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EDUCATION IN HYDROLOGY AND WATER RESOURCES IN THE UNITED STATES— 1965-1974— AN OVERVIEW WITH RECOMMENDATIONS

Final Report of the
Work Group on
Education and Training
of the
U.S. National Committee
for the
International Hydrological Decade

National Research Council

National Academy of Sciences
Washington, D.C. 1976

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

The purposes of the International Hydrological Decade (IHD, which began in 1965, were to strengthen the scientific basis for water use and conservation, to stimulate education and training, and to improve the ability of developing and developed countries alike to cope with their water problems. More than 100 countries participated in the Decade.

Education and training are processes through which knowledge is passed from one generation to the next and from culture to culture. These processes also make the benefits and responsibilities of technological advancement available to the peoples of the world. The advanced state of hydrological and water resources technology in the United States and the highly developed educational system of this country gave the United States the opportunity and obligation to contribute to the goals of the IHD.

The Work Group on Education and Training made every effort it could to make modern technology available to other countries through educational support programs. With the assistance of the Universities Council on Water Resources (UCOWR), the UCOWR/IHD Fellowships and Assistantships in Hydrology Program operated successfully for 6 years. Although the UCOWR/IHD Program was not as extensive as had been envisaged during early planning stages, it developed into an operationally simple and highly pragmatic activity. So much so that the operational procedures have been taken over by the American Geophysical Union to continue the IHD effort in hydrological education and, in the near future, perhaps to extend it to other geophysical fields. The Work Group

also concerned itself with education and manpower problems in this country.

Although our educational system has been successful in producing technical manpower, there is always room for improvement. Two areas where this need was perceived to be greatest were those of technology transfer, both in this country and to others, and the diffusion of basic hydrological and environmental knowledge to the hydrological professions and to the larger nonhydrological segments of our own society. This report of the Work Group attempts to bring into focus these educational needs at home and our educational and training involvement with other countries.

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Acknowledgment

Financial support of education in the United States is a major budgetary item at all levels of government, reflecting the national commitment to provide quality education for all citizens of the country and the national recognition of the role of science and education in technological advancement. The International Hydrological Decade (IHD) presented an opportunity for the United States to make its expertise in hydrology and related water-resources fields available to the nations of the world. This was the function of the US/IHD Work Group on Education and Training. In addition, the Work Group felt that, although we are justifiably proud of our educational system, we should never hesitate to take any opportunity to improve it and to take advantage of new insights and developments. In this final report, the Group summarizes its experiences and offers some recommendations for the improvement of many aspects of U.S. education in the water-related sciences.

The U.S. National Committee for the IHD provided the terms of reference for the Work Group and monitored and guided its activities during the course of the Decade. This report has been reviewed, accepted, and endorsed by the National Committee, and portions of it and its recommendations will be included in the National Committee's own final report.

The National Committee is grateful for the efforts of its Work Group on Education and Training and thanks the many scientists, educators, universities, and other organizations that contributed to this portion of the US/IHD program. Without their support, the UCOWR/IHD Fellowships and Assistantships in Hydrology, the Syllabus for Hydrology Courses and the three International Symposia for

Hydrology Professors would have been neither possible nor successful.

The list of people who made this program a success is too extensive to be presented here in full, but the Committee wishes to express its gratitude to all who were involved.

Special mention should be made of Mr. L. L. Kelly, Chief Hydrologist (Ret.) of the Agricultural Research Service of the Department of Agriculture, who worked as a consultant to prepare the first draft of the Syllabus, contributing many hours and much advice in its regard, far beyond the ordinary call of duty. Dr. J. M. Kennedy, Senior Scientist for Ocean and Energy Systems of the TRW Corporation, provided valuable assistance in cross-checking, proof-reading, and retyping the Syllabus.

The National Committee is also grateful for the continued support provided by the National Science Foundation for the activities of the U.S. National Committee for the International Hydrological Decade and its Secretariat.

