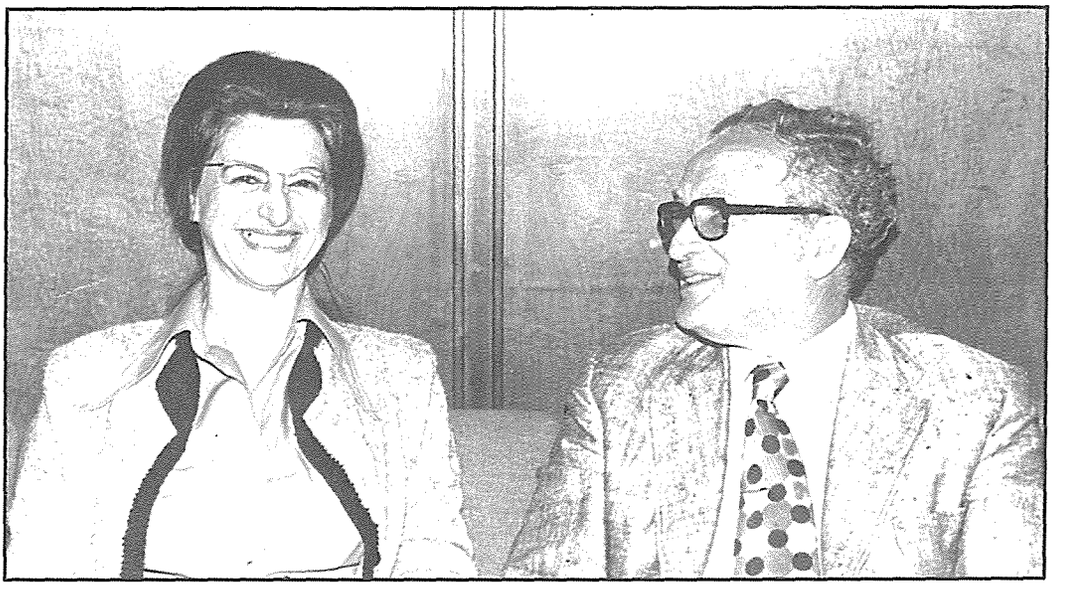
Revised procedures in respect of Steering Committees

The Commission's control over projects being funded under contract, is exercised by way of specific steering committees. Experience has shown that this system, although essential for financial and technical control and the involvement of interested parties, showed certain shortcomings with regard to direct contact between the Commission and the relevant projects. It was therefore decided to decrease the number of compulsory meetings of steering committees from two to one per annum and to encourage the establishment of sub-committees which could act more rapidly and incisively, and that the Commission's advisers should visit projects more often to evaluate progress and discuss possible problems with project leaders.

Contact with water research in Israel

At the end of 1975 a team of South African water scientists visited Israel to participate in an Israeli/South African symposium on the recycling of wastewater for agricultural and industrial use. Two of the Commission's advisers presented papers on this occasion.

Subsequent to the symposium Israel's Water Commissioner, Mr M Kantor, accompanied by two high-level scientists, visited South Africa in 1975 to discuss co-operation in the field of water research. The Commission took an important part in these discussions.

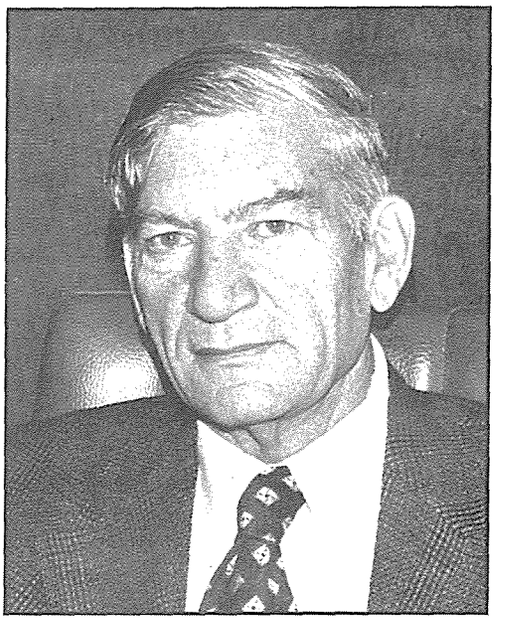


The Water Commissioner for Israel, Mr M Kantor (right), visited South Africa during the year under review and held high level discussions concerning cooperation with Israel in the field of water research. He was accompanied by Dr C Serruya, head of the Lake Kinneret Limnological Laboratory in Israel.

During the course of the year the Chairman of the Commission also visited Israel to advise on a large sewage purification scheme at Tel Aviv.

Water quality networks

During the year under review the Commission obtained the consulting services of Prof B B Berger, University of Massachusetts, Amherst, USA, to advise the Commission on research aspects which may be necessary in establishing water quality networks in South Africa. A water quality network entails a systematic and continuous programme of sampling at selected sampling points in a catchment in order to maintain a progressive and integrated picture of water quality in the catchment. By means of this information trends with regard to changes in water quality can be determined in good time and rational planning can be done to protect the quality of water sources.



Prof B B Berger of the University of Massachusetts in Amherst (USA) visited the Republic during 1976 as a consultant to the Water Research Commission to advise on the design, operation and utilization of water quality networks.

Technical manuals

The Commission has decided to publish a series of technical manuals in which results of specific Commission projects will be consolidated in as useful a form as possible. The first manual in the series – on the control of eutrophication – should be available early in 1977. It is envisaged that a second manual, on water reclamation, will also be completed during 1977.

Chapter 2

Water reclamation

A study of the Republic's water balance reveals that water demands for the next few years are escalating at such a rate that there will be little disparity between the country's water credits and debits by the year 2000. However, it is envisaged that the application of certain measures will increase the assured yield of, and decrease the demand for, water in South Africa so that there will be an estimated water credit of 10,7 milliard m^3 per annum by the turn of the century (see Chapter 1, 1975 Annual Report). Of the proposed measures for decreasing water demand, the most important is undoubtedly planned water reclamation and reuse since it will yield an estimated 7,2 milliard m^3 per annum. Water reclamation, furthermore, provides the key to the prevention of water pollution and the protection of the utilization value of water.

In view of the foregoing the Commission has, since its inception, awarded high priority to research on water reclamation.

Research done by the National Institute for Water Research (NIWR) and elsewhere has already proved the technological feasibility of water reclamation. There are two aspects, however, that still require specific attention, *viz.* development of general design and operational criteria for reclamation plants, and health implications of water reclamation.

As far as the *development of design and operational criteria* is concerned, it should be realised that the CSIR's research which, in 1969, led to the commissioning of the well-known Windhoek reclamation plant, was specifically aimed at the problem situation in Windhoek. In order to develop design and operational criteria which would be valid for a wide spectrum of industrial and domestic reclamation, it was necessary to thoroughly research the effectiveness of the unit processes, singly and in various combinations. This was, in fact, the objective of the NIWR's research at the Stander Reclamation Plant, Daspoort, Pretoria, utilising a 4,5 Mℓ/d test plant. Since 1972, the Commission has been able to considerably accelerate the progress of research through financial support, and it is envisaged that the first manual on water reclamation, based on research results obtained thus far, will be completed in 1977.

By financially supporting the modernisation of the Windhoek plant in accordance with the latest research data, the Commission created an opportunity for the operational testing of research findings.

Supplementary to the foregoing, and in collaboration with the NIWR and the Cape Town Municipality, the pilot scale testing of industrial and unlimited reuse of sewage effluent is being sponsored. In the planning of sewage purification in the Cape Peninsula, the Municipality of Cape Town decided to segregate, as far as possible, industrial and domestic wastewater. This creates an ideal situation to reclaim water separately for industrial and domestic reuse.

As far as *health aspects of water reclamation* are concerned, there are two directions that need to be researched. Firstly, the microbiological quality of reclaimed water, which entails long term monitoring programmes; and, secondly, the occurrence of organic micro-pollutants in reclaimed water as well as in potable water produced by conventional purification of water from surface sources. Within the framework of contracts awarded by the Commission, microbiological monitoring of reclaimed water and other potable water supplies in Windhoek is done by the NIWR, the Windhoek Municipality and the South African Institute for Medical Research (SAIMR). The latter also undertakes epidemiological studies in the area. The NIWR and SAIMR monitor the water produced by the Stander Reclamation Plant. Research on the occurrence and nature of organic micro-pollutants in the water of the Stander Plant and in conventional potable water supplies is done by the NIWR with partial financing by the Department of Health.

The remainder of this chapter is devoted to reports on Commission projects related to water reclamation.

RESEARCH PROJECTS

Reclamation of water at the Athlone Sewage Works, Cape Town

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

The increasing demand for water in the Greater Cape Town region and the scarcity of sites for freshwater impoundments have necessitated studies into the possible reuse of reclaimed effluents. Investigations carried out by the Cape Town Municipality and the National Institute for Water Research (NIWR) have indicated that the reclamation and reuse of purified effluents can make a noteworthy contribution to water conservation in the Cape Peninsula. Proposals have been made that the siting of future sewage treatment and reclamation plants should be planned on a regional basis for optimum reuse, so as to obtain the benefit of scale and to allow for the segregation of domestic and industrial effluents.

The objective of the tripartite agreement is to evaluate the technological and economical feasibility of reclaiming sewage effluent for industrial reuse. For this purpose, research is being conducted at the Athlone Sewage Works on a 300 m^3/d pilot plant, which is operated by the Municipality, while the NIWR provides specialist services. Construction of this plant was started towards the end of 1975 and commissioning commenced during August 1976.

The process design of the plant includes an aerated biological stage after lime treatment and ammonia stripping to ensure quality equalisation and higher efficiency in the removal of organic carbon and ammonia. Subsequent physical/chemical unit processes include secondary clarification, sand-filtration, disinfection and activated carbon adsorption.

During the forthcoming period a research programme providing for the operation, control and monitoring of the plant will be implemented.

Adaptation of the Windhoek Water Reclamation Plant to the latest research data and technological development

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

This project entails modernising the Windhoek Water Reclamation Plant in accordance with the latest research data generated by the National Institute for Water Research (NIWR). An evaluation of these data during practical and large-scale operation will be very valuable in implementing water reclamation systems in the Republic.

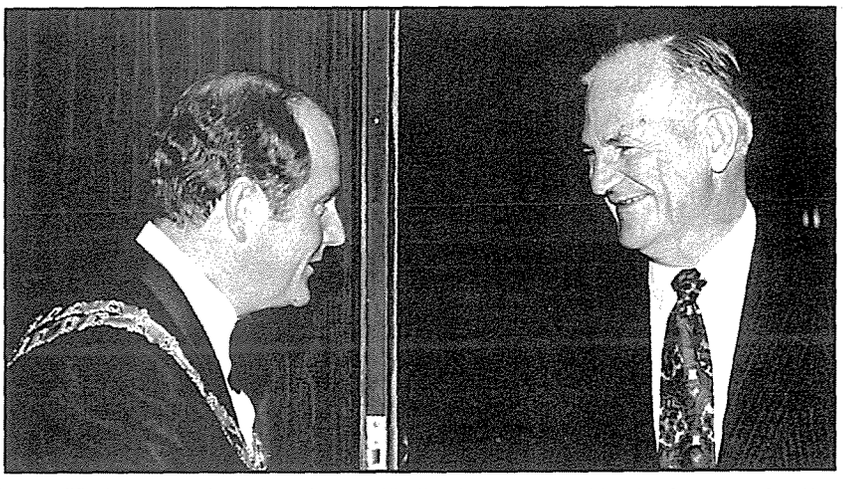
The original plant played a vital role during a period of acute water shortage (from 1969 to 1971) until water from the Von Bach Dam was integrated in the city's supply. The plant reclaimed purified sewage for domestic use on a continuous basis – a feat which has not yet been repeated anywhere in the world.

As foreseen in the Commission's previous Annual Report, the modified plant was completed by the Windhoek Municipality during the year under review, and the modified plant was officially opened on 19 May 1976, at which date mechanical and electrical installations were substantially complete. Various experimental runs have been made, and the initial problems encountered in the ammonia stripping tower have been solved.

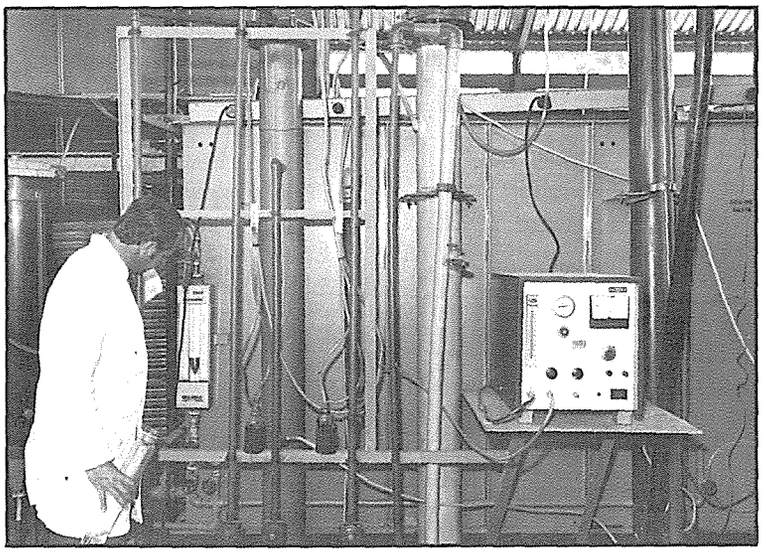
The National Institute for Water Research has assisted with the training of the operators and has also studied various process units in detail which has resulted in several improvements.

Virological testing has yielded very favourable results, and it is envisaged that reclaimed water will again be integrated in the city's water supply within the foreseeable future.

Since the quality of the reclaimed water must at all times rigorously comply with the microbiological and chemical qual-



The modified water reclamation plant at Windhoek was opened by the Secretary for Water Affairs, Dr J P Kriel, in May 1976. Dr Kriel (right) is shown here in conversation with His Worship the Mayor of Windhoek, Councillor A G C Yssel, during the opening ceremony.



The equipment which will be used to study ozonation as an alternative to chlorination as a process of disinfection in the research on water reclamation at Daspoort.

ity requirements for potable water, monitoring investigations are being conducted by four separate organisations viz. the NIWR, the Municipality of Windhoek, the SA Institute for Medical Research and the Department of Water Affairs (SWA Branch). No unacceptable deviations were detected during the year under review.

Technological development of water reclamation and pollution control

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

The main objective of this project was to develop design and operational criteria for full-scale application of water reclamation. The first phase of the contract with the National Institute for Water Research was concluded, when research at the Stander Water Reclamation Plant at Daspoort, Pretoria, proved the technological feasibility of water reclamation. At that stage it was deemed necessary to renew the contract for a second phase research programme in order to conduct research on carbon regeneration, lime sludge handling, ozonation and the reclamation of activated sludge effluents. Concurrently this presented the opportunity for continued quality and health surveillance as well as the refinement of operational and design criteria.

In 1976 the plant has been operated on a continuous basis for two consecutive periods of 3½ and 4 months, during which it was possible to introduce a number of process refinements which, coupled with meticulous operator control, led to a more effective and reliable production of reclaimed water. This was confirmed by microbiological quality monitoring results.

A modified lime make-up and dosing system was introduced to alleviate the problems of inconsistent lime slurry concentration and frequent blockages. This resulted in a 55 per cent improvement in the pH control of the lime reactor.

Centrifugal decanting of the lime sludge proved to be a highly effective process for the disposal of all the sludge resulting from continuous water reclamation. Although rapid wear of the scroll resulted in frequent interruption of the process for scroll rebuilding, it was found that wear of the scroll could be reduced considerably by reducing both its absolute and differential rotational speeds.

The considerable uptake of carbon dioxide in the equalisation pond and ammonia stripping tower led to the elimination of primary recarbonisation. Consequently the use of the secondary clarifier became superfluous.

The disinfection process unit has been made more reliable by the introduction of a free chlorine residual cell coupled to an automatic shut-off valve and alarm system. The shut-off valve is activated by an unacceptable low free chlorine level which diverts the water to the drain.

In order to study ozonation as an alternative to chlorination for disinfection, an ozonation system comprising a 2 kg per hour ozonator and contacting equipment has been designed and is at present under construction. It is anticipated that the system will be completed and ready for commissioning early in 1977.

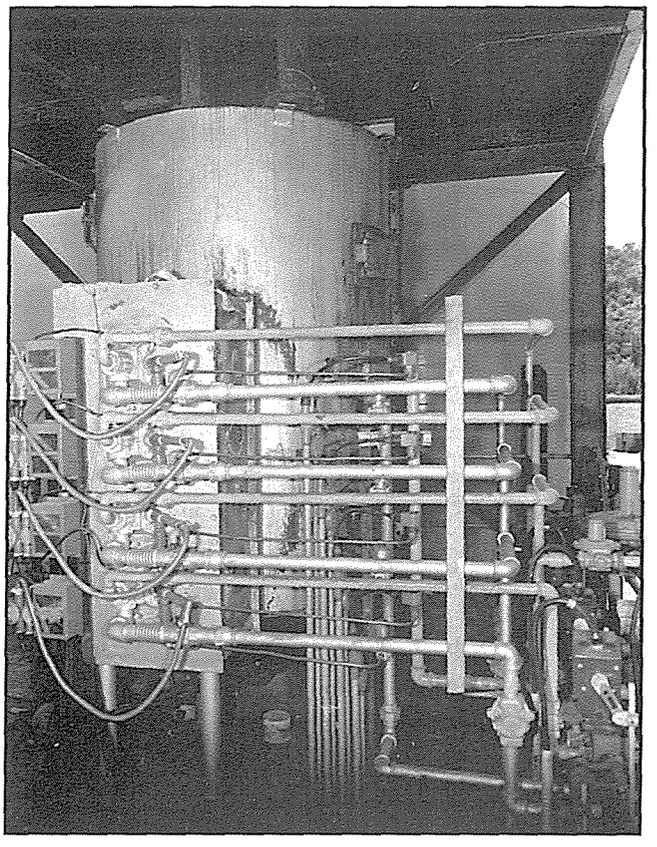
For the purpose of producing water on a continuous basis as well as ensuring maximum utilisation of activated carbon, a second adsorption stage consisting of two columns was incorporated. The introduction of the second stage provides a safety barrier against possible breakthrough of dissolved organic contaminants. From an operational point of view this two-stage system performed satisfactorily and resulted in a marked improvement in water quality with respect to dissolved organics.

The high cost of activated carbon necessitated the introduction of a regeneration furnace which was brought to full

production towards the end of January 1976 and during the year about 50 tons of carbon were regenerated. The cost of thermally regenerated carbon was found to be about one quarter of that of virgin carbon. The regeneration process is fully integrated into the water reclamation system and should be regarded as an essential ancillary unit.

In accordance with the approved research program for 1976, the change-over from humus tank effluent to activated sludge effluent as raw water supply, was implemented as from July 1976.

The final cost of reclaimed water for a 5 Mℓ d^{-1} plant has proved to be approximately 30 cents per m^3, of which the running costs constitute about 50 per cent. Projected cost for a 50 Mℓ d^{-1} water reclamation plant came to a total of approximately 13 cents per m^3, of which 60 per cent was running costs.



The furnace used for regeneration of activated carbon. The cost of thermally regenerated carbon has proved to be approximately one-quarter that of virgin carbon.

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

(Existing project: Contract with the CSIR – National Institute for Water Research.
New project: Contract with the Cape Town Municipality)

The reclamation and reuse of purified sewage effluent in the Cape Peninsula could substantially contribute to the alleviation of water supply problems encountered in this region. The main purpose with this project is, therefore, to evaluate, by means of basic investigations, the technical and economic feasibility of full-scale water reclamation of purified sewage effluent and its storage in and abstraction from the sand beds of the Cape Flats, and to develop the required design criteria for its full-scale application.

During the year under review extensive studies were undertaken on the hydraulic suitability of the sand beds in the Cape Flats for the storage, infiltration and abstraction of natural water or purified effluents. After thorough planning, a start was made on the construction of process units and the preparation of a site for the execution of experimental investigations. Provision is also made in the design of this plant to keep abreast of the latest developments in the field of water purification technology and of the requirements of local authorities.

Geohydrological studies showed that there is currently a daily subterraneous flow to False Bay of 75 Mℓ, i.e. approximately 3 m^3/d per metre of coastline. This water could be intercepted and thus utilised by drilling 50 boreholes in one or more lines parallel to the coast. Utilisation of the Cape Flats as a coastal aquifer entails that specific attention should be paid to the possible intrusion of sea water. Studies in this regard have shown that the sand along the coast is, in fact, very permeable and that suitable preventative measures against the possible intrusion of sea water will have to be taken should large-scale withdrawal occur further inland.

The use of boreholes for the artificial recharge of water is an unattractive technique owing to the particularly high water level in the greater part of the area. Artificial recharge by means of exposed or covered infiltration channels or ponds, however, seems to be a feasible method and it is possible to store the expected 220 Mℓ of purified domestic sewage effluents, which will be available daily in the southern Cape Flats, for a period of one year whereafter it could be abstracted together with the natural groundwater.

The possible pollution of the water also received considerable attention under the project. In this regard attention is specifically focussed on the possible effects of solid waste disposal sites and the use of agricultural fertilisers and pesticides. It is evident, however, that these pollution sources have up to the present had a very small influence on the quality of the subterranean water, a fact which strikingly illustrates the stabilising effect and purification potential of the aquifer. Nevertheless, efforts should be made to at least limit or, preferably, to prohibit activities of this nature within the catchment area of the Cape Flats.

