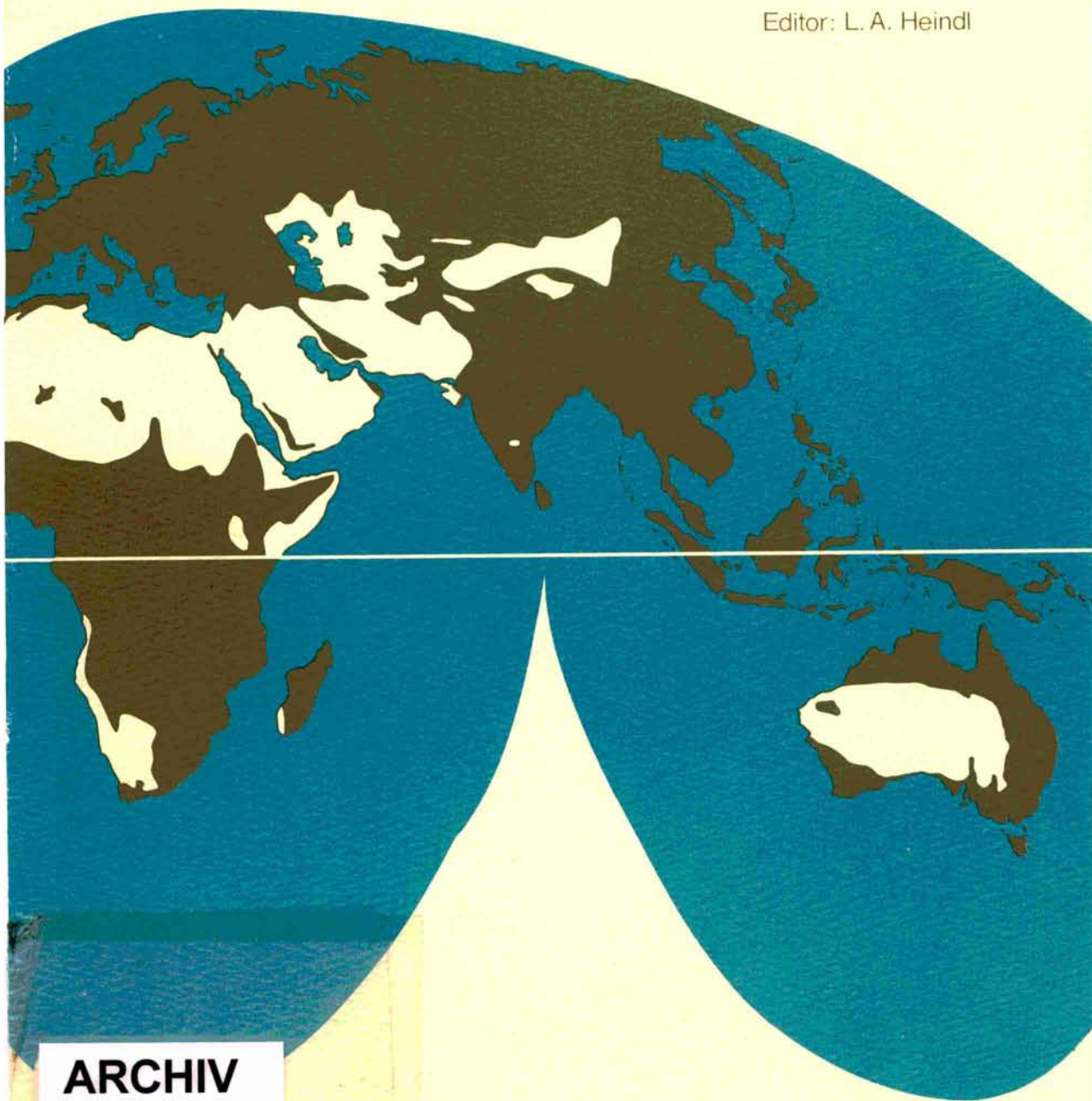


# HIDDEN WATERS IN ARID LANDS

Editor: L. A. Heindl



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report of a workshop on groundwater research needs  
in arid and semi-arid zones held in Paris, France