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Conclusions and Recommendations

The objectives of the Work Group's IHD program were first, to further understanding and appreciation of the physicial basis of the hydrological regimen and of the stresses imposed on it by man's activities and demands; and second, to promote and encourage the study of water sciences and applied practices by foreign experts and students in the United States and by U.S. students and experts abroad.

Although the full scope of the Work Group's initially proposed program was never achieved, the original plan was used as the basis for US/IHD activities in education and training. Through the cooperation and assistance of interested groups within and outside of the university sphere, the Work Group's accomplishments are considerable, even though only limited financial resources were available. These activities and accomplishments are summarized in Appendix B.

Its activities and involvements gave the Work Group many opportunities to assess educational activities in water-related fields, particularly in the United States, and the Work Group believes it is justified in making some recommendations representing its evaluation of the consensus of the opinions it encountered. Where appropriate, the Work Group has modified and expanded the consensus to make its recommendations realistic and realizable. It has also, in many cases, indicated the organizations that might be suitable to carry them out.

Recommendations apply directly to education and training, both nationally and internationally, to the assessment of educational programs, and to the implementation of the recommendations themselves. Recommendations

regarding international activities apply only to what may be considered to be the area of U.S. interest; they do not seek to recommend regarding the activities of other countries or of the international agencies. Similarly, the recommendations regarding assessment and implementation apply only to what the United States could--or should--do. Thus the recommendations are directed specifically at the U.S. community of scientists and professionals and at U.S. institutions concerned with education and research in the water fields.

The Work Group fully realizes that some of its recommendations cannot be implemented unless changes in current practices also occur elsewhere. However, it firmly believes that some changes are needed, and that the United States can maintain a world leadership position in the water field only by being among the first to make the necessary changes at home. It can only reiterate what has been said many times: Water problems will remain with us for the foreseeable future; they are not insurmountable, but they will be resolved only insofar as this country educates and trains a body of honest and competent professionals, technicians, educators and researchers, and a public with a realistic understanding of what they are trying to do. The Work Group submits its recommendations with the conviction that they will help this country achieve that goal.

Education at the University and College Levels

Students taking hydrology and water resources courses in universities and colleges expect to enter a wide variety of professions. Some become water specialists; others enter professions concerned with water as one of many problems; and still others simply wish to know something about water. In each case, the students should be provided with the information, concepts, and training appropriate to their respective needs. In this regard, the Work Group offers four recommendations.

The Work Group contends that many water specialists are graduated with extensive training in modern computational systems and analytical techniques but with less than adequate instruction in hydrology, in the physics, chemistry, and biology of water, and in the application of these principles to real-world problems.

RECOMMENDATION 1: Education of scientists and engineers specializing in water should provide a firm grounding in the physics, chemistry, geology, and biology of water, the integrating processes of the hydrological cycle, and the applied and socio-economic aspects of water-related problems.

The lack of hydrology or water resources departments in universities has left the development of appropriate curricula to interdepartmental arrangements. In many instances, these are ad hoc, and ineffective in meeting the varied needs of the student body.

RECOMMENDATION 2: University interdepartmental arrangements should be developed or strengthened so that participating departments can contribute appropriately to the curricula of water scientists and engineers, water-oriented specialists in other professions, and the general student.

The Work Group has noted with concern the long-standing circumstance which has led to much mutual criticism between academia and private enterprise wherein (1) university and college faculties, oriented to theoretical problems, are criticized for not training students adequately to work in the practical world, and (2) practicing professionals, concerned with their daily demands to produce, are criticized for being slow to apply new theoretical concepts and techniques. Exchanges between universities and private enterprise have been developed successfully in a few places and the Work Group urges that the practice should be applied far more broadly.

RECOMMENDATION 3: "Internship" programs should be developed cooperatively by universities, private enterprise and public agencies to provide (1) faculty members with the opportunity to apply their theoretical training and research to practical problems, (2) practicing personnel in applied fields to teach and share their experiences with the university community, and (3) undergraduate and graduate students with

opportunities to obtain practical experience as part of their curriculum.