A preliminary mathematical model has been developed for determining through simulation the behaviour of the groundwater resource under a wide range of conditions and this can be utilised for the evaluation of a number of withdrawal situations. During the next year, this model will be further refined.

New contract with the Municipality of Cape Town

In view of rapid urban development in the Cape Flats, the Municipality of Cape Town had to adopt an accelerated programme of action as regards the construction, modernisation and extension of sewage purification facilities. Three sewage purification works, with an eventual combined capacity of approximately 400 Mℓ/d are currently under construction along the coast of False Bay. In two of the three installations provision is made for the biological removal of nitrogen and phosphate, with the result that the design of future reclamation works which will use some of these effluents, could be simplified considerably. The Cape Flats sewage purification works which will replace the oxidation pond system will be commissioned by the end of 1978 and an improved effluent will thus be available for the proposed 4,5 Mℓ/d demonstration reclamation plant.

In the light of these developments, it was necessary to reconsider the research programme and, as a result, the Commission entered into an agreement with the Municipality of Cape Town.

The new agreement provides *inter alia* that the construction of the complete 4,5 Mℓ/d reclamation plant be delayed until such time as the new Cape Flats sewage purification works becomes operational, enabling the reclamation plant to be planned and operated as an integral part of the sewage purification works. In the meantime, only part of the 4,5 Mℓ/d reclamation plant will be constructed to enable the NIWR to complete the infiltration studies in terms of the original contract. The Municipality of Cape Town will be responsible for the construction and operation of the interim plant.

Monitoring of microbiological quality of drinking water

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

The increasing world-wide consciousness of the importance of health aspects of water use has resulted in the Commission contracting the South African Institute for Medical Research (SAIMR) to undertake an intensive bacteriological, virological and epidemiological study of water produced by the reclamation processes in Windhoek and Daspoort and of conventional drinking water supplies.

Monitoring at Daspoort

During the year under review, the SAIMR laboratories in Johannesburg continued monitoring the microbiological qualities of water samples at different stages of purification in the Stander Reclamation Plant (Daspoort) in Pretoria.

Microbiological testing of these samples was performed in conjunction with the National Institute for Water Research (NIWR) who used similar techniques for their testing procedures and submitted duplicate samples to the SAIMR. In addition a limited number of samples was collected at monthly intervals by the SAIMR staff and subjected to microbiological examination.

From 1st April 1976 virological examinations were performed by the National Institute of Virology (NIV) in addition to those done at the NIWR laboratories. As expected, enteroviruses were found in the feed water, but no viruses could be recovered from samples after the final treatment process of the reclamation plant.

Bacteriological examinations were performed by the NIWR and SAIMR laboratories, using standardised techniques.

The results obtained by both these organisations indicated that the bacteriological quality of water samples after the final treatment process was high and conformed to international standards for public water supplies.

Monitoring in Windhoek

The SAIMR laboratories in Windhoek continued their research on health aspects of water in the three important fields of epidemiology, virology and bacteriology.

As far as the epidemiology is concerned, a close watch was kept on the occurrence of certain diseases relevant to this study in the Windhoek Municipal area. Intensive studies on patients admitted to both White and Non-white hospitals revealed no change in the pattern of disease known to exist in Windhoek. Attention was directed in particular to the occurrence of virus diseases. The Institute's new virus laboratory in Windhoek greatly facilitated work in this field.

Virological examinations were regularly carried out by the NIWR (Pretoria) and the SAIMR (Windhoek) for fixed sampling points. Virus was harvested in the Windhoek laboratory and submitted to the National Institute of Virology in Johannesburg for identification. Virus was not isolated during the year from sampling points after final treatment.

Bacteriological examinations were performed by the NIWR, SAIMR, Windhoek Municipality and the Department of Water Affairs (SWA branch).

The results from the different laboratories generally correlated well. The quality of samples of water drawn from the distribution system to the consumers conformed with the accepted standards for drinking water.

Chapter 3

Groundwater research

The efficient development and utilisation of the Republic's groundwater resources could make an important contribution in maintaining the country's water balance. The order of magnitude of the groundwater potential, however, cannot be predicted with certainty since adequate data are not available.

It is extremely difficult, with existing techniques, to obtain sufficient data on the exploitation potential of the Republic's groundwater sources due to large differences in the geohydrological characteristics of the waterbearing formations in the Republic, the conditions under which they occur and the variability of the climatological conditions.

Most of the techniques currently in use were developed in Europe and America and are applicable mainly to primary and artesian aquifers which do not generally occur in South Africa. These techniques must, therefore, be modified and new techniques developed for application under South African conditions.

Aware of these shortcomings, the Commission had already, in 1973, initiated various projects aimed specifically at the development of techniques for the determination of the groundwater potential which would be applicable under South African conditions. Progress reports for these projects are discussed further on in this chapter.

Study Group for Groundwater Research

From submissions received by the Commission from various organisations involved in groundwater research, it was clear that investigations and research had to be co-ordinated properly and executed methodically. The Commission considered it important that the expert advice of all interested bodies be obtained and, therefore, established a Study Group for Groundwater Research comprising representatives of the Department of Water Affairs, the Geological Survey of the Department of Mines, the Weather Bureau of the Department of Transport, the Department of Agricultural Technical Services, the Department of Forestry and the Water Research Commission. (The aims of the Study Group are discussed in detail in Chapter 2 of the 1975 Annual Report of the Commission).

As a result of excellent co-operation between members of the Study Group, a National Master Research Plan and a Priority Research Programme were already approved and accepted by the Commission during the first year of the Group's activities. The former contains the framework of different disciplines and aspects which require research and development, whilst the latter presents a broad outline of task areas which will need attention in the near future (see Chapter 2 of the 1975 Annual Report).

Visits by Study Group

During the year under review, the Study Group for Groundwater Research visited different problem areas in the country as well as various organisations involved in groundwater research and development programmes. The visits were arranged, firstly to identify research priorities and secondly to become acquainted with the activities and facilities of the relevant organisations in order to promote an effective co-ordination of the existing research activities.

Field visits were directed mainly at those projects supported by the Commission, and those undertaken by Geological Survey on behalf of the Department of Water Affairs and/or those initiated by the Department itself. The following visits were undertaken:

- Oviston, where a joint hydrogeological investigation is being undertaken by the Council for Scientific and Industrial Research and the University of the Orange Free State. The laboratories of the University were visited at the same time.
- The problem areas Pietersburg, Dendron and the Nile River Valley, where the Geological Survey and the Department of Water Affairs are actively engaged.
- The dolomitic area of the Far West Rand where intensive surveys are being undertaken by the Geological Survey.
- The Cape Flats, Mamre, Saldanha, Goudini, Rawsonville, De Doorns, Hex River and Beaufort West, where Geological Survey, the Department of Water Affairs (through the offices of the "Bureau de Recherches Géologiques et Minières" of France) and the CSIR are actively engaged in investigations.

- Sishen/Gamagara catchment where Geological Survey and the Nuclear Physics Research Unit of the University of the Witwatersrand are active.

Visits to research laboratories included the following:

- The Geophysics Division and the Isotope Research Laboratory of the National Physical Research Laboratory of the CSIR.
- Geological Survey.
- The Nuclear Physics Research Unit of the University of the Witwatersrand.
- The Hydrological Research Institute of the Department of Water Affairs.
- The Atomic Energy Board at Pelindaba.

The latter visit was arranged specially at the request of the Director-General of the Atomic Energy Board with the aim of determining the extent to which the Study Group could co-ordinate the collection and analysis of groundwater samples in order to allow uranium determinations to be carried out as well.

During discussions between representatives of the Atomic Energy Board, the Department of Water Affairs, Geological Survey, the Geohydrological Research Institute of the University of the Orange Free State and the Commission, it was arranged that as far as possible aliquots of all water samples collected during geohydrological surveys would be made available to the Atomic Energy Board for uranium analyses. It was also arranged that the results of these analyses would be stored in the data bank of the Department of Water Affairs and that the necessary precautionary steps would be taken to ensure confidentiality. The Board will evaluate the data progressively and publish reports on the results.

The Study Group considers this development to be of considerable importance since possibilities exist that the results of the uranium analyses may at a later stage elucidate the occurrence and movement of groundwater.

Recommendations resulting from the visits are currently awaited by the Commission from the various members of the Study Group.

Specialist services

As early as 1973 the Commission had approved certain recommendations on future groundwater research in the Republic, amongst which the following two aspects were specifically accentuated:

- Identification of priority problems and the determination of task areas and disciplines involved;
- Effective co-ordination of research activities in the Republic, *inter alia* by means of overseas expertise.

As a result an Israeli firm with extensive experience of groundwater investigations was approached to assist the Commission in identifying specific projects which should receive attention.

In the meantime the Commission has also obtained the services of Dr J F Enslin, former Director of Geological Survey, as specialist consultant for groundwater research and development. Dr Enslin will assist the Commission *inter alia* in preparing a situation statement on groundwater problems in the Republic of South Africa and on the development of priority research programmes.

Richards Bay

Lake Mzingazi, with an estimated assured yield of 55 × 10^3 m^3d^{-1}, has thus far been the only source developed as a water supply for Richards Bay and according to projections by the Richards Bay Town Board, the demand for water will exceed this figure by 1980. In order to satisfy future demands and to protect the existing water supply source against possible pollution as a result of the rapid urban and industrial development, the Department of Water Affairs had already planned a dam in the Mhlatuzi River, and the Town and Regional Planning Commission of the Natal Provincial Administration, in collaboration with the Richards Bay Town Board and through the Council for Scientific and Industrial Research, had commissioned an investigation into the origin and flow pattern of the subterranean inflow of water to the Mzingazi River. Coupled with this, the Industrial Development Corporation (IDC) had also commissioned investigations into the occurrence and possible exploitation of groundwater to serve as a water supply source for the extraction of titanium ore from the sand dunes along the coastline north of Richards Bay.

In the light of these requirements and to ensure that local sources are fully developed and utilized, the Department of Water Affairs requested the Commission at the beginning of 1974 to evaluate the findings from the investigations of the CSIR and the IDC and to make appropriate proposals with regard to the necessity for expanding or accelerating these activities in order to determine the groundwater potential of the area as a whole. After considering a report on this matter and because of indications that considerable quantities of groundwater are available in the area, the Commission decided to establish a Co-ordinating Research and Development Committee (CRD committee) to develop a suitable research and development programme and to make recommendations with regard to the co-ordination and execution of the project. The CRD Committee consisted of representatives from the Department of Water Affairs, the Department of Forestry, the Department of Mines (Geological Survey), the Industrial Development Corporation, the Town and Regional Planning Commission of the Natal Provincial Administration, the Richards Bay Town Board, the Council for Scientific and Industrial Research and the Water Research Commission.

On the basis of the findings of the CRD Committee it was estimated that the assured yield of groundwater from the sand deposits on the coastal plain between Richards Bay and the Umfolozi River amounts to approximately 160 × 10^6m^3 per annum. Owing to the complexity of the geohydrological conditions it became very clear however, that practical problems would be encountered in effectively exploiting this source and the Committee therefore recommended that

Dr Y Bachmat of the Hebrew University of Jerusalem visited the Water Research Commission as specialist consultant on groundwater research in the Republic. Dr Bachmat was previously closely involved in developing groundwater resources in the coastal plains of Western Israel.

a specialist consultant be appointed to undertake an in-depth study in this regard.

Acting on the recommendations of the CRD Committee, the Commission appointed Dr Y Bachmat of the Hebrew University of Jerusalem as specialist consultant. Dr Bachmat had been closely involved in the development of the groundwater sources in the coastal plains of the west coast of Israel and is regarded as an expert in this field.

In Dr Bachmat's report the estimated assured yield of the underground aquifer is more conservatively indicated as 93 $\times$ $10^6 m^3$ per annum, instead of 160 $\times$ $10^6 m^3$ per annum as tentatively estimated by the CRD Committee. This difference is attributed to a higher loss of recharge water through evapotranspiration and seepage to the sea. However, the figures are based on information currently available which is insufficient for an accurate estimate of the assured yield of the aquifer and consequently Dr Bachmat suggested that an overall programme of investigation and research be initiated to cover all aspects of the problem. In this regard attention is focussed not only on the collection of the historical hydrogeological data of the area, but also on aspects which determine the practical exploitation of the source.

In order to execute the research and development programme, as suggested by Dr Bachmat, it was necessary to negotiate with suitable local and overseas firms.

During these negotiations it was agreed that the consulting firm TAHAL of Israel, in collaboration with one of the local consulting firms, would prepare a joint proposal for the execution of the project and that this would be submitted to the Commission for consideration. The proposal was considered by the Commission during 1976 and during the ensuing discussions with representatives of the two firms it was decided that the project be held in abeyance until such time as the final report of the Council for Scientific and Industrial Research on work done at Lake Mzingazi is completed. It is envisaged that this report will be available by the end of 1977.

RESEARCH PROJECTS

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

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

This project entails an investigation into the possibility of the storage and abstraction of all excess water of the Eerste River in and from the sand beds of the eastern part of the Cape Flats, i.e. storm water flowing to the sea after demands on the Eerste River for urban and agricultural purposes had been satisfied.

During 1976 an intensive investigation of the eastern part of the Cape Flats was commenced and it was found that it would be possible to accumulate the excess water from the Eerste River in a naturally occurring depression in the sand dunes from which water could possibly infiltrate rapidly into the sand. Boreholes were drilled in this region in order to investigate the nature and extent of the sand deposit and of the associated groundwater.

Sixteen boreholes were drilled in an area covering approximately 20 km^2 and a mean depth of sand of approximately 26 m was found overlying a basement of weathered Malmesbury shale. The basement displays a general slope in a south-easterly direction towards the sea and corresponds roughly to the general slope of the ground surface in the area. Piezometric contours of the groundwater level, as found in the boreholes, indicate that the groundwater is also moving generally in a south-easterly direction towards the sea.

Layers of clay, peat and calcrete were found at irregular depths in the sand deposit. The sand can mostly be described as very fine on the basis of its effective particle size. Fragmented shell occurs generally in the sand, with a few layers containing rough shell fragments, indicative of fluctuations in the stand of the sea level during the deposition of the sand beds.

The groundwater samples from the boreholes generally contain high concentrations of dissolved salts. Total dissolved solids vary between 440 and 17 800 mg/ℓ with fifteen boreholes containing less than 3 000 mg/ℓ and three less than 500 ppm. The salt content of the water of the Eerste River in the Jonkershoek Valley was 40 ppm and less during the summer, whilst lower down, near Faure, it was often 2 200 mg/ℓ. During summer the water of the Kuils River mostly contained approximately 800 ppm dissolved solids at the point where it intersects the old Cape Town-Somerset West Road.

The available statistics on the runoff of the Eerste River and the Kuils River were obtained from the relevant authorities. These data are now being studied with a view to

compiling synthetic runoff figures by means of which an operational analysis can be carried out to estimate the volume of water which could be stored annually in the sand beds when operating within the limits of a specific system.

Information on planned land use in the eastern part of the Cape Flats, from Weltevreden Road to the Eerste River, was collected and a map compiled. This map will assist in determining the constraints of any proposed system of water storage and withdrawal in this part of the Cape Flats sand beds.

Development and evaluation of techniques for determining the exploitation potential of groundwater resources in the southern Orange Free State and North Western Cape

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

Most towns and farming communities in the Southern Free State are dependent mainly on groundwater as a water supply source. These underground sources normally have low yielding rates, are susceptible to changes in rainfall, not very reliable and are difficult to locate. The development of additional techniques for determining the groundwater potential of these resources is, therefore, essential and research on this is currently being done by the Institute for Groundwater Studies of the University of the Orange Free State under contract to the Commission. At the same time the Institute is also doing research on the development of techniques for the determination of the groundwater potential of the dolomites in the Northern Cape.

Southern Free State

Dolerite basin structures in the Southern Free State, especially in the area immediately to the north of the Orange River, are well exposed and these structures are currently being subjected to geological and geohydrological investigations. Special attention is being given to the determination of the mode of occurrence and the relationship between the basin structures and other dolerite intrusions such as dolerite dykes and sills. This involves the measurement of the basin wall gradients to enable depth projections to be made. Joints are subsequently analysed and weathered zones in the basin structures investigated. This work will be followed up during the coming year with geophysical research.

An interesting aspect exposed by research is that the dolerite dykes are of a more recent age than the basin structures. The dykes therefore cut through the dolerite of the basin structures and may serve as drainage canals from the latter. The question of whether the dykes at great depths are sufficiently permeable to drain the basin structures completely, will however still have to be investigated.

The groundwater in the area can also be divided into two categories, *viz.* old and recent water – the distinction can clearly be proved by means of chemical analyses of the groundwater. In general the aquifers in which old groundwater occurs exhibit the largest yield and consequently this water is used for irrigation on a number of farms. The older water, however, usually contains relatively high concentrations of sodium and chloride, which necessitate the periodic application of agricultural lime to the soil.

As soon as sufficient information on the nature and distribution of the aquifers in the Southern Free State has been obtained, observation boreholes will be drilled at selected localities.

Northern Cape

As a result of the heavy rains of the past three years the groundwater in the area rose to levels which created many new fountains. Owing to the raised groundwater level, surface water cannot drain away and totally anomalous geohydrological conditions have arisen. This has impeded the geohydrological research considerably, since the observations made during this period cannot be projected to the more prevalent dry period conditions. The yield of an observation hole drilled at Vryburg, for example, was calculated during a pump test to be more than 6000 m^3/d. It will, however, be of much greater significance to determine the yield of this borehole during a drier period.

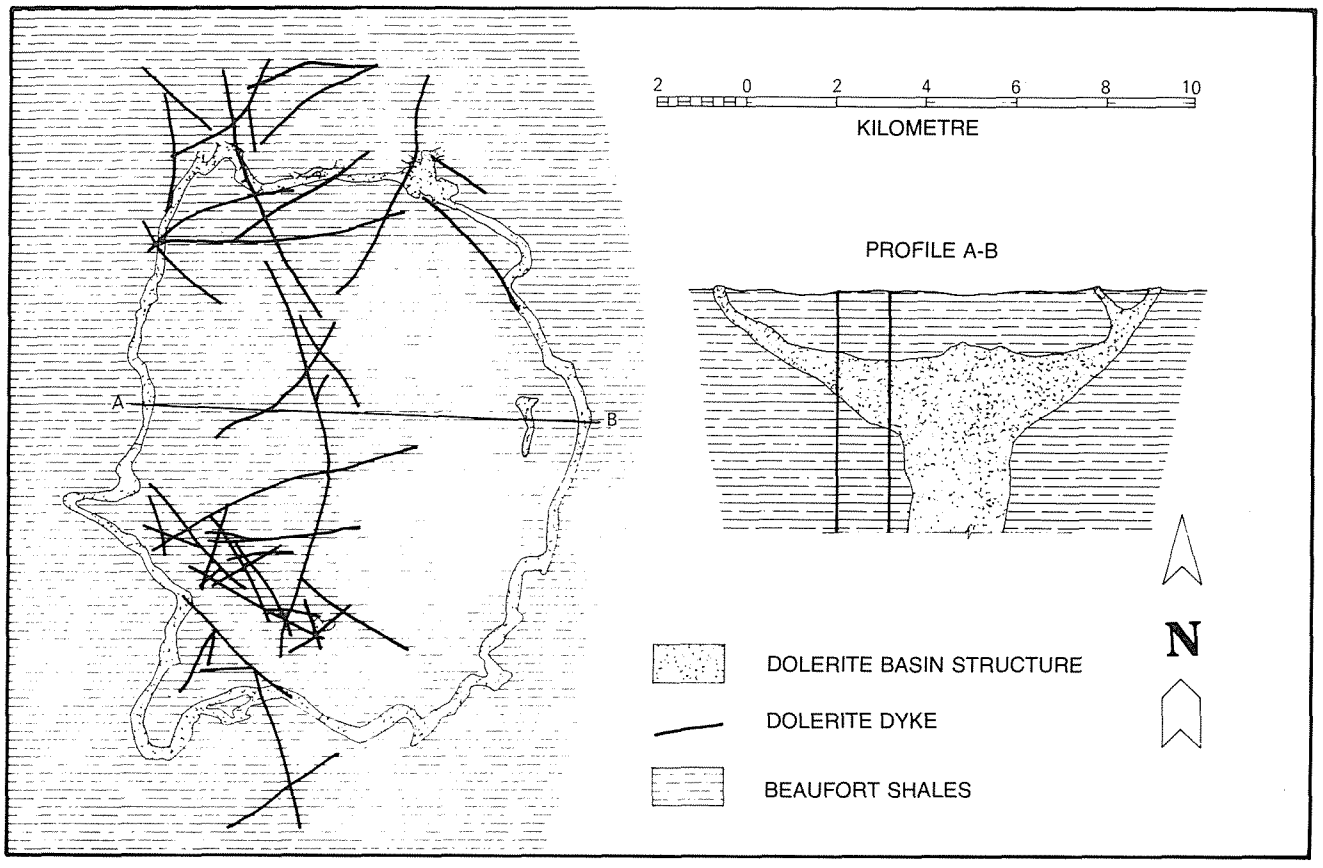
Despite these unfavourable conditions, good progress has been made. The preliminary investigation into the groundwater potential in the Vryburg area has been completed and a mathematical model simulating the water level fluctuations has been developed. Currently more observation holes are being drilled and geohydrological parameters measured on a regular basis. This investigation has also been extended to the south-west of Vryburg and field work is currently under way in the Reivilo region. Research is directed towards the demarcation of the water compartments which will enable the strategic siting of boreholes for the determination of the specific yields of such compartments.