25 November 1975

## ABSTRACT

The Association of Geoscientists for International Development (AGID) held a workshop on groundwater research needs in arid and semi-arid zones. The objectives were to single out some specific research needs in relation to the use and management of groundwater in arid and semi-arid lands, and to focus the attention of the geoscience community on the hydrological effects of drought. This report of the workshop includes details on the availability of groundwater, groundwater quality and sources, the environmental and cultural impact of groundwater development, and coping with drought. Also included are conclusions and recommendations relevant to the research needed to accelerate and guide groundwater use and development.

## RÉSUMÉ

L'AGID, Association géoscientifique pour le développement international, vient de tenir un atelier sur les besoins en recherche sur les eaux souterraines dans les zones arides et semi-arides. Cette réunion avait comme objectifs, de dégager les besoins en recherche spécifique sur l'utilisation et la gestion des eaux souterraines dans les régions arides et semi-arides, et d'attirer l'attention de tous les savants en sciences de la terre sur les effets hydrologiques de la sécheresse. Le rapport de cet atelier traite de l'accessibilité des eaux souterraines, de leur qualité et de leurs sources, de l'impact produit sur la culture et l'environnement par l'exploitation de ces eaux et de la lutte contre la sécheresse. Le rapport comprend également des conclusions et des recommandations relatives à la recherche nécessaire pour diriger et accélérer l'utilisation et l'exploitation des eaux souterraines.

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*The views expressed in this publication are those of the authors and do not necessarily  
represent the views of the International Development Research Centre.*

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## INVITATION TO READERS

AGID is keen to have your reactions to this report, and views on groundwater research in general, so we have provided a tear-out questionnaire at the back of this book. We invite you to fill out the form to help us determine the value of our recommendations and the directions future groundwater research in arid and semi-arid lands should take.

## PREFACE

AGID was formed in response to the interest shown during the 1972 Symposium on Earth Science Aid to Developing Countries held during the 24th International Geological Congress at Montreal, Canada. The participants in this symposium showed a concern for exchange of information (or technology transfer as it seems proper to call it in today's jargon) regarding a gamut of problems encountered at all working levels by geoscientists involved in international development. The intensity of many comments revealed a sense of frustration that was obviously rooted in the general lack of opportunity to discuss these problems widely with one's peers and specifically with those who set policy, procedures, or basic programming. The substance of many comments was that this lack of communication too often leads to inadequately planned and poorly implemented projects. The question raised at the symposium was really, "How do we, geoscientists, get the ear of those who make the decisions to give them the benefit of our professional expertise and experience?" The answer offered was to form an international association.

In May 1974 the international workshop on Earth Science Aid to Developing Countries was held in St. John's, Newfoundland, Canada. The result was the formation of a new association — The Association of Geoscientists for International Development (AGID) — that has grown to an international body, grouping about 400 geoscientists from 60 countries, mostly from the Third World, and more than 20 organizational members.

Thanks to the International Development Research Centre (IDRC), funds were made available to enable AGID to hold two international workshops, in conjunction with the 25th International Geological Congress, before AGID's First General Assembly, in Sydney, Australia. The purpose of these workshops was to specify lines of research needed in the earth sciences so that they might be better applied to developing countries. This report is the result of the first of these two workshops, originally scheduled for Nicosia, Cyprus, but held on 25 November 1974, at the headquarters of the International Council of Scientific Unions (ICSU) in Paris, France. This workshop was designed to point out some specific needs in relation to use and management of groundwater in arid and semi-arid zones.

### **Why Groundwater Research?**

Research on groundwater problems in arid and semi-arid lands was selected as a topic because of the importance of water to the development of these areas, particularly in light of the recent Sahelian drought. By drawing on the expertise and experience among its own members and by inviting carefully selected international authorities,

AGID hoped that it could identify certain key lines of research that deserved to be highlighted in the management of groundwater in arid and semi-arid zones of the Third World. The subject matter covered by the workshop was, of course, well known to hydrogeologists, but it was felt to be well worth selecting topics most deserving of the attention of researchers and developers in the immediate future. A secondary purpose was to define the possible role that AGID could play in focusing the attention of the geoscience community on the hydrological effects of droughts.