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 project entails the development of techniques for the determination of 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.

During the year under review the work in an area at Venterstad south of the Hendrik Verwoerd Dam was completed. The geophysical work consisted mainly of electrical soundings, as well as the application of the rectangle of resistivities technique and magnetic surveys whilst the geological and geohydrological observations consisted mainly of geological mapping, chemical analyses of groundwater and other hydrological aspects.



Plan and section of the Doornkloof basin structure in the Venterstad area.

Geophysical surveys showed an east-west trough in the upper part of the Karoo Super Group in this region in which definitely less dolerite occurs than in the adjacent areas. The southern side of this trough corresponds to the east-west jointed area of Shaft 2 of the Orange Fish tunnel. From electrical soundings done in the Venterstad, De Aar and Britstown areas it appeared that dolerite greatly influences the electrical profiles. A thorough study of this has shown that the electrical resistivity method is not a very suitable geophysical technique for indicating variations in the electrical characteristics of the basement under these geological conditions, since very large current electrode spacings are required. Variations in the basement could indicate a fault zone or jointed area and it is, therefore, important that this should be located.

A regional magnetic survey was also done and positive magnetic anomalies were found which could be traced from the border of Lesotho to Upington. It would seem that the reason for these anomalies are to be found in the basement and that an indirect structural relationship exists between the "Doornberg Fault Zone" and the magnetic anomalies. Geophysical work consisting mainly of electrical soundings is currently being done in the vicinity of Prieska.

The most important conclusion which has resulted from the geological and geohydrological observations in the vicinity of Venterstad is undoubtedly the fact that two generations of groundwater occur in the area. The first, namely recent groundwater, is of little importance because of the relatively small extent and permeability of the aquifer and is, therefore, used mainly for cattle-watering and domestic purposes. In contrast, the second type of groundwater is older and representative of deep circulating water. Hydrochemical techniques allowed a distinction to be made between the two types of groundwater, and in addition the results of the chemical analyses gave a clear indication of aspects such as the relative ages of groundwater occurrences, the relative degree of mixing of the two types of water and the influence of bacterial action during circulation of the second type of groundwater.

Although the older type of groundwater currently occurs mainly in the presence of dolerite dykes it would at a deeper level possibly be connected to a fault zone. Should this be the case, chemical analyses of groundwater samples could play an important role in tracing the fault zone to both sides of the area of investigation.

In order to test this method, the hydrochemical investigation was extended to the Vosburg region. In addition, geohydrological surveys in the Prieska area were commenced. This investigation mainly involves the following aspects:

- Compilation of a geohydrological map.
- Measurement and representation of any geological structures which may indicate the presence of aquifers.
- Measurement of water levels, water temperatures and borehole yields.
- Sampling of groundwater for chemical analyses of macro and trace elements.

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)

Groundwater in the Gamagara catchment in the north-western Cape (important for its agricultural potential and its mining development) is being studied using environmental isotope techniques in order to evaluate these techniques as quantitative tools for geohydrology in this semi-arid environment, and at the same time to contribute to the knowledge of groundwater movement, storage and recharge. This study is being supplemented by chemical, trace element and other speciality observations, and is conducted in close co-operation with geologists and geohydrologists of ISCOR and the Geological Survey.

The environmental (naturally occurring) isotopes used are either radioactive, *viz.* ^{14}C (which allows for long-term water age determination) and ^{3}H (with which short-term water movement can be determined), or stable, *viz.* ^{2}H, ^{13}C and ^{18}O, the concentrations of which vary with change of phase and chemical composition and, therefore, type the water according to origin and history.

During the year under review, most of the research effort has been concentrated at and around Sishen Mine, situated in the southern headwaters region of the catchment, where large and potentially troublesome volumes of groundwater are being encountered. Northwards, where sub-surface drainage tends to concentrate into so-called troughs filled with recent or Kalahari deposits, groundwater supplies are generally smaller.

The picture that began to emerge during the first project year (see 1975 Annual Report) has been developed and aspects were examined in greater detail. Repeated sampling of certain dewatering points has indicated the remarkable constancy and therefore extent of some of the water bodies encountered. Superficial, intermediate, and deep (age >30 000 years) cycling waters are being identified in the southern catchment. Regional sampling is providing a clearer picture of regional groundwater flow and possible areas of infiltration further north.

Portable pumping equipment specially designed for this project is used extensively to obtain water samples from observation boreholes and at different horizons. The technique for analysing soil moisture from the unsaturated zone has been refined. Stable isotope determinations are now conducted on a routine basis and the rate of handling ^{14}C measurements has been increased.

Trace element analysis by means of charged particle induced X-rays has been developed and is employed as an additional tool in identifying groundwater bodies. Chemical analyses are correlated with isotope data, providing new insight into the chemical evolution and recharge patterns of groundwater in this environment.

Data acquisition is expected to continue well into 1977, when information will be collated in the form of a final report. A further period of about six months will be needed to correlate isotopic and other geohydrological data.

Chapter 4

Water economy measures

Considerable opportunities exist in the industrial and municipal sectors for water savings which could be effected if the necessary techniques were developed and applied. The Commission already supports a few projects in this regard and has also established a Co-ordinating Research and Development Committee for Water Economy Measures in Urban Areas to determine relevant research requirements and to identify water economy measures and equipment which could be implemented and utilized without delay.

Investigations which relate to water saving and which are already being financed by the Commission, are the following:

- **Dry cooling.** Wet cooling is one of the industrial processes responsible for large-scale consumptive use of water. Dry cooling offers an alternative whereby large volumes of water may be saved, but the associated capital cost is high and it is, therefore, being applied only on a limited scale. Investigations by the National Mechanical Engineering Research Institute are directed at the optimisation of heat exchangers for dry cooling systems at power stations.

- **Water losses in distribution systems.** Considerable water losses occur in distribution systems – in some cases as much as 14 per cent of the water supplied. The Department of Chemical Engineering of the University of Pretoria is investigating losses from pipe networks with a view to determining the causes and extent of water losses and, secondly, to testing methods for the prevention of these losses.

- **Water consumption patterns.** The per capita consumption of water in South Africa's urban areas is relatively high and it is necessary to establish standards for various uses. With this in view, the Department of Chemical Engineering of the University of Pretoria is investigating the water consumption patterns of the domestic and industrial sectors. Attention is focused on the influence of variations in stand sizes, different income groups and differential water tariffs on water consumption. In addition the question of water metering is studied since effective metering promotes good consumption control.

More information on the abovementioned research and the progress already made follows below.

RESEARCH PROJECTS

Research on dry cooling

(Existing project: Contract with the CSIR – National Mechanical Engineering Research Institute)

During the year under review investigations were continued into the optimization of heat exchangers for dry-cooling systems for power generating stations.

In the conventional wet-cooling system the water to be cooled is sprayed into the air stream within the cooling tower. The cooling effect is therefore, principally by evaporation of water into the air. This evaporated water is discharged into the atmosphere and never recovered.

With dry cooling, however, the water to be cooled flows through tubes of a heat exchanger positioned at the air inlet to the cooling tower. This process eliminates direct contact between the water to be cooled and the air and thus prevents the loss of water due to evaporation.

However, the capital outlay of a dry-cooling system is approximately 50 per cent costlier than that of a conventional wet-cooling system, due to the high costs of the heat exchangers.

Work carried out in terms of this contract is aimed at developing a high performance heat exchanger for dry-cooling systems in order to make these systems economically more competitive with conventional water-consuming wet systems. A survey was, therefore, undertaken of a large number of different heat exchanger types, and some were tested in the Institute's wind tunnel.

Test results allowed prediction of the performance of these heat exchangers when operating under natural draught dry-cooling conditions. On the basis of these performance data two different designs were selected for further development. Both designs are of the tube-fin extended surface type. One type comprises steel tube water passages and aluminium fins although other tube and fin materials can also be used; the other is a modified truck radiator comprising brass tubes and copper fins.

Prototypes of the two heat exchangers were manufactured by two industrial firms and the heat transfer and pressure drop characteristics of these units were determined in the Institute's wind tunnel.

The basic concept of the exercise was to evaluate the performance and the engineering problems of prototype dry-cooling units and to establish whether their large scale manufacture would be commercially viable.

Results thus far indicate that commercial manufacturing of the relevant heat exchangers may cause problems. Feasibility testing in this regard is not included in the assignment of the Commission and the CSIR and endeavours must be made to obtain the interest of commercial undertakings in this matter.

Water losses in pipe networks

(Existing project: Contract with the University of Pretoria – Department of Chemical Engineering (Water Utilization))

This project consists of two phases, *viz.* determining the extent of water losses in pipe networks, and its prevention and control.

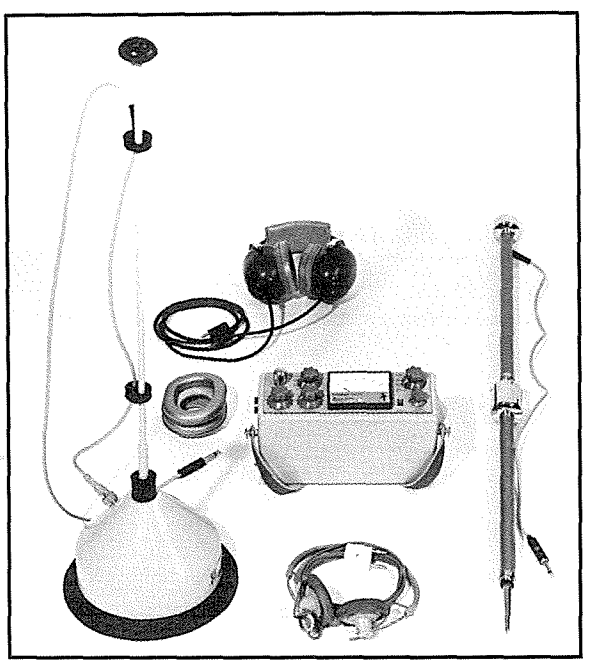
Losses in pipe networks have serious implications for water supply systems: more water must be transported, and more purification and storage is necessary. This project can therefore contribute to the alleviation of these problems. The research has already given an indication of the extent of losses and how they may be detected. The methodology, however, still has to be investigated, regulated and tested, whereafter it can be made available to interested parties.

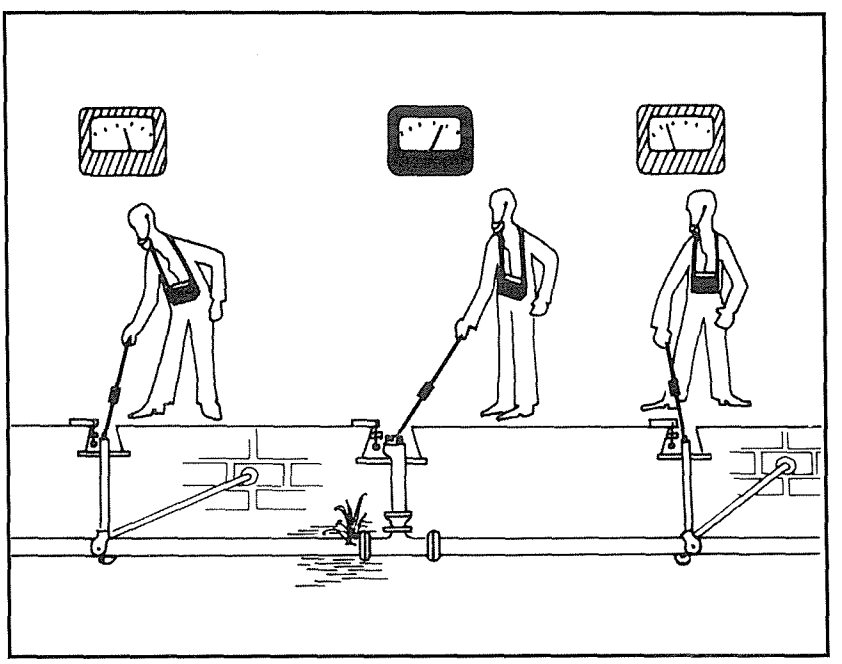
During 1976 further subdivisions of the first phase of the project were completed. The following assignments were completed totally or in part during the year under review:

- Literature study of detection methods.
- Study of detection apparatus and its suitability under South African conditions.
- Field investigations into network losses and determining the components of non-accountable water for certain selected areas in Pinetown, Cape Town, Johannesburg and Pretoria.

The first two assignments have been completed and also the field investigations in Pinetown and Cape Town. From the

Equipment used for tracing leakages in pipes.
The diagram shows the way in which the equipment is applied.





literature study it would seem that a combination of detection methods would yield the best results and field investigations were therefore based on this principle. Field investigations comprise *inter alia:*

- Selection and preparation of residential areas with 200–400 water consumers.
- Installation of bulk flow meters in each area in order to measure total water consumption.
- Determination of flow loss rates for the selected areas when all consumer connections are shut down.
- Determination of the minimum night flow rates between 02h00 and 04h00.
- Sonic investigation of the pipe network in the areas by means of electronic detection apparatus. Leakages found during detection are pinpointed and repaired and the order of magnitude of the leakage is estimated.
- Non-accountable water is determined on a monthly basis by means of bulk and consumer meters.

As a result of delays in the delivery and transport of the bulk flow meters, field investigations will only be completed by the end of May 1977.

The second phase of the project, which entails a study of methods for the prevention and control of water losses, will commence in January 1977 and will be undertaken in conjunction with the remaining field investigations.

Water consumption patterns in urban areas

(Existing project: Contract with the University of Pretoria – Department of Chemical Engineering (Water Utilization))

Domestic and industrial water consumption currently constitutes almost 25 per cent of South Africa's total water consumption. It is calculated that by the end of the century this could amount to more than 55 per cent. In the light of these trends, it became desirable to obtain information on water consumption patterns in the industrial and domestic sectors, as this could provide guidelines for future water allocations and for the planned reuse of water. It could also lead to the optimization of water systems.

During the year under review, research dealt with the first seven tasks of the project assignment, *viz.*

- Water consumption patterns in respect of dwellings, apartment buildings and commercial and industrial sectors.
- Water consumption per capita on residential stands of varying sizes and for varying income groups, in both dwellings and apartments.
- Water consumption patterns in the domestic and commercial sectors.
- The effect of water tariffs on consumption patterns.
- Water consumption patterns for public purposes in areas controlled by local and other authorities.
- Water requirements for sanitary purposes.
- Establishment of norms for water consumption in the different geographic areas, based on the investigation.

During the period under review it was endeavoured to collect existing data as well as to generate information for those tasks hampered by a paucity of information. The literature study has been completed and liaison has already been established with relevant organizations at the investigation centres.

Water consumption patterns in the domestic sectors are currently being investigated by means of questionnaires. Data should be available in the near future and should give an indication of the following:

- Basic consumption: household, cleaning, drinking, boiling, personal hygiene, hand washing of clothes and dishes, toilets.
- Consumption in appliances: washing machines, dishwashers.
- Consumption in special appliances: air conditioners, waste disposers.
- Consumption outside the home: gardening, washing of paved surfaces, car washing.
- Wastage: leaking taps and appliances.

During the investigation into the per capita water consumption on residential stands, the influence of consumption limiting installations on water usage in Black residential areas is *inter alia* being studied. It has been noticeable that water consumption figures differ substantially for Blacks in different areas and of different ethnic groups, with the consumption figures of homeland residents being substantially higher than those of the urban Black.

The influence of private boreholes on water consumption patterns is also being studied. The investigation can only be done in inland cities however, since very few private boreholes are to be found in coastal cities.

Chapter 5

Effluent and waste treatment

In a country with limited water resources it is vitally important that pollution of existing water supplies be limited as far as possible since the utilization value of water sources could be seriously impaired by the discharge of effluents which have not been adequately purified. An advanced technology with regard to the purification of municipal and industrial effluents is therefore required and for this reason the Commission applies funds to this end.

As far as the purification of municipal effluents is concerned, the Commission currently concentrates its funding on projects (at the University of Cape Town and the National Institute for Water Research) which aim at the biological removal of nitrogen and phosphorus by means of the activated sludge process. Excessive quantities of these elements in water bodies lead to eutrophication and their limitation in effluents could to a large extent contribute to the control of eutrophication problems. Although the research has not yet been completed, results are already being applied in the country at a few large sewage purification works which effectively remove phosphorus and nitrogen.

Certain industries in South Africa produce effluents which are difficult to manage and to purify in order to meet the quality requirements of the Water Act. The Commission deems it to be of national importance to assist these industries in developing techniques to improve the quality of their effluents and simultaneously to encourage internal reuse of water. This is done on a basis of collaboration whereby the industry itself contributes an input by means of facilities and manpower. In determining the needs and in planning for this type of research, the Commission established close liaison with different industries by creating Co-ordinating Research and Development Committees for the following industries: the textile industry; mining industry; fruit and vegetable canning industry; and the abattoir, tanning and related industries.

The Commission also follows the procedure, where possible, of bringing overseas specialist consultants to the Republic to evaluate effluent management in specific industries against the background of overseas practices, and to make recommendations on research which may be required. On this basis an expert has already visited the Republic on behalf of the abattoir, tanning and related industries, and early in 1977 an expert will be arriving in South Africa to study the water and effluent problems of the fruit and vegetable canning industries.

Up to the present the Commission has paid only limited attention to the management of sludge and toxic wastes. The only relevant research being actively supported at this stage is a project on the management and disposal of water works sludge by the University of Pretoria. It is becoming increasingly clear, however, that more effective attention should be paid, also on a research level, to the disposal of sludges, and of solid and toxic wastes and the Commission is planning steps for 1977 to determine the needs in this regard and to initiate applicable research where necessary.

RESEARCH PROJECTS

Research on the activated sludge process

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

Treatment of organically polluted effluents by means of the activated sludge process is effective not only in removing the carbonaceous energy from a wastewater, but also in removing the eutrophication elements nitrogen and phosphorus. With the objective of developing general design criteria for optimum overall removal of nutrients, various aspects of the activated sludge process are being investigated.

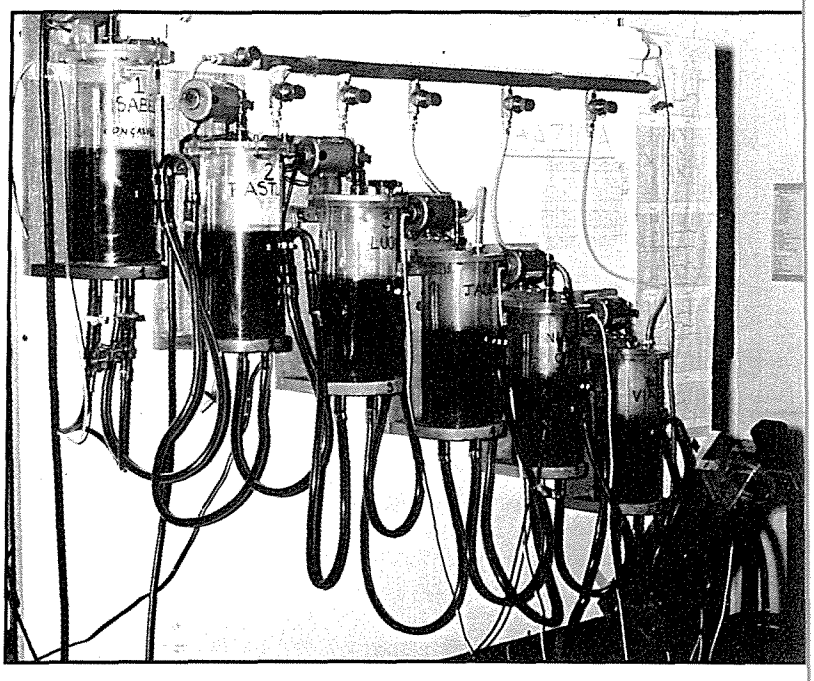
Research on the removal of nitrogen and phosphorus from wastewaters by biological means is continuing and during the

year under review it was established that the processes are temperature dependent. The work on nitrogen removal at lower temperatures is essentially complete and allows design criteria to be formulated. Phosphorus removal still presents many problems, as the basic mechanism which brings about removal is not understood. Work at 20°C has shown that the process achieves maximum efficiency when the retention time in the anoxic reactor is approximately ½ hour. Investigations designed to determine optimum retention times at lower temperatures have been commenced, but are still at a relatively preliminary stage.

Investigations were also commenced to settle the vexing question of whether phosphorus removal is a chemical or a biological process, or both. The research work shows conclusively that the removal of phosphorus in Cape waters is exclusively biological.

Research into the kinetics of the activated sludge process has facilitated the compilation of a generalised computer programme to simulate the activated sludge process in either series or completely mixed systems. This program predicts the performance under any system of cyclic input loading. Work on the steady state behaviour of the system is essentially complete and has been presented in a final report submitted for publication.

Studies into dissolved-air flotation as applied to the activated sludge process are complete. The basic relationships describing the process behaviour have been developed for activated sludge and verified, using sludges derived from treatment of the brown waters of the Cape. A number of papers on this aspect have been published, or submitted for publication.



Laboratory-scale equipment used by the Civil Engineering Department of the University of Cape Town for studying the activated sludge process.

Development of criteria for removal of nitrogen and phosphorus from sewage effluents by means of improved biological treatment processes

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

As the previous Annual Report reflects, it is now generally accepted that it is possible to achieve enhanced phosphorus removal in activated sludge processes, and there is a large measure of agreement as to the conditions under which it is likely to be achieved.

Workers in this field have this year had to reckon with the fact, however, that it is not yet clear how the very high removals of phosphorus that occasionally occur may be reliably achieved. Moreover, there is as yet no widely acknowledged explanation of the mechanism of phosphate removal.

This year's progress has included valuable confirmations of certain previous hypotheses, but on the other hand much of the work has produced results of which the interpretation is not yet clear. Fundamental bacteriological investigations are presently being undertaken in order to gain a better understanding of the mechanisms involved.

It is most encouraging that at this difficult stage of research the liaison between the South African research groups active in this important field (NIWR, University of Cape Town, and Johannesburg City Council) has been greatly strengthened. In order to establish this liaison the Cape Town group was involved in the NIWR's project and, in fact, one of the team members executed a research programme of six months at the NIWR's pilot plant at Daspoort, Pretoria. As a result of the findings up to that stage and of the fact that the Johannesburg Municipality already possesses a large-scale plant which reliably removes high percentages of nitrogen and phosphorus, representatives of the three groups met in October 1976 and it was resolved that their respective expertise and scientific knowledge were to be shared on a collaborative basis and that a joint programme would be executed. The programme will concentrate on practical problems relating to the design and operation of full-scale plants. The eventual objective is to establish design and operational criteria for plants directed at the removal of nitrogen and phosphorus from wastewater in order to limit the inflow of nutrient elements to the water environment and in this way to alleviate eutrophication problems.

Removal of sludge and wash water at water purification installations

(Existing project: Contract with the University of Pretoria – Department of Chemical Engineering (Water Utilization))

This project entails the development of technology and criteria for the economic treatment and disposal of coagula-

tion sludge and wash waters derived from water purification works.

Sludge arising from the treatment of polluted waters causes odour problems and, where discharged into the water environment, exercises an oxygen demand and can sometimes cause corrosion and possible toxicity. In contrast, the effect of sludge derived from the treatment of natural waters is less clear. Apart from suspended material which it contributes to the water environment, it would probably not impose many other detrimental effects.

The water works at Bronkhorstspruit, Witbank, Rietvlei, Brits and Temba were selected for the initial investigation as waters of varying qualities are being treated at these plants and because the plants are of limited capacity. Natural water is purified at the first two plants and polluted water at the last three. Aluminium sulphate is used as coagulant at all the installations. Sludge and wash water characteristics are being studied as well as the effect of the purification method on quantitative sludge production.

During the study period, sludge volumes at the different installations varied from 0,46 per cent to 1,31 per cent of the purified water, whilst wash water volumes varied from 0,37 per cent to 1,75 per cent.

The quality of the sludge and wash waters falls far short of the general standard for industrial effluents in terms of the Water Act. The concentration of suspended matter in the sludges varies from 4 400 to 7 000 mg/ℓ whilst that of the wastewater varies from 40 to 1 240 mg/ℓ. The chemical oxygen demand (COD) of sludges derived from natural waters is approximately 500 mg/ℓ whilst that of sludges derived from polluted waters varies from 820 to 1 200 mg/ℓ. The COD of the wash waters varies from 8 to 150 mg/ℓ.

The ease with which various sludges can be filtered, differs to a greater or a lesser extent. Sludge from primary sedimentation filters more easily than that from secondary sedimentation, whilst wash water sludges, which consist of pure aluminium hydroxide are the most difficult to filter. It has been established that pH has a definite effect on the ease of filtration and that there is an optimum pH for filtration. It has been further established that the ageing of sludges derived from polluted waters improved the filtration process. This could probably be ascribed to the oxidation of organic material.

At Witbank, where the effect of two different sedimentation processes on sludge production has been investigated, it has been found that the quantity of sludge produced by the radial flow clarifiers is approximately half that produced by the vertical flow clarifier. The reason for this is that sludge thickening occurs to a much greater extent in the radial clarifier where, as a result of scraping, of better mechanical flocculation and of the sludge withdrawal method, a thicker sludge can be discharged.

At Rietvlei, where the effect of lengthened intervals of sludge withdrawal has been investigated, it has been found that sludge production was dramatically decreased by lengthening the intervals of withdrawal. At intervals varying from 8 to 96 hours sludge volumes decreased by 92 per cent. This corresponds to 0,54 per cent of the treated water which could additionally be reclaimed.

It has also been found that the simultaneous application of flash mixing and mechanical flocculation produces smaller sludge volumes than their separate applications. The use of an organic polymer coagulant in conjunction with aluminium sulphate produces smaller sludge volumes than the use of aluminium sulphate only. The use of polymer coagulants to reduce sludge volumes will be further investigated.

Sludge and wash water characteristics are currently being studied at the Rand Water Board's Zuikerbosch water works. Sedimentation studies for thickener and lagoon designs are being undertaken and different mechanical methods for sludge dewatering are also being evaluated.

Recycling of water and recovery of chemicals in the textile industry

(Existing project: Contract with the University of Natal – Department of Chemical Engineering)

Complete surveys of the most important effluent problems in the textile industry have shown that the most advantageous system for effluent treatment in this industry entails closed-loop recycling of water and reclamation of chemical waste products rather than treating the final effluent. This is in fact the approach taken by the Pollution Research Group of the Chemical Engineering Department of the University of Natal in its investigations into effluent problems in the textile industry.

Following the identification of the major polluting effluent sources from the textile industry – wool scouring, desizing, dyeing, mercerising and kiering – the research during the year under review has concentrated on two of these, *viz.*, wool scouring and desizing. These two are more amenable to treatment by means of closed loop-recycle operations involving recovery of chemicals and recycling of water than the others, with a consequent major reduction in the quantity and pollution load of the effluent.

The Pollution Research Group had for some time been investigating the management of dyeing effluent on behalf of a prominent textile manufacturer. At the end of 1976 this work was brought under the auspices of the Master Research Plan of the Co-ordinating Research and Development Committee for Effluent Problems in the Textile Industry, which had been established by the Water Research Commission. It was then agreed that the contract with the University be amended to incorporate the work on dye-house effluent in partnership with the manufacturer involved.

Sizing/weaving/desizing effluent

The desizing project involves the recovery of polyacrylate size by ultrafiltration from the desizing wash waters to produce a concentrated size solution for reuse and water of sufficient quality for recycling back to the washer. The success of this closed loop recycle system depends on a number of factors:

- changeover by the weaving mills to polyacrylate size from polyacrylate/starch mixes used for sizing.
- successful reuse of the recovered size.
- high efficiency of removal of the size from the cloth.
- the ultrafiltration separation process.

Sizing and weaving trials based on these principles at two large cotton textile mills have yielded promising results. Some physical deficiencies of the size have appeared during weaving with polyacrylate-sized cloth but it is expected that modifications to the polymer size will overcome these. The polyacrylate sizes are very soluble in water and it has been found that low water-to-cloth ratios in the washing out operation give high removal efficiencies. This is important as the economics of the concentration of the size by ultrafiltration is very dependent on the feed concentration. The laboratory scale ultrafiltration investigations have been most encouraging with good permeate flux rates and high recovery of the size being obtained. A mathematical model of the ultrafiltration stage is being developed to predict optimum performance of the equipment in terms of flux rates, membrane area and pumping costs. The next step will be pilot plant size recovery using high temperature membranes. The future research and development of this system will provide data for the assessment of the technical and economic viability in terms of savings of chemicals, heat, and water together with the impact of the recovery system on cotton mill effluent discharges.

Wool scouring effluent

This effluent, produced by the scouring of raw wool with hot water detergent is complex, highly coloured and very difficult to treat. It contains up to 5 per cent total solids, of which 30–50 per cent are emulsified grease, 20–40 per cent dirt and 20–40 per cent suint. The grease is a valuable byproduct when refined into lanolin and considerable research and development effort throughout the world has gone into efficient extraction methods. The one in common use is centrifugal recovery, but the overall efficiency is only 20–45 per cent and the remaining effluent is still a potent source of pollution.

The two most attractive grease separation techniques to increase the removal efficiency are flotation using adsorbed gas bubbles, and ultrafiltration. Flotation has been found to be the more promising technique.

Flotation experiments with this effluent using electroflotation or pressure dissolved air flotation have indicated that between 50 and 70 per cent of the grease can be removed and that the remainder of the grease can be flocculated out to produce a virtually grease-free effluent. The flotation results are, however, not consistent and attention is now being focused on the control of the physical parameters – pH, temperature, grease particle charge and detergent concentration – to optimise the flotation efficiency.

Attention has also been given to the overall treatability of this effluent after grease extraction with studies on biological degradation, activated carbon, and biosorption in order to assess its recycle potential.

Dyehouse effluents

Work on the closed loop recycle of dyehouse effluents and on the reclamation of auxiliary chemicals is nearing completion and it has been recommended that this work should be extended to cover all dyeing and printing operations in the textile industry. To date, various effluents discharged from wool/synthetic dyehouses have been successfully treated at pilot plant level and the water reused over several cycles. This programme included acrylic, wool, nylon, polyester and viscose fibre types, using basic, acid, metal complex, direct, disperse, after chrome and reactive dyestuffs for the carpet and garment industries.

Future work will be concentrated on printing and dyeing effluents from cotton and cotton/synthetic mills.

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 effluents may adversely affect the performance of sewage purification works. These metals can normally be removed by the addition of chemicals – a costly process.

The Department of Chemical Engineering of the University of the Witwatersrand, under contract to the Commission, is investigating the efficiency of removing these metals in dilute solutions by electrolytic precipitation – a process which does not require the addition of chemicals, which could themselves cause further pollution problems.

Considerable success has been achieved in treating acidic copper sulphate solutions in packed and fluidised bed electrode cells of laboratory and pilot plant size. A plant for use in industry will soon be constructed. This will utilize a packed bed electrode which has been found to be simpler to operate than the fluidised bed and will be located on site to treat effluents from pickling and electroplating wash tanks. It will recycle purified wash water and recover copper and sulphuric acid in a form suitable for re-use.

Progress has also been made with treating other metal effluents such as chromium, nickel and zinc. Considerably lower efficiencies are, however, obtained with these effluents. Low solution conductivity is the main problem. This can to some extent be improved by recycling part of the anolyte which is generally acidic.

A detailed mathematical model of packed and fluidised bed cells has been developed. This can be used to select the optimum operating conditions for a given effluent concentration and flowrate. The effects of scale-up on the performance of equipment can also be predicted. This work has been restricted to dilute copper solutions, but the model can be adapted to the treatment of other effluents.

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

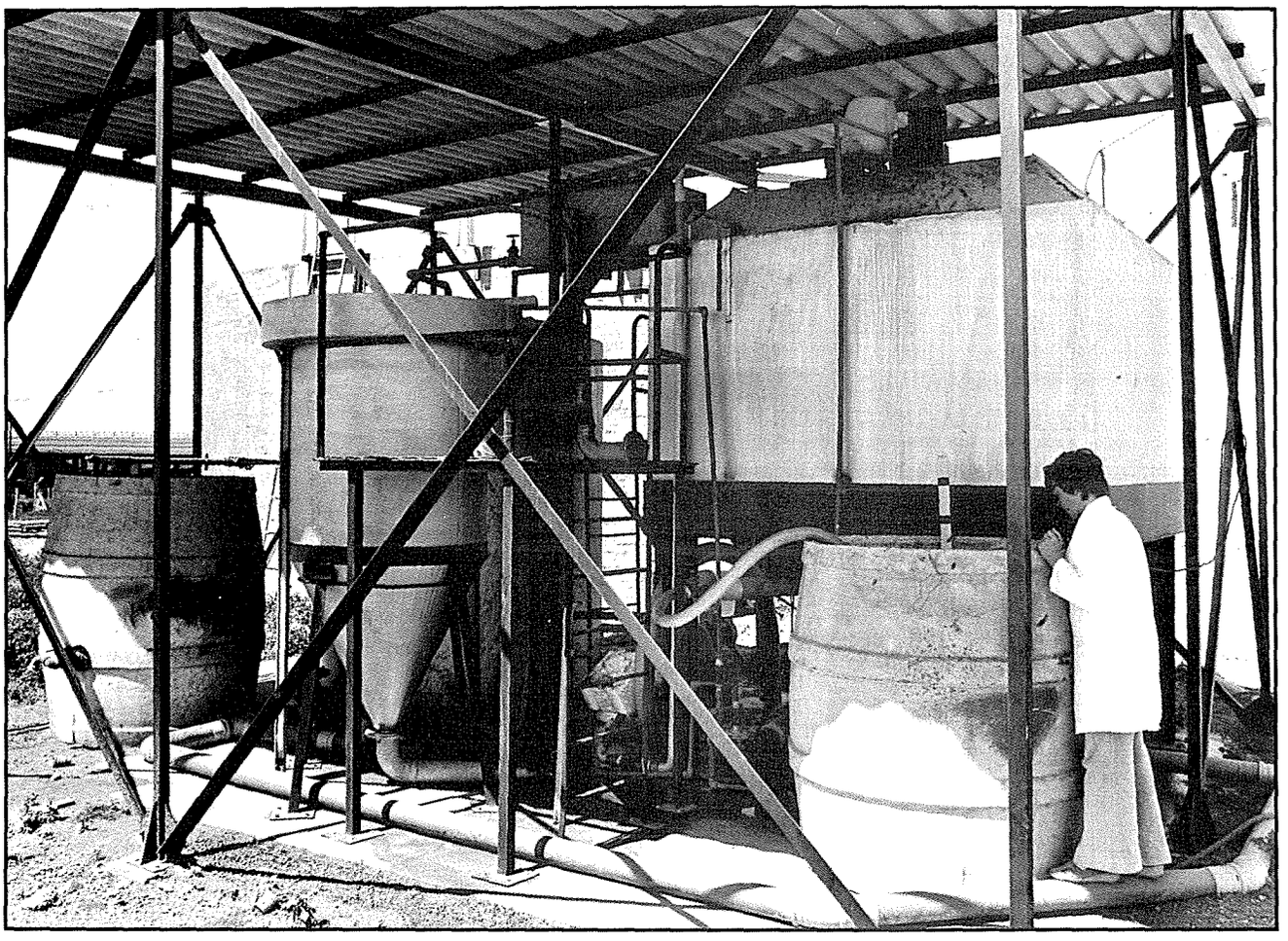
(New project: Contract with the CSIR – Leather Industries Research Institute)

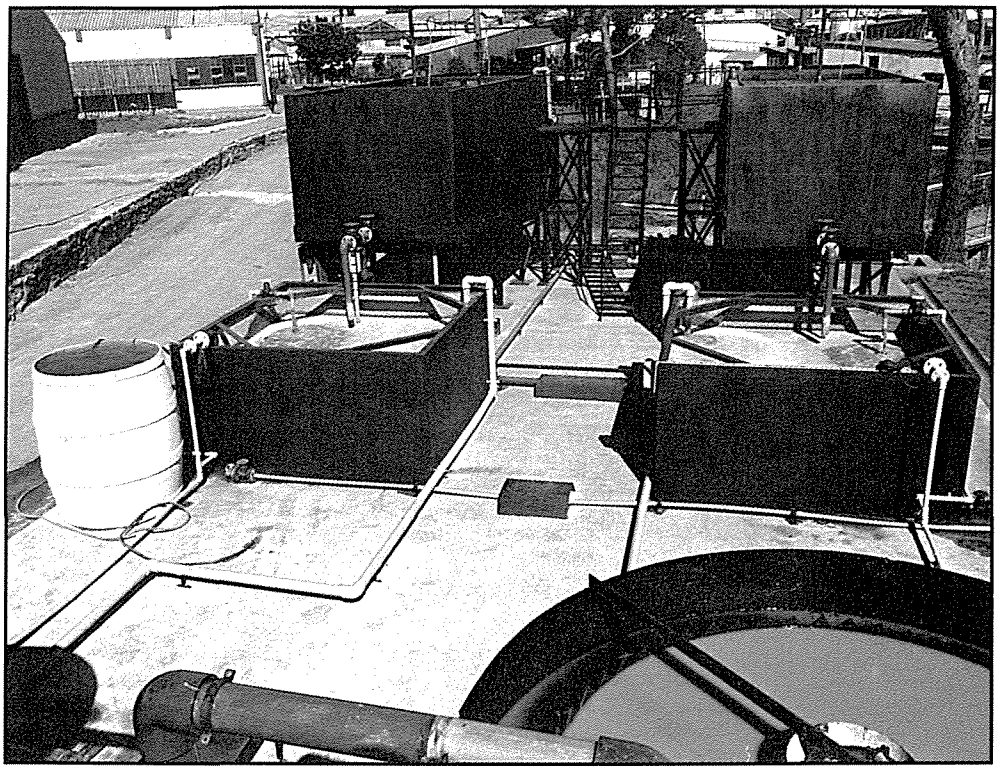
This project forms part of an overall study of water and effluent management in the meat, hides and skins, leather and related industries. The tanning and fellmongering industries in particular have been in some difficulty to find environmentally acceptable methods of disposal of waste waters produced by their processes. The major quantities of waste waters from these industries have been disposed of hitherto by lagooning and/or irrigation, but these methods are causing problems and research is being directed to suitable treatment and to reuse possibilities.

Fellmongering

The work being carried out on the pilot plant located at a fellmongery in Port Elizabeth is aimed at producing the necessary data and knowledge to enable full-scale plants to be designed. The pilot plant will process up to 5 m^3/d of fellmongery waste water using the activated sludge principle. The removal of sulphides and reduction of organic content to levels suitable for discharge to sewer, discharge to sea and for reuse will be studied. The quality of treated effluent in relation to economic criteria will also be studied to provide the necessary information for formulating future water and effluent management policy within the fellmongery industry. The industry is co-operating to the fullest extent in this research work.

This pilot plant located at a fellmongery in Port Elizabeth is treating highly polluted effluent from the factory with a view to producing water of a quality suitable for discharge. The investigation is being carried out by the Leather Industries Research Institute.





The Leather Industries Research Institute is investigating the treatment of tannery effluents on behalf of the Water Research Commission. The pilot plant used for this purpose is located at a large tannery in King William's Town.

Tanning

With the active co-operation of the largest chrome tannery in the Republic, a comprehensive study of waste water treatment is being undertaken at the factory in King William's Town. A parallel stream pilot plant has been built to investigate the treatability of the waste waters from various tanning processes either singularly or in admixture with other process waters. The pilot plant is capable of processing 25 m^3/d in each stream. The unit operations include balancing, sedimentation, catalytic oxidation, and biological oxidation (activated sludge process). The work will determine the feasibility of total treatment to produce effluent which can be reused or discharged to the environment without adverse effects, and will examine the impact of current processing trends on water and effluent management within the industry.

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

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

Wine distillery waste or spent wine is the residue left after alcohol or brandy has been distilled from fermented grape juice. The noxious nature and high pollution potential of spent wine invariably creates disposal problems for the distilleries or local authorities concerned. Spent wine effluent has conventionally been treated by means of lagoons, but this has been found unsatisfactory and often leads to river pollution.

An effluent with such a high concentration of organic matter can best be dealt with by means of anaerobic digestion and extensive investigations into this approach were undertaken by the National Institute for Water Research (NIWR) since 1960. The research proved the practical feasibility of the anaerobic digestion of spent wine.

Various problems, however, were still encountered in the practical application of the process. The NIWR consequently arranged with the Municipality of Stellenbosch to erect a pilot anaerobic digester for further investigations. For some four months in the first half of 1976 the NIWR conducted experiments on this unit and proved conclusively that the spent wine currently available was amenable to anaerobic digestion without any inhibition of the process.

Further research needs were, however, identified and the Commission entered into a contract with the NIWR with the primary object of overcoming certain operating problems frequently encountered in the treatment of the spent wine by means of anaerobic digestion. The proposed research and development programme has been designed to find solutions to the problems which are currently encountered in the large-scale application of this technique.

Chapter 6

The water environment

The field covered in Chapter 5 (effluent and waste treatment) relates closely with that of the water environment, in that effluents, after treatment, are discharged to the environment except where direct reuse is practised.

Research on the water environment is important to the Commission for at least two reasons. In the first place, in considering the degree of effluent treatment that should be required it is necessary to establish the impact of different levels of pollutant on the environment. This is of prime importance for authorities such as the Department of Water Affairs and the SA Bureau of Standards, in the setting of regulations governing effluent quality.

In the second place, it is desirable that the current state of knowledge of the dynamic processes at work in the environment in response to pollution loads be improved. This is important in order that one may be better able to predict the effect of pollution discharges to water bodies and to understand mechanisms whereby the effects of pollution can be minimized or controlled.

The two research contracts reported on below illustrate some aspects of the value and importance of such research. The first, that on the eutrophication of rivers and dams, concentrates on several dams which are already showing the effects of pollution by the nutrient elements, nitrogen and phosphorus, and include studies on dams which are being artificially enriched. Attempts are being made to correlate the deleterious effects found with the level of pollution experienced. The second, that on the role of macrophytes in maintaining the trophic status in Swartvlei, is designed to afford a greater understanding of the mechanism whereby a large amount of nutrient is "locked up" in the form of biological life present in the macrophyte zone in the shallow borders of the lake, in spite of low levels of nutrient in the open water.