Obviously no group, however large, could do justice to the topic in a one-day session, and the report says nothing new. But it does state what we feel is necessary in order that groundwater resources of arid and semi-arid zones can be managed satisfactorily.

We hope the report is read seriously by those who initiate, encourage, and promote research. Groundwater experts should realize that we are only paraphrasing what many have said repeatedly. However, decision-makers should become convinced that wisdom, knowledge, and care are necessary to exploit the full potentials of groundwater. Project hydrogeologists should themselves realize that our suggestions are really akin to theirs and that they are intended to help the local population and its administrators to adjust to new capabilities and responsibilities in groundwater procurement.

Finally, I would like to thank all those who made the meeting possible and who contributed to its success, including the participants and guests of AGID. We appreciated the hospitality and kindness of the ICSU in providing space and facilities for the meeting, and in particular of Dr F. W. G. Baker and his staff, who made the workshop and related meetings pleasant and productive.

I also wish to express my appreciation to Dr L. A. Heindl for acting as editor of this report.

Deborah Enilo Ajakaiye  
*President*  
*Association of Geoscientists for International Development*

## INTRODUCTION

The purpose of the Paris workshop was to single out some specific research needs in relation to use and management of groundwater in arid and semi-arid zones. The task was not to prepare a monograph or to present a series of reports that might be published. On the basis that those leading the discussions were reasonably well versed in the subject, the intent was rather to use the breadth of experience available to select and discuss some important topics of applied groundwater research. A secondary purpose was to identify the possible role that AGID could play in focusing the attention of the geoscience community on the hydrological effects of droughts.

The workshop operated simply. There was a loose agenda to guide discussion and to provide the basis of time control. Questions and comments were permitted freely. Dr Enilo Ajakaiye, President of AGID, acted as moderator, and deserves everyone's thanks for guiding the discussion and enabling the agenda to be covered in close to the allotted time. Three working documents were used in the morning session as general background, and are included in this report on microfiche in a pocket on page 3 of the cover.

The seven country reports or case histories presented during the afternoon session were informal and often entirely extemporaneous. They were more like answers to questions and comments than expositions of assigned topics; however, they promoted useful exchanges of opinions. Discussions during the symposium were so concentrated, the scope of subject matter so broad, and the diversity of opinion so great, that there was very little time to formulate conclusions. The Editor was asked to sort out the conclusions and recommendations and to submit his draft to a small panel for comment and revision. The final report follows.

## SUMMARY AND CONCLUSIONS

Arid and semi-arid zones encompass about one-fifth of the earth's surface. Increasing numbers of people continue to expand the use of these regions for food production and living space. The shortage of water for domestic, municipal, and irrigation purposes can be eased in many regions by use of the huge reserves of groundwater stored in confined aquifers underlying these areas. Yet, in many regions the amount and the quality available are unknown.

### **Availability of Groundwater**

The exploitation of groundwater, even under the best of circumstances, is neither simple nor without drastic long-range consequences. If it is "mined," i.e. withdrawn at rates greater than it is replenished, it becomes a finite resource. After the aquifer is depleted to the fullest extent practical with existing techniques, future generations will have to make extreme and expensive adjustments in water supply and use, and perhaps even in their social systems. Nevertheless, provided that those who make the decision to mine the groundwater are made fully aware of the long-term consequences, the production of groundwater through mining is an acceptable form of development. It is comparable to the mining of other nonrenewable resources.

If groundwater is exploited as a renewable resource, i.e. at a rate consistent with local surface supplies and precipitation, the aquifer could be used indefinitely. However, arid and semi-arid zones receive highly variable amounts of precipitation, both seasonally and over long periods, so such balanced use can be neither as intense nor as reliable as when the groundwater is mined.