In chapter 1 reference was made to the liaison that has been established with the CSIR's National Programme for Environmental Sciences. Most of the activity in this regard relates to research projects on the water environment. Such projects will in particular be those whose results will be more of long term value to the Commission, laying down foundations of more fundamental knowledge on which research projects of a practical nature can be built in the future.

RESEARCH PROJECTS

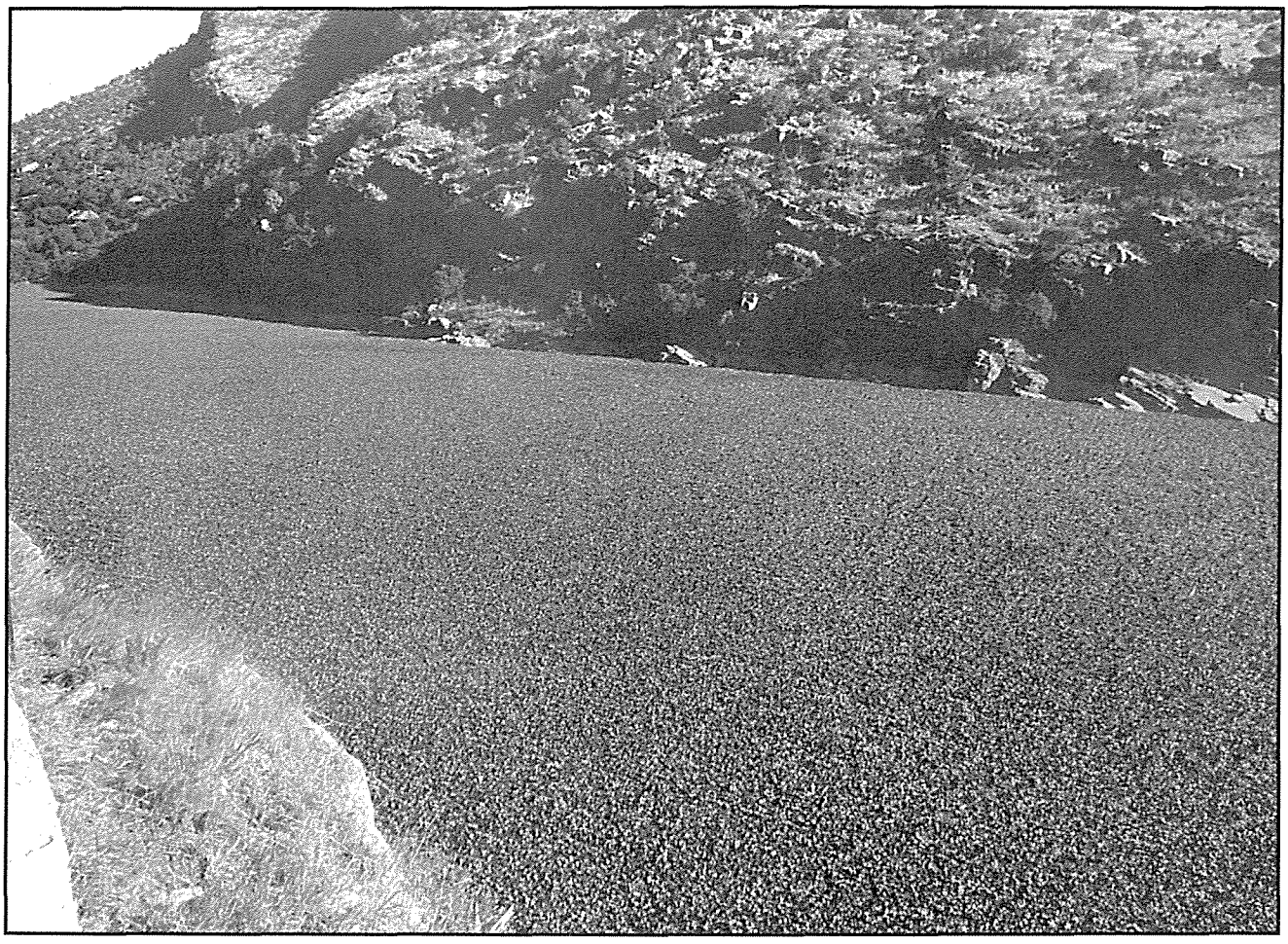
Eutrophication of rivers and dams

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

Eutrophication arises from high levels of plant nutrients (nitrogen and phosphorus) within a water body. Excessive nutrient loads lead to the development of nuisance growths of algae and aquatic weeds.

During the year under review research has continued towards establishing more clearly the nutrient load/algal response relationship of selected impoundments. The main part of the programme involves the study of two impoundments where the effects of controlled artificial enrichment with fertilizer are being studied. The two impoundments represent a relatively clear water system (Buffelspoort Dam) and a silty/turbid system (Lindleyspoort Dam).

Weekly sampling of the waters in these two impoundments prior to the addition of fertilizer has yielded valuable information showing that the plant nutrients within the silty impoundment are not utilized as effectively as those of the clear water impoundment. Consequently, although the clear water impoundment received a lower load of nutrients than the silty impoundment, phyto- and zooplankton populations were greater in the clear water impoundment. This suggests that silt has an important regulatory role on algal populations through the restriction of light penetration.



A bank-to-bank carpet of water hyacinths in the Hartbeespoort Dam near Pretoria reflects the extent of eutrophication in this impoundment. The Water Research Commission finances an investigation into the enrichment of water by the plant nutrients phosphorus and nitrogen which cause, inter alia, *excessive growth of these plants. (Photograph: Oggendblad, Pretoria).*

The nutrient loads into both these impoundments were extremely high and according to certain criteria applied in the northern hemisphere both impoundments should be highly eutrophic. This is not the case, and hence a high proportion of the nutrient loads into both impoundments must be unavailable for algal growth. Weekly fertilizer additions over a period of 19 weeks have as yet produced no nuisance algal blooms within either of the two systems. An interesting development is that the silty impoundment has become more transparent since fertilizers have been added.

A separate part of the project which has recently been initiated involves studies on nutrient load and algal response relationships for the Laing, Bridledrift and Nahoon Dams in the East London area. These impoundments are extremely silty and the study should yield more information on the role of silt in the eutrophication process.

A document giving tentative guidelines for the control of eutrophication of South African impoundments has been prepared and will be made available to organizations involved with the water environment throughout South Africa.

This information will be of great value to urban and industrial planning in catchments. The document describes practical measures for the rehabilitation of eutrophic impoundments and will also assist planners in determining criteria for controlling eutrophication, especially with regard to nutrients derived from non-point sources.

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

(Existing project: Contract with Rhodes University – Institute for Fresh Water Studies)

The Swartvlei ecosystem provides a unique opportunity for a quantitative study of the role of littoral and submerged weed beds in the maintenance of particular trophic conditions in shallow lakes. It is expected that the results of this research will be applicable to other lakes and purification systems in maintaining trophic conditions.

The western part of Swartvlei, Wilderness, where Rhodes University's Institute of Fresh Water Studies is investigating the role of aquatic plants in maintaining trophic conditions. It is envisaged that the result of this research will be applicable to other lakes and purification systems for the maintenance of trophic conditions.

Research during the year under review involved continued monitoring of Swartvlei with respect to a number of physico-chemical parameters, *viz.* salinity, oxygen, temperature and a number of nutrient elements. These studies are being conducted in the main lake and in the littoral zone. The growth rates and primary production of the submerged aquatic plants have been studied, and the rate of nutrient accumulation by the aquatic vegetation is now being investigated. Similarly, a recently established long term experiment on nutrient loss from decaying vegetation is also under way, and these data will be used to calculate rates of nutrient turnover by the extensive aquatic macrophyte beds in this lake. Next to the sediments, the macrophytes form the largest reservoir of phosphorus and nitrogen in the lake, but nutrients in the plant material are obviously more mobile. Current research indicates that, as inflowing waters from the catchment are low in nutrients, the role of the macrophytes in maintaining the trophic status of Swartvlei may well hinge on the mobility (i.e. rates of accumulation and release) of the nutrients and organic matter in the macrophyte beds, rather than on any direct filtering of the inflows as previously postulated.

During 1976 a related project was begun by the Institute for Fresh Water Studies on the estuary linking Swartvlei with the sea. Since sea water intrusions via the estuary into Swartvlei occur regularly, and may play an important role in the biological life of the lake, this project is of vital importance to the Commission's project on the main lake, and the two are being pursued in close collaboration.

The overall picture which will eventually emerge could provide valuable indications of the role which controlled macrophyte belts may play in the removal of nutrients from effluents and water courses.

Chapter 7

Irrigation

The general rainfall distribution pattern in South Africa, namely that two-thirds of South Africa receive 500 mm or less rain per annum and one-third 250 mm or less per annum, is well-known. It is furthermore a general phenomenon that the lower the rainfall, the more variable its occurrence. Under these circumstances it is clear why irrigation and its stabilizing influence is important, especially when viewed in the light of the fact that 28 per cent of the country's total food and fibre production is produced under irrigation on 10 per cent of the total arable area.

Up till now water has constituted the least expensive commodity in the agricultural production process and this has led to various inefficiencies in irrigation. The situation has now been reached, however, where all future development of water sources for irrigation purposes will be of such a nature that irrigation water will become an expensive commodity. Furthermore, the traditional statement that agriculture should enjoy preference with regard to the country's water supplies has become invalid because of the competitive demands of industries, mines and urban development. Although direct comparisons of industrial and agricultural production per unit of water could lead to unfair conclusions, the crux of the matter is that if development should continue at the current rate, the demand for water will increase accordingly and the agricultural sector will have to accept a smaller allocation. The ratio between agriculture and the other sectors with regard to their respective share claims on the limited water supplies will be of decisive importance to the future of both agriculture and the other sectors.

Since agriculture is responsible for such a large portion (approximately 75 per cent) of the annual water consumption, even a small improvement in the effectiveness of water utilization for irrigation will contribute greatly to the balancing of the Republic's water consumption budget. It follows that an increase in the yield per unit of water, rather than unit of land area, should be the preconceived aim of all irrigation research. In order to achieve this aim, irrigation practices and the management aspects of irrigation farming, in particular, will have to be improved. This has the effect that irrigation in future will develop into an extremely specialized industry, to be practised by the most expert entrepreneurs. Irrigation water will have to be used within a production pattern comprising highly improved and modified cultivars of highly remunerative crops, supplemented by judicious fertilizing, effective rotational cropping systems, soil cultivation and by properly applied and continuous programmes of insect and disease control.

In order to enable irrigation farmers to produce the maximum yield per unit of water, the necessary technical know-how must be available. It is also necessary that basic irrigation aspects such as soil, climate, topography and hydrology should be researched before specific schemes are planned. In this way complications of a technical and social nature, which may occur later, can be prevented.

Task of the Water Research Commission

With the foregoing as background, the Study Group for Irrigation Research, established in 1974 by the Water Research Commission, investigated the current status of irrigation and irrigation research in South Africa. Eighteen selected irrigation areas and research organizations, which may be considered as representative of irrigation in South Africa, were visited in order to identify specific problems. During the investigation it became clear that constraints occurred to a greater or lesser extent in all irrigation areas. In broad terms these may be summarized as follows –

- Water resources: Some of the most important problems were water shortages, quality of water resources and methods of water supply. Despite ample allocations of water to farmers, representations for increased allocations are continually made.
- Water requirements of crops: A serious lack of knowledge exists especially concerning the water needs of crops during different stages of growth and the moisture critical stages during the growing season.

- Irrigation scheduling: Scheduling criteria for use at farm level, are required, as well as the necessary instrumentation to promote and facilitate the scheduling.
- Physical and chemical aspects of soil require attention, especially with a view to preventing and combating salinization and drainage problems.
- Climatic factors: Information is required in respect of rainfall, temperatures, evaporation, winds, frost and hail and on the limitation of evaporation losses.
- Irrigation techniques and equipment: With regard to surface, sprinkle and micro-irrigation methods a number of constraints exist. The most important of these are design criteria and water losses associated with each of the methods applied.
- Drainage aspects: Apart from design criteria for surface and subsurface drainage systems, the disposal of drainage water also causes problems.
- Aspects of agricultural economics: The most important facets of agricultural economics requiring attention are the relative economy of the production of different crops under irrigation and economic plot and farm sizes for irrigation farming.
- Extension services relating to irrigation farming: Despite the good work being done by the relevant government departments in this regard, the general feeling is that the gap between irrigation practice and irrigation research is too wide.

With the aid of this information on the constraints in agricultural practice and other information supplied by the Departments of Agricultural Technical Services, Agricultural Economics and Marketing, and Water Affairs, a draft research plan for irrigation was formulated. This draft research plan was considered by the Study Group and after slight modifications it was accepted to serve in future as a Master Research Plan for Irrigation. In terms of the Plan the whole field of irrigation is divided into nine task areas, each with its subdivisions. The nine task areas correspond basically to the problem areas described above.

The next task of the Study Group, namely the establishment of a Priority Research Plan, has already progressed considerably. A draft Priority Research Plan has been formulated and already been accepted by a sub-committee of the Study Group. In this case also, submissions from the Departments of Agricultural Technical Services and Water Affairs served as guidelines. The plan will finally be ratified at the next meeting of the Study Group. The Water Research Commission will endeavour to steer future irrigation research in the directions indicated by the Priority Research Plan.

Although the Priority Research Plan as such has not yet been finally approved, the Water Research Commission has already contracted the Universities of Pretoria, the Orange Free State and Fort Hare to undertake specific irrigation research projects. These projects deal with the water requirements of certain agronomic and horticultural crops and certain soil factors which influence the optimal utilization of irrigation water. Financial support for other irrigation research projects is envisaged for 1977.

In addition negotiations are currently under way to bring two contract research workers to South Africa during 1977 to investigate specific problems with regard to the salinization of soil and the automation of flood irrigation, in collaboration with officers of the Department of Agricultural Technical Services. Hopefully, this would stimulate research in these fields and hasten the generation of practically applicable results.

RESEARCH PROJECTS

An investigation of soil compaction at the Vaalharts Irrigation Scheme

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

The mechanical resistance of soil particles to deformation by roots is known as soil strength. High soil strength values (as a result of the compaction of soils by certain cultivation practices, of excessive application of water or simply as a result of its inherent physical characteristics) are one of the most important factors causing poor root development in South African soils.

Poor root development of crops in soils with a potentially deep root zone is at the moment one of the most important production limiting factors at the most prominent irrigation schemes in the central areas of South Africa.

In the research on the problem, undertaken by the Department of Soil Science of the University of the Orange Free State, the three most important soil series used for irrigation in the central areas as well as at Vaalharts, *viz* the Annandale, Mangano and Shorrocks series, were selected as experimental soils. Research entails a field investigation, field tests, laboratory studies and pot tests. Progress in each of the four categories during the year under review was as follows:

- A field investigation was carried out on twelve farms during the past winter season in order to determine the relationship between soil compaction, irrigation, cultivation practices and the root development of wheat. At the start of the summer season similar observations were commenced on ground nuts, cotton (which is especially vulnerable to soil compaction) and maize as test crops.
- A start was made with a field test in which ground nuts, cotton and maize were planted as test crops for comparing a new method of cultivation with existing practices.
- The influence of the degree of compaction on some hydrological characteristics of the abovementioned soil series was studied in the laboratory: for example, the influence of compaction on the moisture extraction characteristics, saturated hydraulic conductivity and relationships between soil strength and moisture content.
- Glasshouse pot tests were used to investigate the influence of soil compaction on plant growth. The influence of different soil strength values and of the three soil series mentioned earlier on root development, surface growth and nutrient intake of ground nuts, wheat, cotton and maize was determined. A most informative fact to emerge

was the tenfold decrease in root length per maize plant (in other words also in the volume of soil effectively utilized by the roots) when soil strength was increased from 6 to 30 bar. During the field investigation, for example, it was found that soil strength values of 30 bar occur generally.

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)

This project is being carried out at the Vaalharts Agricultural Research Station by the Department of Agronomy of the University of the Orange Free State.

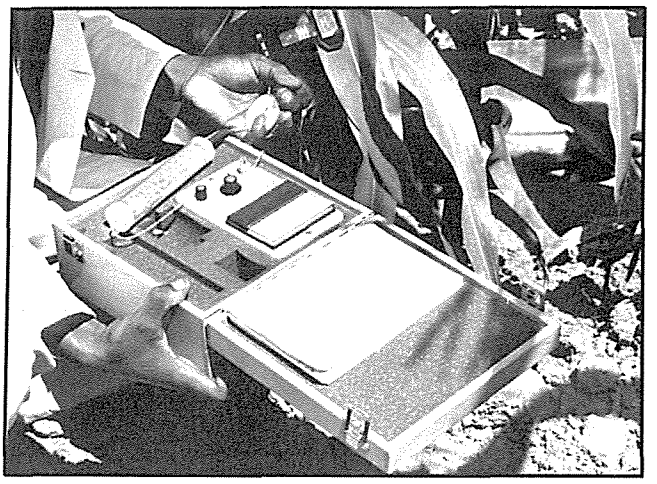
Research is aimed at determining the extent to which vegetative growth and yield are influenced by moisture supply and internal moisture stress during the various growth and development stages of crops. Information obtained in this way will enable a determination of optimal irrigation scheduling which will ensure maximum results with the minimum application of irrigation water.

Experiments at Vaalharts commenced with the first planting of wheat during the winter season of 1975. The first series of data was collected for wheat and during the following summer season for ground nuts and cotton. The equipment for determining soil moisture has been received and with continued planting of crops to which varying levels of irrigation are applied, basic plant and soil moisture constants can now also be determined.

Research on the soil factors effecting the optimal utilization of irrigation water in Bantu homelands

(New project: Contract with the University of Fort Hare – Department of Soil Science)

The potentially irrigable land area in the Homelands amounts to more than 100 000 ha. A considerable portion of the agricultural products required by the Homelands can be produced under irrigation. Owing to the problem associated with dry land crop production, irrigation plays an important role in the Homelands. Available water supplies, however, is a much greater limiting factor than available irrigable soils and therefore optimal utilization of water is of the utmost importance in the development of these areas. It can be expected that irrigation farming will increase rapidly in the Homelands as a result of water developments undertaken by the Xhosa Development Corporation (XDC) and the Department of Bantu Administration and Development.



A diffusion porometer is used for measuring the rate with which water vapour moves through the stomae of a leaf. This gives an indication of the extent of stoma closure and therefore of the internal moisture status of the plant.

For the optimal utilization of irrigation water and the continued longterm productivity of irrigated soils, it will be necessary to base irrigation practices on reliable scientific data. Information on the physical and chemical characteristics of irrigation soil is of paramount importance since it will not only determine the irrigation technique to be applied, but also influence the planning and design of irrigation and drainage systems.

With the foregoing as background, the Commission has entered into an agreement with the University of Fort Hare, in terms of which the University's Department of Soil Science will investigate the following aspects:

- Determination of the plant-available water in soils relative to specific crops and climatic conditions. Reliable estimates of the amount of freely available water within the root zone of each crop in varying types of irrigation soil are required to prevent the excessive application of water. Apart from the fact that over-irrigation is wasteful, it can also lead to waterlogging and salinization problems. Four different methods for determining the plant-available water in a soil profile will be investigated. It will, therefore, be endeavoured to develop a method which could, with relative ease, be used in practice to determine the plant-available water for different combinations of crop, soil and climate.

- Determination of important physical and chemical soil parameters relating to irrigation and drainage. Since surface irrigation occurs most commonly in the Homelands, it will be endeavoured, on the basis of this information, to develop guidelines to determine the desired lengths, and slopes of irrigation beds as well as rates of application.

Since most of the required information is area-bound, it would be undesirable to apply results obtained elsewhere to this region, and accordingly the research will be done under regional conditions in the Ciskei. A large variety of soils, some of which may be regarded as problem soils, are to be

found here. The impact of research is also extended by the fact that irrigation in the area varies from that applied by small farmers to that applied in sophisticated XDC projects.

The first field test, with wheat as test crop, commenced in July, 1976. It is being done on the Fort Hare farm in the Ciskei on a soil which is representative of many of the irrigation soils in the Ciskei. Field plots for infiltration studies were also prepared on the Fort Hare farm.

Water requirements of agronomic and vegetable crops

(New project: Contract with the University of Pretoria – Department of Plant Production)

The real water requirements of crops and programming in the application of the required water are undoubtedly some of the most important factors in the optimal utilization of irrigation water and requires extensive and continuous research. Since research in this field is specific for the type of crop, area, climate and soil, it has to be done at different localities. For this reason the Commission contracted the University of Pretoria to undertake a project, through its Department of Plant Production, in the vicinity of Pretoria and in the Groblersdal and Loskop areas where this type of research had not been done before.

The specific aims of the project are as follows:

- To investigate, in a systematic way, the water requirements of crops with a view to the planning and refining of irrigation programmes.

- To determine water production functions for the crops in order to establish the most economic irrigation level and the most effective application of limited irrigation water.

- To simplify and test the practical application of the evaporation pan in irrigation programming.

The work programme entails the testing of irrigation programmes with ground nuts and dwarf beans as summer crops and wheat and cabbage as winter crops which will be rotated over a period of three winter and three summer seasons on 46 plots. Different irrigation programmes, which will be modified on the basis of information obtained in previous seasons, will be tested on each of the crops.

Field tests will be supplemented by water culture studies; with pot lysimeter and model plot tests to study, with regard to the crops mentioned, soil moisture development patterns, root development and soil/plant/water relationships relative to atmospheric conditions; and with glasshouse pot tests to determine the influence of moisture stresses and various stages of growth.

Chapter 8

Surface hydrology

Knowledge of the extent and potential of a country's water resources should be as accurate as possible. Since approximately 90 per cent of South Africa's water consumption is derived from river flow, and since only 8,1 per cent of the mean rainfall reaches rivers as surface runoff*, it is clear that hydrological information is of cardinal importance especially from a planning point of view.

Apart from establishing an effective network of hydrological gauging stations for observing rainfall and runoff and the analysis of results, hydrological research also entails investigations of atmospheric processes (for example the inconsistency of rainfall and the occurrence of evaporation losses), determination of the influence of land utilization practices, investigation of groundwater processes, evaluation of the chemical and physical quality of water and detection and evaluation of groundwater resources. The field of hydrological research is therefore a broad one and requires specialization in divergent facets.

The Water Research Commission's involvement in geohydrological research is described in chapter 3. As far as surface hydrology is concerned, the Departments of Water Affairs and of Forestry have already been recording rainfall and runoff for a number of decades and this will be continued and extended in future. In addition, the Hydrological Research Institute of the Department of Water Affairs is engaged in hydrological research on a wide front. In the light of this, the Commission's efforts to promote research on surface hydrology are directed towards supplementing the aforementioned work by supporting certain hydrological research at universities:

- Financial support of the Hydrological Research Unit of the University of the Witwatersrand. The Unit undertakes several projects of direct importance to the Commission and also supplies advisory services in respect of certain projects being financed elsewhere by the Commission.

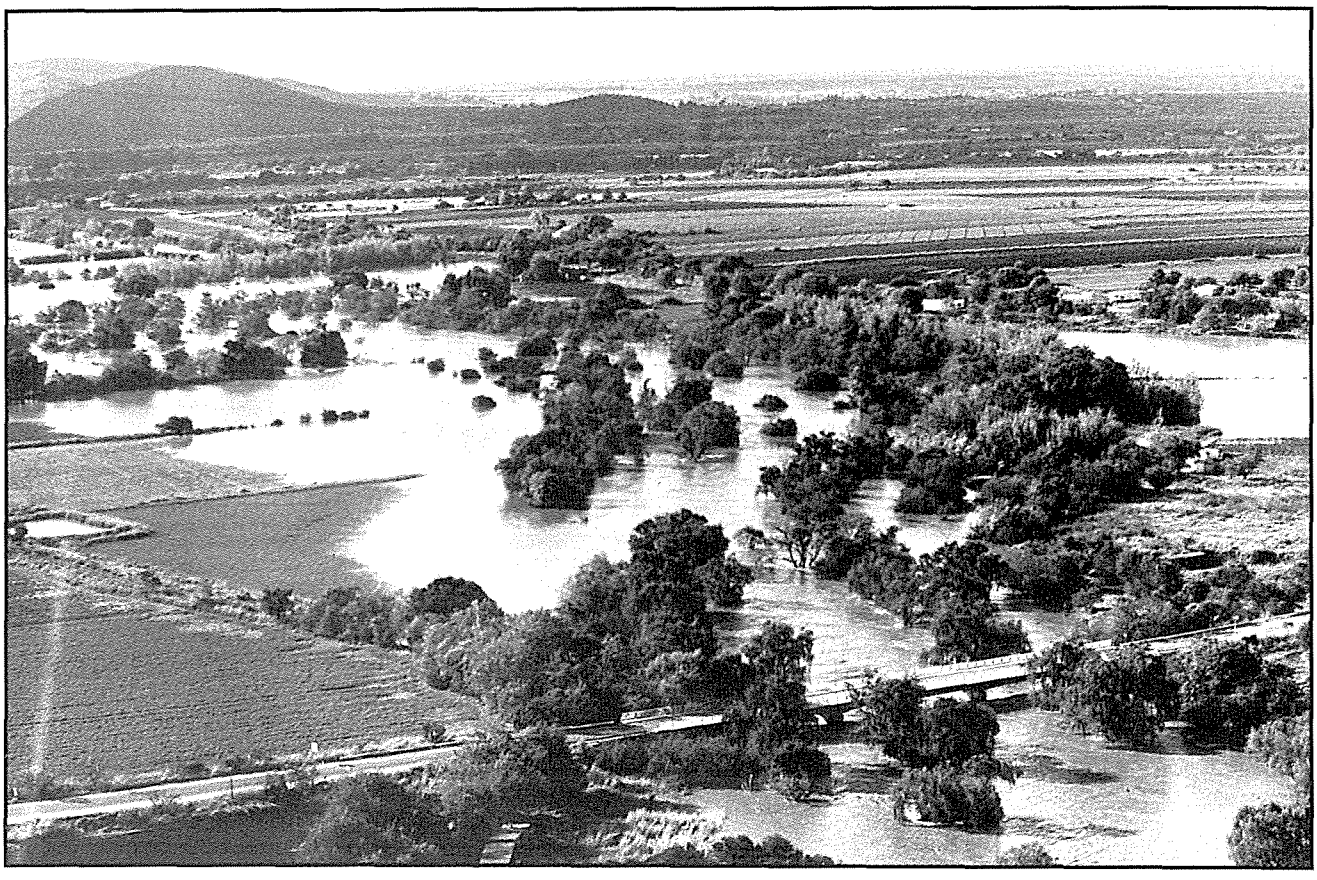
- Projects on rainfall-runoff relationships of small catchments by the Universities of Natal (Department of Agricultural Engineering), Zululand (Department of Geography) and Rhodes (Department of Geography). These projects are executed under varying climatic, geographical, topographical and land utilization conditions, and are directed at testing and refining mathematical simulation models, developed for larger catchments, for application to small catchments.

- The development of the runhydrograph concept by processing historic flow records, by the University of Natal (Civil Engineering Department). This project is undertaken in close co-operation with the Department of Water Affairs.

- The determination of flood damages which occurred in selected river stretches during March 1974 by the Institute for Social and Economic Research (University of the OFS) and the Bureau for Economic Research (University of Stellenbosch). These investigations, indirectly coupled to hydrological research, are aimed at developing the methodology of determining flood damages and predicting the extent of flood damage by means of mathematical models so that the vulnerability of an area to flood damage can already be brought into consideration at the planning stage.

In supporting this research at universities, the Commission expects that, in addition to the generation of specific research results, a more extensive hydrological expertise will develop at universities which will constitute a useful input to hydrological research in South Africa. More details on the projects mentioned are given below.

***Report of the Commission of Enquiry into Water Matters (RP34/1970), p 40.**



Owing to the fact that the best irrigation land in South Africa is often situated in the flood plains of rivers, irrigation farmers from time to time suffer serious flood damage. The Institute for Social and Economic Research of the University of the Orange Free State and the Bureau for Economic Research of the University of Stellenbosch are investigating the methodology for determining flood damages as well as the occurrence of flood damages in selected river stretches during the floods of March 1974 (Photograph: Oggendblad, Pretoria).

RESEARCH PROJECTS

Research on flood damage

(Existing project: Contracts with the University of the Orange Free State – Institute for Social and Economic Research; and the University of Stellenbosch – Bureau for Economic Research)

Urban and industrial development, communication and transport connections and a part of the best irrigable land in South Africa are often situated in the flood plains of rivers, giving rise to serious damages during floods.

Since research on the total economic impact of floods has not previously been undertaken in South Africa, and since the results of such research will meet certain planning requirements, the Institute for Social and Economic Research of the University of the Orange Free State and the Bureau for Economic Research of the University of Stellenbosch were contracted by the Commission to undertake research on the determination of flood damage in certain river stretches. These two organizations collaborate closely in the execution of the investigations.

Bureau for Economic Research (BER)

The research programme on flood damage at the Bureau for Economic Research comprises surveys with regard to rivers in the Karoo and the Eastern Cape. A considerable period of time was intially spent on methodological and literature studies. At the end of 1975 site investigations were commenced in flood areas and this in fact represented the most important research activity during the first three quarters of 1976.

During June 1976 the project leaders of the flood damage research programmes at the BER and the Institute for Social and Economic Research of the University of the Orange Free State visited the United Kingdom and the USA in order to obtain information especially on the methodology of research on flood damage and flood control.

Since data acquisition has formed the greater part of the research activities up till now, no final conclusions are as yet available. The investigation at the BER will, however, be completed during 1977 and a report on the findings will then be published.

Institute for Social and Economic Research (ISER)

The ISER is responsible for research relating to certain stretches in the Orange River and the Karoo. Research is currently in the stage of collecting basic information and its classification and processing. Almost all information has already been obtained from authorities and public organisations. Field work relevant to damages in towns has been completed and the accompanying cartographic preparation has progressed well. Although the determination of agricultural damage is an extensive task, universal coverage was achieved in involving most of the river stretches. An exception was the lower Orange River downstream from the Buguberg Dam, where, for specific reasons, stratified sampling had to be done and a total picture of the damages will have to be obtained by extrapolation.

In some cases it is a problem to distinguish between rain and flood damages. The seemingly logical method for solving this problem would be an attempt to determine what the extent of damages would have been in the absence of rain. Even at this stage it is clear that the extent of damage varies considerably between river stretches and that these differences are closely allied to the land use pattern. This aspect will require attention with a view to future flood control measures by the individual, community or authorities.

Financial support for hydrological research

(Existing project: Joint CSIR–Witwatersrand University Council – Hydrological Research Unit)

The Hydrological Research Unit (HRU) again received a block grant from the Water Research Commission during the 1976 financial year, in accordance with its undertaking to prosecute research in fields of interest to the Commission.

The main research work of the Unit continues to be the development of mathematical models of various hydrological and hydraulic systems, progress in each of which is reported below.

Watershed models

A numerical model has been perfected for generating daily average hydrographs from daily or (where available) hourly rainfall inputs. The model is being applied to a wide variety of problems, e.g. developing the basic hydrology for the PWV project (mentioned below); identifying the effects on streamflow of afforestation, irrigation abstractions and other human interferences in the catchment; real-time flood prediction; and general water resources appraisal.

With data from the Jukskei catchment comparisons are being made of the HRU model, the Stanford Watershed Model and other rainfall-runoff models. The hope is that a general re-appraisal of the water resources of South Africa (and possibly of some neighbouring countries) can be undertaken with the most suitable of the models.

Flood hydrograph synthesis

A tentative start has been made on urban flood hydrology studies to meet the demand from consultants and town engineers in many parts of the country and neighbouring territories.

Collaboration is established with Natal University (Department of Civil Engineering) where testing of the runhydrograph technique is being undertaken. Using data prepared for that study the Unit shall endeavour to generate daily average hydrographs with the aid of the HRU watershed model. Daily time resolution is generally adequate for routing through major reservoirs, to determine spillway capacity, and to optimize flood gate operation.

A major study is in hand in the Vaal catchment to perfect methods of real-time flood prediction and procedures for unsteady-state-routing of floods through reservoirs and for optimizing gate manipulation to minimize downstream flood damage.

Flood plain modelling

Development of a set of models is in hand for dynamic routing of floods through complex channel and flood plain systems to establish the depth and duration of inundation as well as the time graph of the average velocity vector anywhere in the system (and thus the extent of scour or sediment deposition). If "damage functions" in terms of these parameters can be compiled for the various categories of land-use or occupancy of the flood plain then the model can determine the damage likely to result from a flood of given frequency. If the frequency distribution of flooding in the particular catchment is known then the model can establish the mean annual damage expectancy or risk and thus provide the basis for an economic analysis of any proposed flood mitigation measure.

Collaboration has been established with the Bureau for Economic Research (University of Stellenbosch) and the Institute for Social and Economic Research (University of the OFS), both of which are studying flood damages in selected river stretches on behalf of the Water Research Commission. It is hoped that information generated by these investigations will enable the HRU to build up a library of "damage functions" that will be compatible with the Unit's models.

Swamp, lake and estuary models

The final report on a study of Lake St Lucia has been completed. The report provides, inter alia, the results of tests of about 50 options for improving conditions in the lake. The results are presented in the form of frequency distributions or duration curves of lake level and salinity in various parts of

the lake for virgin conditions, for present-day and future conditions and for conditions if each of the various ameliorative measures were to be implemented in turn. It is fairly clear which measures would be rewarding and it remains to cost them and perform the economic analysis needed for decision making.

The models developed during this extensive study have been adapted for several other applications, such as the studies on Richards Bay, the Barrage model of the PWV project, the Koeberg cooling water intake and the Mfolozi flood plain.

Water and effluent circulation in the PWV-complex

The hydrological model of the tributary catchment to the Barrage has been calibrated and the trends due to man's activities identified. The water budget for the Barrage can now be operated for virgin conditions. Work is in progress to develop the means of operating the model for quality, i.e. imposed TDS, and for future time horizons.

General

Computer programs developed in the course of the Unit's research are being generalized where possible and user manuals are being prepared.

Dissemination of research results is accomplished not only by publications in the technical press but also through the Unit's report and manual series.

Furthermore, short courses, seminars and workshops are periodically arranged.

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)

Work done by the Department of Civil Engineering of the University of Natal on the flow records of the Vaal River at Standerton led to the development of a theory for the "runhydrograph", 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.

Continuous, instantaneous streamflow records of reasonably long duration and accessible to a computer, form the necessary data bank for this project which is undertaken by the University under contract to the Commission. Such data has been available within the Department of Water Affairs, but it has not been processed in a form suitable for computer input. It was therefore necessary to establish an organization which could capture the data in a satisfactory form.

Various possible means for data capturing were investigated and it was decided that the most practical and least expensive method would be to hire a firm which specializes in this kind of work. Tenders were invited and a contract duly awarded to a commercial firm. It was soon discovered that the data files of the Department of Water Affairs needed preparation before they could be processed and it was necessary to employ two technicians to do this work and also to check the captured records. The Department of Water Affairs supplied a third technician to help with this work.

At present, the records of 112 streamflow stations are processed which comprise 3 000 years of continuous streamflow records on magnetic tape.

Only one streamflow record, namely the Vaal River at Standerton, has been analysed. It is estimated that the project will be completed during late 1977 and that a manual will thereafter be published which could be useful to civil engineers and those concerned with floods.

Hydrological investigations of small catchments

It is estimated that the annual runoff of rivers in the Republic constitutes some 8,1 per cent of the mean annual rainfall. Approximately 90 per cent of the country's water consumption is derived from river flow and it is therefore vitally important to study the relationship between rainfall and runoff more intensively.

Mathematical simulation models, based on data collected by the Departments of Water Affairs and Forestry, have been developed for the prediction of river flow in large catchments. These models have to be modified and refined to be applicable to small catchments.

In an effort to achieve this objective the Commission has contracted three Universities *viz* Natal, Zululand and Rhodes, to study smaller catchments varying in mean rainfall, vegetation, land utilization, soil type, topography and geology.

Investigations in the Grahamstown area

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

Construction of the weirs and flumes for the measurement of runoff in the Ecca River catchment has been completed and the recorders were installed just in time to record the floods that occurred during the last week of March.

By the 1st August 1976 a total of 9 discrete flow events had been recorded – the highest flood peak being of the order of 8 cumecs which is well within the capacity of the measuring structures.

Rainfall, runoff and evaporation data obtained during the year under review have been used to calibrate and assess three simulation models that require hourly rainfall input. The calibration has highlighted some inadequacies in the applicability of the models for simulation in small catchments and the research programme has been orientated to the improvement of these aspects in the various models. Much computer time has been spent on examination of the sensitivity of the model parameters and experience has been gained in understanding the complex inter-relationship between the parameters and their relevance to the physical features of the catchment.

The research programme has also focussed on collection of catchment data that will aid the analysis of the models, such as the analysis of the slope pattern in the catchment, the mapping of the geology, and monitoring boreholes to assess changes in the water table. The borehole measurements have been used to develop a simple mathematical model for simulating changes in water level as this information is relevant to the groundwater aspects of the models being examined.

The data processing and storage system has been improved with the use of a number of computer programs and by the inclusion of disc facilities in the Nova computer.

The available runoff data for the Ecca River catchment will enable the research programme to be orientated towards detailed analysis of digital simulation models and the research programme for 1977, which is summarised below, reflects this emphasis on model analysis:

- The continuing collection, manipulation and storage of rainfall, evaporation and runoff data for the catchment together with maintenance of the gauging network and equipment.

- Calibration of the simulation models that require hourly input data in each of the sub-catchments and the further development of the models to suit small catchment conditions.

- Calibration and possible refinement of the large version of the Stanford Watershed model for the Ecca catchment using the subcatchments as the components. (This version is set up for simulation at five flow points).

- Calibration of the simulation models that require daily input data in each of the sub-catchments and the further development of the models for small catchment conditions.

- Development of a simulation model based on the experience gained with other models. It is intended to programme the model in such a way that a variety of functions for infiltration, attenuation properties of channels and time delay are offered and a number of sub-models can be constructed from the options to suit specific needs without involving additional programming.

Investigations in the Natal Midlands

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

In the course of the year the five gauging weirs at Cedara were constructed and recording of streamflow commenced. These data are supplemented by records from a network of autographic and storage raingauges at ten selected sites. With these basic data now available and the digitizing programs already in use, this project is now fully operational.

Aerial colour photographs at a scale of 1 : 10 000 were prepared and these were used in a detailed land use survey in which characteristics of the vegetative cover that could affect interception, evapotranspiration and ultimately runoff were monitored from nearly 400 land use units comprising the Cedara catchments. The photographs also proved invaluable in a soil survey which was carried out, and from which some nine soil series, each with different hydrological properties were identified in the catchments.

Associated research at Ukulinga Research Station saw the virtual completion in 1976 of a laboratory rainfall simulator and the highest number of surface runoff events in twelve seasons at the runoff plots.

Hydrological simulation modelling focussed on the Huggins flood model (applied to data from the De Hoek experimental catchments) and the Pitman model (used in runoff modelling for small dam design). Considerable effort was also spent digitizing hydrological data from the De Hoek catchments.

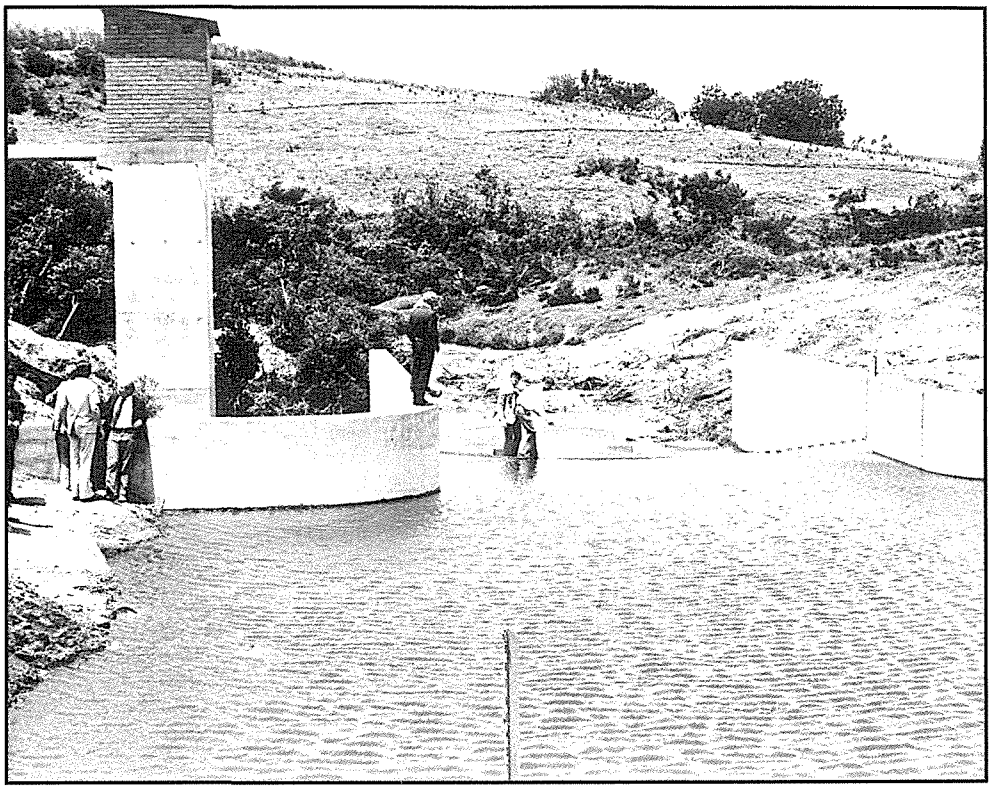
In a year marked by severe floods a survey of potential flood producing rains in Natal has yielded valuable maps on probabilities and magnitudes of extreme rainfall events. Finally, with the emphasis placed on simulation modelling in contemporary hydrology, a successful workshop/symposium on this topic was held in Pietermaritzburg.

Investigations in the Natal Coastal area

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

During the year under review the construction of six weirs in the Ntuze River catchment was the most important task. In conjunction with the Hydrology Division of the Department of Water Affairs a variety of measuring structures were designed, including a Crump weir – the first of its kind in the Republic. This type of weir is less vulnerable to flooding and offers a more advantageous C-co-efficient. The criterion used for weir design was an accuracy of 5% plus and 5% minus for 20-year flood frequency. The weirs have been equipped with autographic water level recorders whilst at two structures a cableway is being used to obtain flow velocity data at peak flow in order to calibrate the section.