Thus, one major aspect of groundwater exploitation is its *availability*. Huge reserves do exist in many confined regions of arid and semi-arid zones. These extensive aquifers, although not available in all regions, could be used much more extensively than at present. Their development, however, is not simply a matter of putting boreholes into the ground and directing the water to areas cleared for irrigation. A major obstacle is the depth limit from which water can be drawn; this limit is set by the available pumping equipment and power sources. A technical breakthrough could enable us to lower the water-pressure levels to the extent that much greater quantities of water could be made available for use. However, such breakthroughs also carry a price, not only in the cost of more highly sophisticated and powerful equipment, but also in the danger of provoking land subsidence.



## Groundwater Quality and Sources

A second major consideration in the use of groundwater is its *chemical* content. The quality of groundwater often decreases with depth, but in many regions the water in even the topmost aquifers is already of marginal quality. It could be saline and thus suitable for only a few crops. It could be corrosive, resulting in serious problems of pump, casing, and conduit maintenance. Or it could be both. Technologies for dealing with saline and corrosive water are available and are being improved, but they are neither as far advanced as they should be, nor as widely known or applied in water development projects as they could be. The fact remains that the reserves of saline water underlying many areas are greater than the reserves of potable or irrigable groundwater. This great water resource remains virtually untapped.

Improvement of desalination techniques, especially partial desalination using appropriate membranes, will have considerable impact in selected areas in the future. When tied to low energy consumption and the use of salt-resistant crops, such techniques may open new regions for settlement and development.

One of the major untapped resources in all arid regions is the *big desert floods*. Unfortunately only a small amount of this water is normally utilized even when the floods occur during droughts. Surface reservoirs are not the best answer because of the large variation in the amount of water, and conservation measures require large structures on streams with small average flow. There always is also the danger that reservoirs will be filled with flood-carried silt. High temperatures and winds during and after the rainy season cause high rates of evaporation with consequent loss of large amounts of water and possible deposition of salt pans or saline muds.

Turning flood water into groundwater, either by spreading it on permeable layers like alluvial fans or sand dunes, or by forcing it to infiltrate behind small dams or through injection wells, allows the storage of water for possible future droughts. This matter deserves further attention. However, the use of floods to recharge groundwater requires extensive construction and maintenance even though the final result is not as spectacular as a dam and the reservoir behind it. The most promising proposals so far are those in which artificial recharge from flood waters is carried out together with the development of conjunctive uses of ground and surface water supplies.

## Environmental and Cultural Impact of Development

Two other aspects of groundwater development in arid and semi-arid zones need to be considered. The first is the influence of groundwater development on the physical and ecological environment. The second is the interaction of this development with the cultural, social, economic, and political characteristics of the people affected.

For example, the arid and semi-arid regions are highly sensitive to developmental changes. When it is necessary to open new areas to advanced irrigation development to support a growing population, the environmental impact is of little concern. However, the use of desert lands for any man-made purpose disturbs the existing stage of adjustment. The effects of environmental stresses caused by man, regardless of whether they are irrevocable or correctable, must be considered in assessing the benefits of such new developments. The well-known case of severe soil erosion caused by overgrazing by cattle moved by their nomadic owners to central well locations in the Sahel illustrates this point.

Even more serious are the social and cultural aspects of groundwater development. There can be little justification for massive programs of well-drilling and water installations if the pumps break down through wear or improper use and remain out of service because of the inability to make repairs, or if the people affected do not understand the related problems of sanitation, drainage, and waste disposal. Likewise, the situation should be avoided whereby the installation of a new facility creates new social and political difficulties among the users, such as who takes water from where, with whom, and from whom?

Not too many years ago it was sufficient for a hydrogeologist to be able to estimate the key variables inherent to his disciplinary speciality. Where is the groundwater? At what depth can it be reached? What is its extent? How much is there? What should be the pumping and distribution pattern? Even the question of quality was rarely asked, for the accessible groundwater was in general touted as being inherently clean and good.

Today it is vital for the hydrogeologist to be alert to the environmental and cultural impacts of groundwater development. Until he can be assured that they will be considered adequately by someone in the matrix of decision-makers, he has a responsibility to provide a first approximation of their effects because his data and interpretation determine the feasibility of development in the first place. In this regard, hydrogeologists are much more conscious of the scope of their problem than a few years ago, but much progress remains to be made.

### **Coping with Drought**

The development of arid and semi-arid zones is never far removed from simultaneous consideration of droughts. This is particularly so when a drought of the duration and severity of the one in the Sahel is very much in the public eye. When considering droughts in the context of the water regimes of arid and semi-arid zones, it is important to discriminate between two types of problems.

In the first place, the problem of minimizing or ameliorating the effects of a drought is essentially a matter that should have been resolved before the drought occurred, or at worst, that must be dealt with while the drought is in progress. The steps taken to alleviate the effects of a drought are obviously based on knowledge and information gathered beforehand, and they are mainly palliative; they are far more connected with the problems of the people and their livestock than they are with climatic causes and hydrological effects. Hydrogeologists and other scientists and professionals can usually on short notice find some emergency supplies based on what they have learned in earlier studies, but this is not dealing with the basic problem of the cause of droughts.

Secondly, the problem of anticipating or predicting droughts — or worse, the long-term decreases in precipitation as part of a climatic variation — requires scientific studies whose results can be expected only in terms of decades, not years. Therefore, unless such studies are supported now, people in drought-prone areas will always be battling droughts on an emergency survival basis. At best, they may be aided by far-sighted emergency plans and contingent arrangements for them to live out the drought and pick up what is left of their lives when the rains come again. If no plans are laid, they will simply be added to the long list of victims devastated by one unforeseen drought after another.

Clearly a long-range approach to droughts is needed. Studies have indicated that droughts have limits in space and time and that they can alternate within short time ranges with periods of greater-than-normal precipitation. The archeological and geological records of the past few millenia give ample evidence for periods of time and space dominated by excessive or deficient moisture. The Sahelian drought is generally acknowledged as being within the so-called normal scheme of meteorological events on the basis of about 100 years of record. But such information is more a matter of record than assistance to those living in regions where droughts are part of a traditional way of life. So far as is known, no major effort has been made to predict droughts as they occur in time and space. Considering the damage caused by droughts — and not just in arid and semi-arid regions — a concerted program of research into the nature of droughts, aimed at developing a predictive system, deserves serious consideration by national and international institutions.

## RECOMMENDATIONS

The AGID workshop lasted only one day and involved the experience and opinion of only a small group of hydrogeologists and others concerned with international development. It was impossible to cover the whole field of groundwater research needs in arid and semi-arid zones. The following recommendations, therefore, do not cover the field; rather they represent a distillation of the thinking of a small group of people. Moreover, these people have not been so far removed from the impact of their own daily professional activities and both the professional and general news media that their views can be either comprehensive or all-encompassing. Nonetheless, we believe the recommendations are relevant to research needed to accelerate and guide groundwater use and development in arid and semi-arid zones.

In compiling their recommendations, the participants of the workshop were conscious that they were introducing them at a time when many agencies had already been working in the groundwater field for many years and that extensive programs of work in the arid and semi-arid zones already existed. Accordingly, these recommendations are offered in the light of the AGID objectives, with particular emphasis on the need for communication and integration of results and on the need for training during the project studies.

**RECOMMENDATION 1:** The science and techniques of groundwater development and management of regional problems should be encouraged and advanced by national and international bodies by the improvement of means of exchange and dissemination of information and by the encouragement of research.

*Commentary:* The participants appreciated the importance of continuing locally oriented studies everywhere. However, it was realized that the solution of many local problems depends on understanding regional conditions, and that many regions involving river and subsurface drainage basins are shared by two or more countries. The importance of regional studies was stressed because: (1) binational and multinational situations are common; (2) it is often difficult to arrange for coordinated investigations of such areas; (3) a large-scale regional approach is basic to understanding local problems; and (4) regional studies are becoming increasingly timely as new pressures arise for finding additional land for agricultural production and living space. The following suggestions were made.