Good progress has been made with field work, with extend-



Investigations into rainfall-runoff relationships in Zululand have reached the productive phase with the completion of the weirs and gauging structures built by the Department of Water Affairs. The picture shows one of the weirs completed during the year under review. The automatic water level recorder is located in the structure on top left.

ing and developing the computer storage systems for collected climatological and run-off data, and with the selection and development of simulation models.

The research programme for 1977 comprises –

- Completion of field surveys.
- Determination of the content and movement of groundwater in the various soil phases.
- Collection of climatic and runoff data.
- Data processing – recent as well as historic.
- Further extension and development of the computer storage systems.
- Further selection and development of simulation models.

Chapter 9

Rainfall stimulation and utilization of atmospheric moisture

Apart from surface and subterranean freshwater resources and the desalination of sea water, the only other source of water accessible to man is the artificial abstraction of moisture from the air. This can be done in two ways. Firstly, rainfall can be artificially stimulated by cloud seeding when conditions are favourable – a subject on which research has been continuing for many years with varying success. A second approach is the direct abstraction of moisture by means of special installations which could be particularly useful during crisis situations.

During 1976 the Commission entered into an agreement with the Department of Transport in terms of which it would provide expert personnel to the Weather Bureau for an extensive research project on the stimulation of rainfall, with Bethlehem as experimental area. Investigations at the University of Pretoria into the application of hygroscopic materials for abstraction of moisture from the air also continued.

RESEARCH PROJECTS

Research on the artificial stimulation of rainfall

(New project: Contract with the Department of Transport – Weather Bureau)

Introduction

Research on the stimulation of rainfall in South Africa commenced in 1971 when the Department of Transport's Weather Bureau established certain facilities at Bethlehem and launched a programme of investigation. However, the project could not be operated continuously or progress satisfactorily as a result of inadequate financial support and a shortage of scientific and technical staff.

Despite these problems the Weather Bureau succeeded in collecting valuable reconnaissance data and in establishing a solid infrastructure which included facilities and equipment such as aircraft, radar and other electronic and meteorological apparatus, as well as extensive computer facilities.

After negotiations between the Department of Transport and the Water Research Commission agreement was reached that the Commission would contract expert personnel overseas for seconding to the Weather Bureau in order to place the Bethlehem project on a viable base. As meaningful results can only be obtained through longterm research, the project is scheduled to run for a period of eight years. The Weather Bureau will assume full leadership in the execution of the project which will be under the management of an advisory steering committee comprising representatives of the Department of Transport, the Water Research Commission, the Department of Water Affairs and the CSIR.

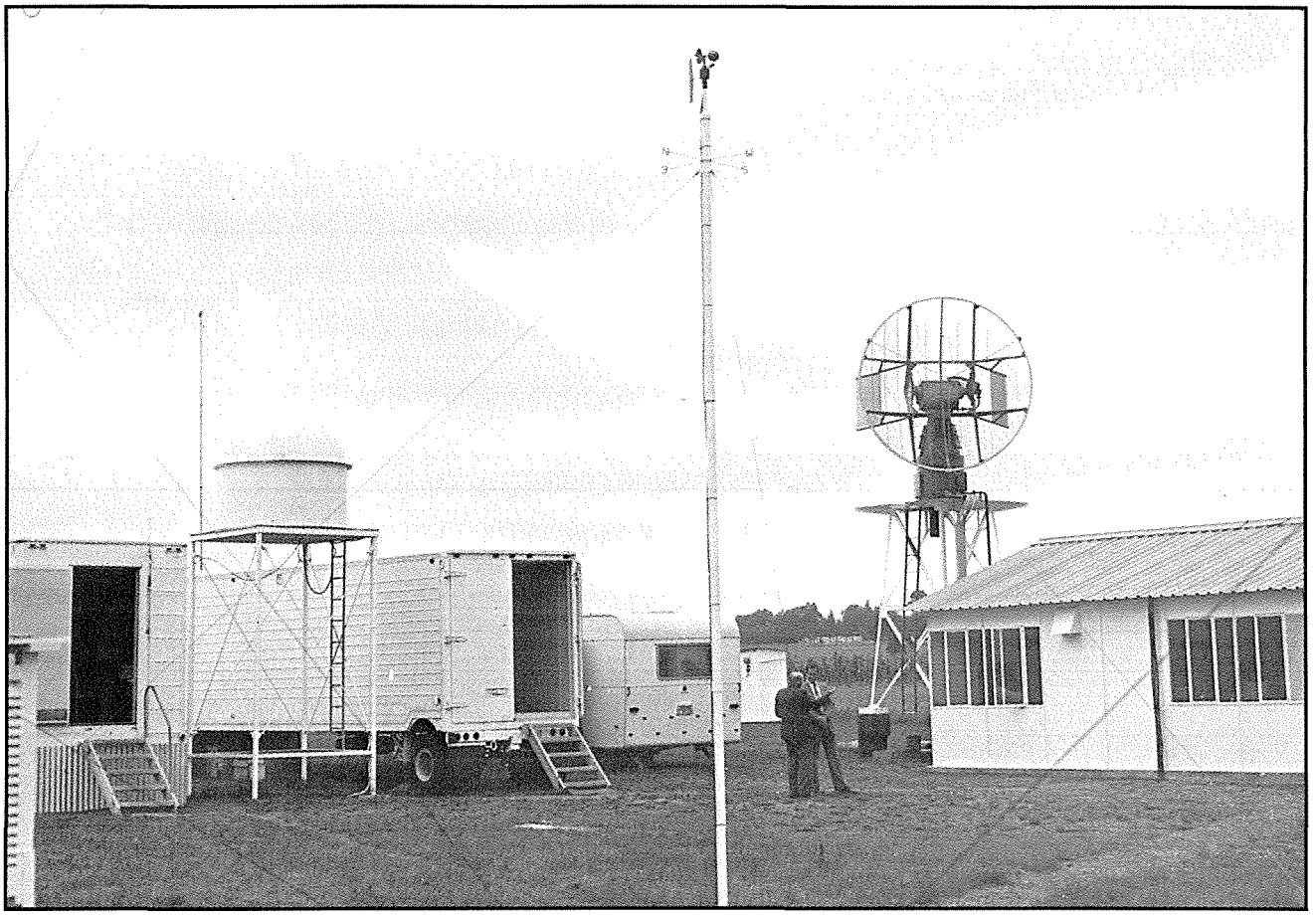
Objectives

The main objective of the project is to determine the extent to which it is feasible to increase precipitation by cloud seeding in the catchment of the Vaal Dam – the most important reservoir in the Republic. Parallel to this, although a somewhat secondary part of the project, hail storms will also be studied and seeded. Investigations in this respect, however, will be directed at determining the extent to which seeding for hail control will influence total precipitation.

Selection of the experimental area

The Bethlehem region was selected as experimental area for various reasons of which the following are the most important:

- The project area covers a large part of the Vaal Dam catchment. A successful increase in the rainfall of this area



The research station at Bethlehem where a long term investigation of rainfall stimulation is being undertaken under leadership of the Weather Bureau.

and the availability of additional water sources, particularly to the PWV-area, will obviously be of the greatest national importance.

- The area includes mountainous regions as well as grass plains, which makes it possible to study variations in techniques and effects.
- Although the project area is situated relatively close to large urban centres, it is not in a region over which regular flights are scheduled.
- A secondary advantage is that the radar coverage of the experimental area could possibly lead to an improved warning system with regard to floods in the Vaal River.

Research programming

According to current planning a preparatory phase of three years is envisaged, followed by a five year period of intensive research. Taking into account the data that has already been acquired, it may well be possible to shorten the preparatory phase considerably.

During the preparatory phase a parallel study of seeded and unseeded clouds will be done. This is an important facet because it is the only way to evaluate equipment and techniques before the intensive programme is commenced.

A large amount of data relating to the value of one-dimensional models to predict cloud behaviour had already been collected earlier, but had not been fully processed. This processing will also be done during the preparatory phase.

Progress

Personnel recruited overseas in terms of the agreement between the Water Research Commission and the Department of Transport arrived in the Republic at the end of 1976 and, together with personnel of the Weather Bureau attached to the project, have already commenced processing existing data, installing equipment and getting it into working condition.

Overseas advisers

In order to obtain an objective evaluation of the status of research in South Africa related to weather modification, the Water Research Commission, during 1976, obtained the consultation services of Prof Roscoe R Braham of the Department of Meteorology of the University of Chicago and Dr A Gagin of the Cloud Physics Laboratory of the Hebrew University of Jerusalem. The latter also leads a research team which, for the last fifteen years, has been studying

rainfall stimulation in Israel. Prof Braham and Dr Gagin visited all organizations in South Africa where relevant research is being done, or having an interest in the subject, amongst others the Weather Bureau, the CSIR, the Department of Water Affairs and the hail prevention project at Nelspruit operated by the Colorado International Corporation on behalf of the Lowveld Tobacco Co-operative. At the end of the consultants' visit, a meeting was arranged where these organisations were represented and this afforded an opportunity to exchange information and ideas on relevant research in South Africa and to enable the consultants to complete their impressions. The consultants' final report contained recommendations regarding current research programmes and their integration into a coordinated national programme.

Production of water by abstracting moisture from the atmosphere by means of hygroscopic materials

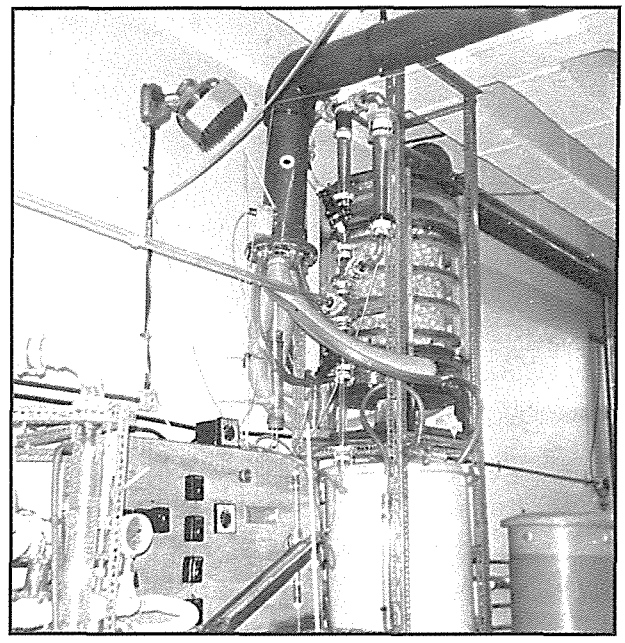
(Existing project: Contract with the University of Pretoria – Department of Chemical Engineering)

The project entails an investigation of the technical and economic feasibility of abstracting, and therefore reclaiming, water vapour from the atmosphere by means of chemical processes. The investigation consists of two parts, *viz*. determination of the most suitable process on a laboratory scale and, secondly, determination of mass transfer data and design parameters for scaling up the process.

During the first phase of the project it was found that the most suitable hygroscopic material for the purposes of this study was a concentrated solution of lithium chloride. Mass transfer data and design parameters as well as proposed scaling-up factors for larger plants were developed on a laboratory scale. Initially the aspect of costs was regarded to be of minor importance and the emphasis was placed on the technical aspects, namely the technical feasibility of reclaiming water from the atmosphere.

During the year under review a small experimental plant was designed and built on the basis of results obtained on laboratory scale. The envisaged programme of investigation has been completed during the year.

A number of useful results has already been obtained by means of the experimental plant, amongst others the following:



The test facility developed for the abstraction of moisture from the atmosphere by means of hygroscopic materials. The water obtained is very pure and in no way polluted by the absorption material.

- Practical problems which occurred led to the early identification of, and finding of solutions for, similar problems which may be encountered with an operational plant. Practical temperature and concentration limits found will make the development of an optimum circuit for a continuous process possible.
- A correlation for mass transfer coefficients is currently being established which should yield dependable results.
- Information obtained with the experimental plant, together with data obtained from laboratory scale research, make it possible to define reasonably dependable scaling-up factors for a wide range of packings in the absorption tower.
- The abstraction of water from the atmosphere appears to be totally feasible. Water obtained is pure and in no way contaminated by the absorption material.

The project has now been completed and the final report on the findings will become available during 1977.

Chapter 10

Desalination

It is already clear that the role of desalination in South Africa's future water economy will be one of considerable importance. In order to achieve optimal use and reuse of saline waters and effluents, it is essential that proficiency in desalination know-how and techniques be developed. This is the motivation for the desalination research being financed by the Commission (see also Chapter 8 of the 1975 Annual Report).

It was considered essential that all the desalination research in South Africa should be properly co-ordinated. To this end a specialist consultant was employed by the Commission in 1975, and a Study Group for Desalination Research was formed and held meetings in December 1975 and April 1976. Representation on the Study Group included the Water Research Commission, The National Institute for Water Research (NIWR) of the CSIR, the Department of Water Affairs (DWA) and its branch in South West Africa, the Department of Agricultural Technical Services, the Veterinary Research Institute and the Universities of Natal, Cape Town and Stellenbosch.

On the recommendation of the Study Group for Desalination Research the Water Research Commission established a Co-ordinating Research and Development Committee (CRD-committee) for Desalination Research. This CRD-committee consists of representatives of the Water Research Commission, the NIWR, the DWA, the DWA (SWA), the Department of Agricultural Technical Services and ESCOM. The CRD-committee met in July 1976, endorsed the *Master Plan for Desalination Research* prepared by the Study Group and recommended a priority programme for implementing the research.

Master plan for desalination research

This Plan makes provision for research and development work in the following areas:

- Reverse osmosis and ultrafiltration
- Electrodialysis
- Ion exchange technology (conventional resins and thermally regenerable resins)
- Distillation technology
- Freeze technology
- Brine disposal
- Techno-economic studies on mineralized waters.

There is provision in the Master Plan for: basic research; laboratory research; pilot plant design, construction and evaluation; a study of available equipment; the application of the research to various types of waters. The latter will include:

- Industrial wastes
- Sea water
- Sewage effluents
- Brackish borehole and river waters
- Waters containing toxic substances
- Waters reclaimed by advance treatment processes.

A priority research programme, based on the Master Plan, was recommended by the CRD committee and approved by the Water Research Commission. This makes provision for basic research (principally by the CSIR) on membrane technology (continuation of the development of new and improved membranes, dynamic membranes, renovation of deteriorated membranes, the problem of membrane fouling, reclamation of industrial wastes using membrane technology and the disposal of desalination brines and mineralized effluents) and for the following projects for which funds may be obtained from the Water Research Commission:

- The development and production of membrane support systems and modules (in progress).
- The reclamation of sewage effluent (in progress).
- The reclamation of industrial effluents (in progress on selected effluents from the textile industry).

- Practical demonstration of the commercial desalination of brackish water by reverse osmosis (to be planned).
- The desalination of sea water by reverse osmosis (planning in progress).
- The application of thermally regenerable ion exchange resins (being examined).
- Desalination and reclamation of secondary sewage effluent by ion exchange (in progress).

It can be seen from the foregoing that the processes of reverse osmosis, ultrafiltration and ion exchange are receiving priority attention, while relatively little attention is at this stage being given to the processes of distillation, freeze technology and electrodialysis.

The two existing contracts between the Commission and the NIWR, namely research on the WAT process for the desalination of sea water and research on the desalination of brackish water, terminated at the end of 1976. Desalination research will continue in 1977 under a new agreement with the NIWR. Research into the desalination of treated sewage effluent by means of an ion exchange process is being conducted by the University of Cape Town. Notes on these projects are set out below:

RESEARCH PROJECTS

Desalination of brackish water

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

The National Institute for Water Research has completed the evaluation studies of commercially available brack water desalination equipment, which has been undergoing tests in the Beaufort West district since November, 1974. The results achieved have been variable, but clearly demonstrate the technical practicability of the reverse osmosis process for desalination of brack waters under difficult field conditions. The final project report and a Brack Water Desalination Manual is in preparation and the former will be available for distribution in 1977.

The research clearly demonstrated that groundwater or surface water that has been effectively clarified, can be successfully desalinated by the reverse osmosis process with the proviso that the high-pressure pump performs satisfactorily. Feed water pretreatment to prevent deposition, will have to be tailored to meet specific requirements. The reverse osmosis process is simple to operate and requires a minimum of high level supervision. Membranes used in the process, exhibit good life characteristics and should provide satisfactory service for three or more years. The cost of desalination by means of reverse osmosis can now be calculated with good accuracy for plants of varying output.

Considerable experience and knowledge has been obtained by establishing and operating the test facility and the successful desalination of brack water by means of reverse osmosis has been proved conclusively. This project has terminated and results will be made available. The information will also be used in the further development of a desalination programme in the Republic and South West Africa. The development work has also led to increased faith in the dependability of the membrane process to such an extent that it will in all probability be applied in other areas, e.g. the reclamation of sewage and industrial effluents.

The WAT process for the desalination of sea water

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

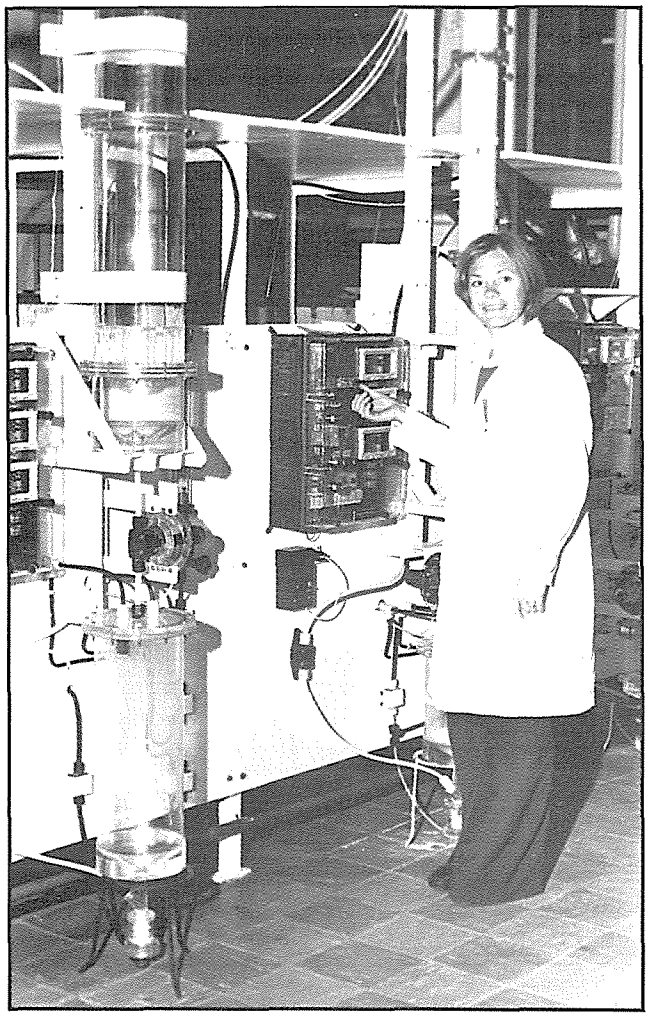
Investigation of the WAT process which was devised in an attempt to reduce the cost of desalting sea water and to recover valuable chemicals from the concentrate, has been terminated and a final report completed which will be available early in 1977.

As previously reported, the WAT process failed to meet its original objectives of providing a new and cheap source of fresh water from the sea, together with by-product chemicals, using an ion exchange process. This was because of *inter alia* the relatively large amounts of wash water consumed by the ion exchange operation. The considerable body of new and valuable scientific knowledge generated has, however, opened up new approaches to research on particular desalination processes. As a first extension of the original work, attention is being paid to the reverse osmosis (RO) and ultrafiltration (UF) processes, and experimental equipment has already been installed.

Preliminary investigations have been carried out on the restoration by heat and chemical treatment of membranes, the salt rejection capabilities of which have deteriorated in use. This work has shown that the most feasible method of improving the salt rejection of deteriorated reverse osmosis membrane modules in an operating plant will be by the periodic addition of certain water soluble polymers to the feed water.

This equipment has also shown that it is possible to concentrate specific types of size material from dilute solutions similar to those produced in the desizing operation in the textile industry. An extension of this work will be carried out shortly at a textile mill in conjunction with the Department of Chemical Engineering of the University of Natal, using a movable RO-UF rig constructed in the NIWR workshop.

Good progress has been made by the Membrane Research Group, at the University of Stellenbosch, on the development of techniques for the laboratory production of cellulose acetate, polyamide and polyimide membranes. Various modifications of the polymers by addition of reactive groups have been studied and promising results obtained. The work of this group is being done in terms of a contract between the CSIR and the University of Stellenbosch, with the financial assistance of the Water Research Commission.



The laboratory-scale test facility used by the Chemical Engineering Department of the University of Cape Town for studying the treatment of waste water by means of ion exchange.

Treatment of waste water by ion exchange

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

This project was initiated by the Water Research Commission in order to establish a method for the reclamation of highly mineralized industrial sewage effluents for industrial reuse.

The ion exchange process for the treatment of wastewater is being developed to give simultaneous removal of inorganic salts and residual organic material. In addition to the desalination, all undesirable nutrient chemicals such as nitrates and phosphates, heavy metals such as iron, copper and zinc and organic colouring matter, such as humic acids, are removed, resulting in a complete tertiary treatment process.

The economic viability of the treatment depends on the regenerant chemical recovery, on the life of the ion exchange resins when subjected to the noxious materials present in the water, and on the specific design of the exchange columns.

A test procedure, in which ion exchange resins are contacted with sewage plant discharge solutions in a simulation of full-scale operation, is running continuously in order to determine resin life. Monitoring of the resin characteristics every 50 cycles have shown no deterioration of properties after 750 cycles.