(1) AGID should promote a series of interdisciplinary conferences jointly with UNESCO and other appropriate intergovernmental and nongovernmental agencies,

such as IAH (International Association of Hydrologists) and IAHS (International Association of Hydrological Scientists), to: (a) exchange ideas regarding exploration, exploitation, and management techniques among geologists, engineers, and geophysicists working in the water resources fields; and (b) achieve and disseminate fuller understanding of the physics and chemistry of flow through the rocks underlying multinational basins. It was noted that many international basins in arid and semi-arid regions are underlain by crystalline and carbonate rocks, whose hydrology is among the most difficult to understand.

(2) Representatives of existing arid-land study centres should establish an integrated program for providing information to the field investigator, the emphasis being on distribution and dissemination capabilities rather than storage and in-house retrieval. In this connection, the participants urged that all hydrogeological reports, except those of a strictly proprietary nature, be made available by having at least the title, table of contents, maps and illustrations, and abstract forwarded to the most convenient arid-lands study centre cooperating in this program.

(3) A casebook of hydrogeological practices in arid and semi-arid zones should be developed under UNESCO's International Hydrological Program (IHP) as a supplement to its existing program of publications on groundwater studies.

RECOMMENDATION 2: The following selected areas of applied research should receive immediate attention from individual agencies or national groups so that the results can be made available to guide decisions regarding the increased use of lands in arid and semi-arid zones for food production:

- (1) identification of areas and regions with similar conditions as a basis for comparative studies;
- (2) identification of special techniques by which short-term hydrogeological studies can be carried out in regions with scarce hydrological data;
- (3) adaptation of geophysical methods used in petroleum and mining exploration to groundwater work in arid and semi-arid zones;
- (4) development of economical large-bore drilling techniques capable of reaching deep saline aquifers (ca. 2000–3000 m);
- (5) development of large-diameter submersible pumps capable of operating with minimum maintenance in deep saline environments;
- (6) development of inexpensive sources of power for pumping water, which are suitable for arid and semi-arid zones;
- (7) comparative field testing of mathematical models to determine their efficacy as both an analytical and managerial tool; and
- (8) development of hydrologically, agronomically, and engineeringly compatible methods for improving recharge techniques, particularly those concerned with capturing otherwise dissipated excess storm runoff.

RECOMMENDATION 3: Each country, individually and in cooperation with its neighbours and concerned international agencies, should develop

a plan for providing itself and its region with adequately trained hydrogeologists and hydrological engineers, hydrological technicians, and field, laboratory, and office assistants. The training should provide the necessary distribution of executive, managerial, professional, administrative, and support staffs.

*Commentary:* The participants agreed that professional education and training are probably the most important requirements for the development of arid and semi-arid lands. Each country's needs are different, and each should assess its manpower needs and decide the means by which they can best be met and in what period of time. The plan thus becomes a frame of reference by which its progress can be judged by its own people. In many instances, by working closely with its neighbours, a country can reinforce and accelerate its program by developing ad hoc regional arrangements to expedite education and training at all levels.

Top-level management must be aware of hydrological principles, and hydrogeologists must be acquainted with managerial problems and must influence the decisions, regardless of the pressures exerted to complete one project and get on with the next. Time must be made available for education and training even if it is wrenched out of project and program schedules.

In support of this general recommendation, these suggestions were made.

(1) Refresher courses should be conducted under regional consortia sponsored by regional international and intergovernmental organizations; such courses should be held in languages known to all participants in a familiar cultural milieu, and with minimal disturbance of local work assignments.

(2) Hydrogeological curricula at all institutions of higher learning should require, as a prelude to any professional hydrological degree, studies of the interrelationships of water development and local customs and practices, and the impact of changes in local water regimes on existing ecology.

**RECOMMENDATION 4:** Managerial practices in the field of water development in arid and semi-arid lands should be made the subject of research designed to provide answers to short- to long-term problems; and a casebook on management of hydrogeological programs, ranging from regional to international investigations, should be compiled under the IHP.

*Commentary:* Managerial practices should be investigated at three different but related levels: (1) management and the existing and proposed conditions of the water regimes; (2) management and the interaction of the proposed program of water development on the regional ecological environment; and (3) management and the interaction of the proposed program of water development with the social, economic, and political practices of the region. In addition to the usual managerial items, special attention should be given in the casebook to problems, such as staff splitting (i.e. geologists vs. geophysicists and geologists vs. engineers); seniority and opportunities for education and training, attendance at conferences, etc.; management of interdisciplinary teams; and interinstitutional coordination.

The participants contended that hydrogeologists should undertake investigations to include considerations of the cultural and environmental impacts of the probable results of their studies. To this end two suggestions were made.

(1) Hydrogeologists should not, in general, complete their recommendations regarding the potential uses of the available water until after they have had the opportunity to discuss their disciplinary conclusions with experts familiar with local customs and ecology. Where this is not practicable for reasons outside their control, they should emphasize in their recommendations the overriding need that the effects of implementation of their proposals should be reviewed in the context of the social, ecological, and economic conditions.

(2) The university training of natural resources managers should include studies in the interrelationship of the use of land, water, and air for development purposes, as well as studies of local customs, traditions, and practices, and the impact of changes in the management of local resources on the existing ecological, social, economic, and political matrix.

**RECOMMENDATION 5:** Inventories, quantitative and qualitative, of regional groundwater resources of arid and semi-arid zones should be prepared and carried out by appropriate bodies as a basis for both long-term development and for the short-term amelioration of disaster conditions.

*Commentary:* This is a project of major importance, which can be accomplished only through the cooperation of national and intergovernmental bodies. The participants suggested that this project, to be linked to the IHP, should encompass these points: (1) the collection of all available information and the determination of its reliability; (2) the interpolation and extrapolation of information to cover areas of inadequate data; (3) the continuation of efforts to improve the methodologies involved in the collection, extension, and dissemination of the data; and (4) the publication of results as they are assembled.

The project should be developed by stages and lead first to an approximation and subsequently to an increasingly accurate estimation of water reserves. It should also be coordinated closely with national and international efforts to advance regional geological and hydrological mapping. As a fringe benefit, the project should provide guidelines for an internationally acceptable format for compiling hydrological and geological data in basins common to more than one country.

**RECOMMENDATION 6:** Hydrogeologists, as a regular part of areal investigations, should collect information on local droughts and make it available, preferably through the most convenient arid-lands study centre, to those involved in drought studies.

*Commentary:* The participants recognized that the problems of climatological and meteorological research are outside the main scope of their concern. However, droughts are more devastating, if not more frequent, in arid and semi-arid zones than elsewhere and are, therefore, central to an evaluation of the impacts of any developmental un-

dertaking. Hydrogeologists can no longer be satisfied with an interpretation of the geological skeleton and the waters that move through it. They must now realize that their work continuously carries cultural and ecological implications and that they must be aware of these factors in order to provide a professional evaluation of their assignment to those responsible for its development, management, and eventual disposition.



## APPENDIX I — PARTICIPANTS

### *Hydrogeologists*

Dr G. Castany, Director, Hydrogeology Section, Bureau de recherches géologiques et minières (BRGM), Paris, France, and Secretary, International Association of Hydrogeologists

Dr J. Cornet, Assistant Director, Hydrogeology Section, Bureau de recherches géologiques et minières (BRGM), Paris, France

Dr D. Gray, Assistant Director, Institute of Geological Sciences of the United Kingdom, London, England

Dr L. A. Heindl, Executive Secretary, United States National Committee for the International Hydrological Decade, National Research Council, Washington, D.C., USA, and member of the AGID Council

Prof A. S. Issar, Desert Research Institute, Ben-Gurion University, Beer-Sheva, Israel

Mr J. L. Mestraud, Secretary-General, Association of African Geological Surveys, Paris, France