Initial bench scale tests on the recovery of ammonium nitrate (a valuable fertilizer) as regenerant chemical have been extended to laboratory pilot plant scale. The earlier favourable results have been duplicated on the bigger scale, indicating that the recovery operation is indeed chemically feasible. On an economic basis, the chemical recovery could mean a 50 per cent reduction in the costs of operating a full-scale plant.

The research has clearly shown that desalination and the removal of undesirable organic chemical residues may simultaneously and successfully be obtained with ion exchange. The process is practically feasible and experimental work is now in progress to develop design criteria with a view to the establishment of a pilot plant. Such a pilot plant could well be erected at the Athlone Sewage Works where research is in progress on the reclamation of purified sewage effluent for industrial reuse (see chapter 2).

A laboratory-scale pilot plant has already been erected, consisting of five columns which vary in diameter from 50 to 200 mm and in height from 3 to 6 m. Together these columns form a treatment plant with a capacity of 5 m^3/d. The work on these columns is at present centred on assessing the characteristics of the ion exchange reactions in each column. This is necessary in order to determine the efficiency of operation and hence the economic evaluation and design of a full-scale unit.

Future test work will be directed towards running the five columns as a complete laboratory-scale tertiary treatment unit for local municipal wastewaters.

Chapter 11

Information and publications

In terms of section 3(1)(f) of the Water Research Act, 1971 (Act No 34 of 1971) it is one of the functions of the Commission "to accumulate, to assimilate and to disseminate knowledge in regard to (water research) and the application thereof, and to promote development work . . . of such application."

The Commission regards this function as having two main facets: Firstly, promoting the *dissemination* of information, and secondly promoting the *application* of information.

Dissemination of information

As far as this aspect is concerned, the Commission has created three formal routes:

- A scientific journal on water – **Water SA**
- A newsletter on water – **SA Waterbulletin**
- The South African Water Information Centre

Water SA was launched in April 1975, appears quarterly and consists of original research articles and review articles on all aspects of water science. The inflow of articles to the journal is still on the increase, whilst feedback by way of commentary and requests to be included on the mailing list indicates that the journal is well-received.

SA Waterbulletin was launched in August 1975. The bulletin contains articles, news snippets and general items of interest on many aspects of water locally and overseas. It concentrates especially on introducing the activities of different organizations dealing with water in the Republic. During 1976 space has been allocated for the introduction of new water equipment and processes, and manufacturers and distributors of equipment have been invited to contribute to this feature. Reaction to this was very encouraging. The mailing list for *SA Waterbulletin* has also grown steadily as a result of requests. Despite the fact that the newsletter is a bilingual publication, requests for it are regularly received from abroad.

The activities of the **South African Water Information Centre** have now gathered momentum and are described later in this chapter.

The application of information

To promote the application of information – i.e. technology transfer – must be seen as an extension of information dissemination, and the two activities should go hand in hand.

As mentioned in chapter 1, the Commission is thoroughly aware of a need to initiate a programme in this respect, and during 1976 sent one of its Senior Advisers overseas to obtain information on this and to formulate proposals which can be implemented in 1977.

Although as yet the Commission does not operate a systematic and purposeful programme of technology transfer, it has already taken action in certain directions which will constitute important elements in such a programme:

- During 1977 the first in a series of manuals will be published in which research results will be "packaged" in a practically useful form. The manuals relate to projects being financed by the Commission.
- As mentioned in chapter 1 of the 1975 Annual Report, the Commission's Co-ordinating Research and Development Committees are eminently suitable for promoting technology transfer in specific problem areas. The committees serve to identify problems clearly and to collect information which could be applied in their solution. These are the ideal circumstances for promoting technology transfer, as the committees are in direct contact with bodies and organizations which can apply such technology.
- The Commission's policy of bringing overseas specialists to the country from time to time to study problem areas in the country's water economy (within a research context and in collaboration with local experts), creates direct points of contact with overseas technology and its transfer to local situations.

South African Water Information Centre

The South African Water Information Centre is operated as an independent unit by the CSIR on behalf of and under contract to the Commission.

The Centre has developed a computerized bibliographic data base, called *Waterlit.* This base contains bibliographic data of articles on water which have appeared in journals and reports and which are available in South Africa. From January to June 1976 approximately 4 000 items from 232 journals and various reports were added to the base. This base is used for the selective dissemination of information via the SASDI service of the CSIR. SASDI compiles an interest profile consisting of a number of combinations of key words, for each user. By means of a computer, this profile is compared with the information appearing in the monthly edition of the data base and corresponding items are abstracted, printed and posted to the user. In this way the article is rapidly brought to the attention of the user who need not scrutinize a mass of material himself. SASDI has already tested 46 profiles against Waterlit.

By using keywords it is now possible, with the aid of a computer, to undertake a retrospective search on both Waterlit and on material which has appeared in *Current Literature on Water* since 1971. This combined base currently contains approximately 44 000 items. From March to June 1976 a total of 56 retrospective searches were done. Thirty-five of the searches were of a purely scientific nature while 21 were of a more general nature.

The Centre has published a register of water research projects and of scientists active in the water field, and intends annually expanding and revising this register. The current register contains details of 293 projects and 243 research scientists. Keywords afford the user easy access to the register.

In 1976 the Centre distributed 909 questionnaires of which 31 per cent were completed and returned. From these questionnaires it was determined that the Centre's two publications, *Selected Journals on Water* and the *Water Patent Bulletin* satisfied a real demand and that there was a need for a bibliographic data base on water. Waterlit will fulfil this need.

The Centre currently offers the following services:

- **Selected Journals on Water** – a current awareness bulletin.
- **Water Patent Bulletin** – abstracts of patents in the water field.
- An SDI service on Waterlit via SASDI.
- Retrospective searches on Waterlit and **Current Literature on Water**.
- A register of water research projects and of research scientists active in the water field.

The Centre has established several international contacts and continues to expand these contacts in order to ensure that South African users can obtain all the information they may require.

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 1976 to 31 December 1976.

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 1976 financial year in Government Notice No 1010 of 18 June 1976:

"(1) 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), to be irrigated at any time during the period 1 January 1976 to 31 December 1976 with water supplied or made available from a Government dam and distributed by means of a canal, irrespective of whether or not such canal 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 which I may levy in respect of the land concerned during the said period in terms of section 66 or section 56 (3) of the said Water Act, or, if no such rate is levied, the rate levied hereby shall be payable to the Secretary for Water Affairs upon demand.

"(2) Twenty (20) cents in respect of each hectare of land scheduled as in paragraph (1), but where the water supplied or made available is not distributed by means of a canal. This rate shall be recovered in the manner described in paragraph (1).

"(3) 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 1976/77 or, as the case may be, the 1976 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 board 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.

"(4) Two-tenths of a cent (0,2c) per cubic metre in respect of metered water supplied or made available during the period 1 January 1976 to 31 December 1976 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 56 (3) or section 66 of the water during the said period.

"(5) 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 1976 to 31 December 1976 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 above-mentioned public supplier during the said period the quantity of water supplied or made available from the Government water work in terms of paragraph (4) 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:

(a) In respect of the period 1 January 1976 to 30 June 1976, not later than 30 September 1976; and

(b) in respect of the period 1 July 1976 to 31 December 1976, not later than 31 March 1977."

In terms of section 11 of the Water Research Act as amended, the Minister of Water Affairs has announced the following rates and charges for South West Africa in respect of the 1976/77 financial year in Government Notice No 1160 of 2 July 1976:

"(1) Forty (40) cents in respect of each hectare of land to be irrigated at any time during the period 1 July 1976 to 30 June 1977 with water supplied or made available from a Government water work. This rate shall be recovered by or by direction of the Secretary for Water Affairs and shall be payable simultaneously with any 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 1976 to 30 June 1977 from a Government water work for purposes other than the irrigation of land. This charge shall be recovered by or by direction of the Secretary for Water Affairs simultaneously with any 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 1976 to 30 June 1977 by the Municipalities of Windhoek and Tsumeb. The rates shall be recovered by the said Municipalities and paid over to the Director of Water Affairs, Private Bag 13193, Windhoek:

(a) in respect of the period 1 July 1976 to 31 December 1976, not later than 31 March 1977; and

(b) in respect of the period 1 January 1977 to 30 June 1977, not later than 30 September 1977."

WATER RESEARCH COMMISSION

STATEMENT NO. 1

BUDGET 1977

ESTIMATED INCOME		
Rates and charges in terms of Section 11 of the Water Research Act		2 920 000
Interest on investment		200 000
		3 120 000
Appropriation from accumulated funds		1 835 600
TOTAL ESTIMATED INCOME		4 955 600
ESTIMATED EXPENDITURE		
Administrative expenses:		
Salaries and allowances	418 600	
Subsistence and travelling expenses	72 300	
Postal, telegraph and telephone	15 000	
Printing, stationery, advertisements and publications	58 000	
General expenditure	83 200	
		647 100
Research Projects:		
Approved projects		
Development of research on the reclamation of water at the Athlone Sewage Works, Cape Town	34 390	
Technological development of water reclamation on the basis of the Windhoek plant	120 000	
Eutrophication of rivers and dams	140 900	
Technological development of water reclamation and pollution control – Daspoort	206 000	
Reclamation, storage and abstraction of purified sewage water in the Cape Peninsula	344 960	
Research on the treatment of waste water by ion exchange	105 000	
Research on the activated sludge process	63 800	
The removal of metal ions from dilute solutions in an electrolytic precipitator	25 530	
The role of aquatic macrophytes in Swartvlei, Wilderness, in maintaining trophic conditions	36 260	
Hydrological investigation of small catchments in the Grahamstown area	18 370	
Hydrological investigation of small rural catchments with specific reference to flood events	38 640	
Hydrological investigation of small catchments in the Mtunzini district	22 500	
Biological denitrification and the removal of phosphate	71 000	
An investigation on the optimal utilization of water in the Eerste River by storage in sandbeds or by other means	84 200	
South African Water Information Centre	125 000	
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	166 760	
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	204 890	
Research on water consumption patterns in urban areas	27 000	
Research on the removal of sludge and wash water at water purification installations	22 300	
Research on water losses in pipe networks	18 000	
Geohydrological studies in the Gamagara catchment using environmental isotope and complementary techniques	98 540	
The development of the concept of the runhydrograph in the analysis of flood hydrographs	66 360	
Research on flood damage – BER	10 460	
An investigation into soil compaction under irrigation at the Vaalharts State Irrigation Scheme	17 190	
An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	8 000	
Research on flood damage – ISER	63 190	
Research project dealing with the microbiological quality of reclaimed water with particular reference to health aspects	124 890	
Research on the soil factors effecting the optimal utilization of irrigation water in the Bantu Homelands	16 000	
Water requirements of certain agronomic and vegetable crops	20 970	
Research in connection with the purification and re-use of effluents from the hides and skins curing, fellmongery and tanning industries	53 000	
	2 354 100	
Other possible projects	1 292 400	
		3 646 500
Contracting of overseas researchers and expertise		362 000
Research and other grants		130 000
Specialist and Consultation Services		170 000
TOTAL ESTIMATED EXPENDITURE		4 955 600

WATER RESEARCH COMMISSION

STATEMENT 2

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD 1 JANUARY 1976 TO 31 DECEMBER 1976

1975	Expenditure		1976
R		R	R
210 173	Salaries and allowances		288 531,93
8 962	Subsistence		12 147,63
1 635	Motor transport		2 433,32
29 370	General transport		47 151,34
—	Commission members allowance		1 283,72
4 811	Postal and telegraph services		3 624,47
6 262	Telephone services		8 569,81
5 793	Printing and stationery		7 149,99
4 719	Advertisements		3 777,40
17 420	Publications and information		32 398,39
3 611	Lease and maintenance of office equipment		6 686,12
3 057	Entertainment expenses		4 721,92
14 627	Office rental		17 417,50
3 993	Maintenance of and alterations to offices		1 203,15
514	Electricity		787,74
5	Maintenance and lease of furniture		102,40
4 234	Depreciation		6 118,40
920	Insurance and licences		1 114,70
31 979	Collection fees		31 424,30
958	Audit fees		720,00
880	Legal costs		571,50
1 147	Registrations and subscriptions		2 206,65
949	Miscellaneous petty expenses		2 255,29
	Research projects:		
2 132	Development and research on the reclamation of water at the Athlone Sewage Works, Cape Town	184 228,22	
14 609	Technological development of water reclamation on the basis of the Windhoek plant	567 495,38	
43 813	Eutrophication of rivers and dams	88 601,00	
396 140	Technological development of water reclamation and pollution control – Daspoort	359 824,00	
78 065	Research on desalination of brackish water	43 576,00	
104 358	Reclamation, storage and abstraction of purified sewage effluent in the Cape Peninsula	429 215,00	
816	Natural draught dry cooling heat exchangers	19 184,89	
42 000	Development of mathematical models for the optimisation of systems for the development of water resources	—	
57 487	Research on recycling of water and recovery of chemicals in the textile industry	—	
77 767	Research on the treatment of waste water by ion exchange	57 595,00	
78 198	Research on the activated sludge process	68 628,24	
6 484	The removal of metal ions from dilute solutions in an electrolytic precipitator	19 679,85	
26 173	The role of aquatic macrophytes in Swartvlei, Wilderness, in maintaining trophic conditions	28 331,67	
17 714	Hydrological investigation of small catchments in the Grahamstown area	46 432,37	

1975	Revenue			1976
R		R	R	R
	Rates: Government irrigation schemes with canal systems:			
	Received	18 008,94		
	Less: Adjustment in respect of previous years	5 347,66		
			12 661,28	
	Plus: Outstanding		53 012,81	
75 354				65 674,09
	Rates: Government irrigation schemes without canal systems:			
	Received		428,94	
	Plus: Outstanding 1976		2 856,31	
2 997				3 285,25
	Rates: Irrigation Board Schemes:			
	Received	26 371,38		
	Less: Adjustment in respect of previous years	1 657,86		
			24 713,52	
	Plus: Outstanding 1976		3 161,40	
29 182				27 874,92
	Charges: Metered water from Government Schemes:			
	Received	1 861 096,03		
	Plus: Adjustment in respect of previous years	27 681,12		
			1 888 777,15	
	Plus: Outstanding 1976		209 262,26	
1 892 369				2 098 039,41
	Charges: Municipalities			
	Received	917 147,47		
	Less: Adjustment in respect of previous years	677,70		
			916 469,77	
	Plus: Outstanding 1976		10 024,56	
925 546				926 494,33
	Charges: S.W.A.			
	Received		33 098,09	
	Plus: Outstanding 1976		12 149,66	
19 444				45 247,75
22 977	Rates and charges prior to 1/1/76			—
221 380	Interest on investments			297 391,34
140	Sundry Revenue			549,13
—	Excess of expenditure over income			421 306,12

54 303	Hydrological investigation of small rural catchments with specific reference to flood events	—			
18 694	Hydrological investigation of small catchments in the Mtunzini district	129 411,38			
78 500	Biological denitrification and the removal of phosphate	57 218,00			
—	An investigation on the optimal utilization of water in the Eerste River by storage in sandbeds or by other means	81 799,77			
52 258	Development of the WAT-process for the desalination of sea water	72 703,00			
36 189	South African Water Information Centre	79 110,95			
11 956	Research on production of water by abstraction of water vapour from the atmosphere by means of hygroscopic materials	19 693,34			
77 336	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	160 244,10			
91 193	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	175 495,41			
5 698	Research on water consumption patterns in urban areas	21 402,46			
11 824	Research on the removal of sludge and wash water at water purification installations	17 277,68			
9 905	Research on water losses in pipe networks	16 814,60			
7 477	Geohydrological studies in the Gamagara catchment using environmental isotope and complementary techniques	74 928,90			
3 225	The development of the concept of the runhydrograph in the analysis of flood hydrographs	—			
52 786	Research on flood damage – Bureau for Economic Research	50 870,00			
13 497	An investigation into soil compaction under irrigation at the Vaalharts State Irrigation Scheme	15 021,72			
15 586	An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	17 775,72			
23 050	Research on flood damage – Institute for Social and Economic Research	42 006,59			
—	Research project dealing with the microbiological quality of reclaimed water with particular reference to health aspects	112 304,88			
—	Water requirements of certain agronomic and vegetable crops	27 472,75			
—	Research on the purification and reuse of effluents from the hides and skins curing, fellmongery and tanning industries	85 060,09			
—	Research on the technological application of anaerobic digestion for the purification of spent wine residues	11 000,00			
			3 180 402,96		
	Contracting of overseas researchers and expertise:				
—	Weather modification		43 711,40		
17 000	Research and other grants		33 154,08		
73 361	Specialist and consultation services		146 196,23		
1 233 776	Excess of income over expenditure		—		
R3 189 389			R3 885 862,34	R3 189 389	R3 885 862,34

WATER RESEARCH COMMISSION

STATEMENT 3

BALANCE SHEET AS AT 31 DECEMBER 1976

1975	Liabilities	1976		1975	Assets	1976		
R		R	R	R		R	R	R
	Sundry Creditors:				Capital assets:†			
11 812	Revenue paid in advance		18 303,80	5 000	Land		5 000,00	
	Fund Account:				Motor vehicles	11 665,76		
5 985 331	Balance at 31.12.75	5 985 330,49			*Less:* Depreciation	3 639,13		
	Less: Excess of expenditure			11 666			8 026,63	
	over income, 1976	421 306,12			Office equipment:	28 309,00		
			5 564 024,37		*Less:* Depreciation	1 415,45		
				19 159			26 893,55	
					Office furniture:	21 276,35		
					Less: Depreciation	1 063,82		
				17 596			20 212,53	
								60 132,71
					Current assets:			
				4 394 194	Investments		3 870 003,69	
				66	Advance payments		—	
					Sundry Debtors:			
					Outstanding Revenue:			
					Prior to 1976	19 320,26		
				270 368	1976	290 467,00		
						309 787,26		
				1 101 499	Project advances	1 255 881,07*		
				—	Subsistence and			
					transport advances	3 700,00		
				50	Deposits	50,00		
							1 569 418,33	
				50	Cash on hand		50,00	
				177 495	Cash in Bank		82 723,44	
								5 522 195,46
R5 997 143			R5 582 328,17	R5 997 143				R5 582 328,17

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

Pretoria, 25 March 1977

(Sgd) G J Stander
Chairman (Chief Executive Officer)

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, 14 April 1977

(Sgd) F G Barrie
Auditor-General

ANNEXURE

PROJECT ADVANCES

R1 255 881,07 – This amount represents the nett outstandings in respect of advances made to organizations for the following projects:

PROJECT	R	R
Development of research on the reclamation of water at the Athlone Sewage Works, Cape Town	123 298,05	
Eutrophication of rivers and dams	5 313,59	
Technological development of water reclamation and pollution control – Daspoort	13 650,29	
Research on desalination of brackish water	4 413,42	
Reclamation, storage and abstraction of purified sewage effluent in the Cape Peninsula	423 896,31	
Development of mathematical models for the optimisation of systems for the development of water resources	60 000,00	
Research on recycling of water and recovery of chemicals in the textile industry	34 473,27	
Research on the treatment of waste water by ion exchange	3 152,00	
The removal of metal ions from dilute solutions in an electrolytic precipitator	10 205,25	
The role of aquatic macrophytes in Swartvlei, Wilderness, in maintaining trophic conditions	61 025,24	
Hydrological investigation of small catchments in the Grahamstown area	29 392,92	
Hydrological investigation of small rural catchments with specific reference to flood events	80 937,22	
Hydrological investigation of small catchments in the Mtunzini district	96 694,55	
Biological denitrification and the removal of phosphate	2 910,88	
An investigation on the optimal utilization of water in the Eerste River by storage in sandbeds or by other means	34 750,23	
Development of the WAT-process for the desalination of sea water	8 846,34	
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	64 744,82	
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	88 481,84	
Research on water consumption patterns in urban areas	519,79	
Research on the removal of sludge and wash water at water purification installations	8 022,32	
Research on water losses in pipe networks	185,40	
Geohydrological studies in the Gamagara catchment using environmental isotope and complementary techniques	67 187,66	
The development of the concept of the runhydrograph in the analysis of flood hydrographs	33 644,80	
An investigation into soil compaction under irrigation at the Vaalharts State Irrigation Scheme	1 896,37	
An investigation into the influence of internal plant moisture stress on the growth and production of certain agronomic crops	708,02	
Research on flood damage – Institute for Social and Economics Research	4 780,68	
Research on the soil factors effecting the optimal utilization of irrigation water in the Bantu Homelands	27 099,00	
Water requirements of certain agronomic and vegetable crops	327,25	
Research on the purification and reuse of effluents from the hides and skins, curing, fellmongery and tanning industries	26 521,07	
		1 317 078,58
Less Excess expenditure over advances for projects		
Technological development of water reclamation on the basis of the Windhoek plant	2 808,41	
Research on the activated sludge process	17 609,24	
South African Water Information Centre	21 509,52	
Research on production of water by abstraction of water vapour from the atmosphere by means of hygroscopic materials	159,53	
Research on flood damage – Bureau for Economic Research	3 655,93	
Research project dealing with the microbiological quality of reclaimed water with particular reference to health aspects	4 454,88	
Research on the technological application of anaerobic digestion for the purification of spent wine residues	11 000,00	
		61 197,51
		R1 255 881,07