Dr G. Ozoray, Hydrogeologist, Alberta Research Council, Edmonton, Canada

### *Guest*

Mr M. Houde, Geoscientific Advisor, International Development Research Centre, Ottawa, Canada

### *Members of AGID Council*

Dr D. E. Ajakaiye, Senior Lecturer in Geophysics, Ahmadu Bello University, Zaria, Nigeria, President

Dr R. A. Blais, Dean of Research, École polytechnique de Montréal, Montréal, Canada, Vice-President

Dr A. R. Berger, Associate Professor of Geology, Memorial University of Newfoundland, St. John's, Canada, Secretary-Treasurer

Dr A. M. Al-Shanti, Director, Centre for Applied Geology, Jeddah, Kingdom of Saudi Arabia

Dr S. Bonis, Geologist, Instituto Geografico Nacional de Guatemala, Guatemala City, Guatemala

Dr W. von Engelhardt, Professor of Mineralogy, University of Tübingen, Tübingen, Federal Republic of West Germany

Dr J. V. Hepworth, Principal Scientific Officer, Institute of Geological Sciences, London, England (formerly Director, Geological Survey of Botswana)

Dr C. Hudson, Economic Geologist, Lima, Peru

Dr S. Singh, Manitoba Department of Mines, Winnipeg, Canada (formerly Commissioner, Geological Surveys and Mines Department, Guyana)

Dr Tan Bock Kang, Lecturer in Geology, University of Malaya, Kuala Lumpur, Malaysia

## APPENDIX II — WORKING PAPERS

These three working papers are included on microfiche for general background information (in pocket on page 3 of the cover).

1. Major groundwater problems in developing countries of the arid zone. Hydrogeology Department, Centre for Applied Geology, Jeddah, The Kingdom of Saudi Arabia.
2. Groundwater research needs. A.S. Issar, Desert Research Institute, Ben-Gurion University, Beer-Sheva, Israel.
3. Notes on a groundwater research program. G. Ozoray, Alberta Research Council, Edmonton, Alberta, Canada.

## AGID PUBLICATIONS

Geoscientists and the Third World: A collective critique of existing aid programs. A. R. Berger, ed., Geological Survey of Canada, Paper 74-57, 32 p., 1975.

Hidden waters in arid lands: Report of a workshop on groundwater research needs in arid and semi-arid zones held in Paris, France, 25 November 1974. L. A. Heindl, ed., IDRC-057e, 19p., 1975.

New directions in mineral development policies. Transactions of international workshop, Bagauda, Nigeria, 8-10 September, 1975 (in preparation).

Mineral exploration research for developing countries. R. A. Blais, ed., Mineral Exploration Research Institute, Montreal, Canada (in preparation).

For more information about AGID and copies of these reports, write to:

Dr A. R. Berger  
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AGID welcomes reader response to the recommendations for research outlined in *Hidden Waters in Arid Lands*. A short list of questions, which identify issues of immediate concern to AGID, is given below. Space is provided for readers to make short comments or suggestions (the limited space should not discourage those who wish to make a fuller response; longer commentaries or position papers can be attached separately). All correspondence should be directed to:

L.A. Heindl, Editor  
*Hidden Waters in Arid Lands*  
3577 N. Powhatan Street  
Arlington, Virginia 22213  
USA

1. What is your scientific discipline?
2. Is your organization directly concerned with groundwater development? Yes    No
3. Are you directly concerned with groundwater development? Yes    No
4. Have you found this report useful? Yes    No
5. Do you agree with all of its recommendations? Yes    No
6. If not, which recommendation(s) do you disagree with?
7. Why do you disagree?
8. What are, in your opinion, the most important practical problems of groundwater development in the Third World?
9. How do you suggest that the lesser developed countries enhance their capabilities in groundwater development?
10. Which hydrogeological problems do you feel merit considerable scientific research?
11. What types of education and training do you think are needed in hydrogeology and related subjects to enable lesser developed countries to adapt foreign research to their endemic problems?
12. What additional comments do you have?

Name:

Organization:

Title within organization:

Address:



**CREDITS:**

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