The Work Group believes that the need for special instruction in water-related fields of three broad groups of students is commonly overlooked. These groups are (1) those who plan to obtain degrees in economics, law, political science, and related disciplines and have interests in the relationships of their eventual professions with water-resources problems; (2) those who intend to become technicians, rather than scientists and engineers, and should know of the opportunities in water-related fields; and (3) those who wish to pursue non-technical degrees but need an understanding of how water affects the environment and their personal lives to equip them for their roles as citizens. The courses should be considered as important departmental offerings, require minimal prerequisites, and have appropriately prepared textbooks and lab manuals.

RECOMMENDATION 4: Special science-based courses should be designed for students who do not intend to become water specialists but desire to know about water.

The UCOWR can and should play a significant role in the implementation of Recommendations 1, 2, 3, and 4. These activities are within the purview of the UCOWR mission and are consistent with past UCOWR endeavors.

Education at the Pre-University Levels

The Work Group strongly supports and encourages the trend it has observed toward increasing attention to the role of water in the environment at all pre-university levels. In many instances, however, the Work Group feels that there is a critical need to train teachers at the pre-university levles so that they will be able to describe and discuss environmental problems in up-to-date terms. At these levels especially, the need to portray the environment as a holistic process, as well as to provide instruction on its separate parts, requires great care in the preparation of course material. The course materials could be presented in seminars, workshops, and field trips, and the participants should be provided with

appropriate teacher's kits, syllabi, and educational films designed to present a balanced understanding of the physical and biological systems and the management issues involved in the use of water resources. Some work has been done along these lines but more is needed, and what has been done has not been applied widely enough to fill the need.

> RECOMMENDATION 5: Teachers of environmental topics at the primary and secondary school levels should have their training augmented in regional and local centers through programs prepared by experts who know water and its relationship to the environment.

Improved instruction must be matched by improved opportunities for participation in applied and research activities. Both the interested student and the teacher should be able to participate in on-the-job types of programs to broaden and deepen their understanding of theoretical and practical water problems.

> RECOMMENDATION 6: Participation by teachers and students from primary and secondary schools in research and summer work programs should be encouraged by a continuing national dissemination of information regarding the availability of existing participatory programs and by research and science foundations through more grants made available for this purpose.

Although programs with objectives similar to those of Recommendations 5 and 6 are currently being undertaken, it is suggested that the U.S. Office of Education in the Department of Health, Education, and Welfare and the departments of education of individual states give these efforts additional attention and support.

Continuing Education and Technology Transfer Programs

The Work Group believes that every possible method should be exploited to provide continuing education in water-related fields. Two specific goals are:

(1) advancing and updating the technical capability of educators, professionals, technicians, and those already engaged in the practice of water-related professions; and (2) enhancing the understanding of water problems among adults whose principal interest in water is how it affects their personal lives. In the first instance it is predominantly the transfer of technology from the researcher to the practitioner; in the second, it is mostly transfer from the practitioner to the consumer. To bridge the gaps between researcher, practitioner, and consumer, other fields have found it necessary to develop specialists in technology transfer. The Work Group feels that this type of "outreach" program is also needed in the water-resources field.

> RECOMMENDATION 7: Specialists in technology transfer in the hydrology and water resources field should be trained and employed by universities and appropiate state and federal agencies to bridge the gap between researcher, practitioner, and consumer, and to assist all groups in identifying problems of common interest in common terms.

Programs of continuing education are best accepted and attended when the courses are tailored to specific needs and schedules of targeted groups. Appropriate state-of-the-art manuals, syllabi, educational films, and other educational aids are needed to translate the results of research into practical applications. Both regional and local approaches are necessary, embracing the cooperation of teachers, hydrologists and water-resources experts.

> RECOMMENDATION 8: Continuing education programs in the water resources fields, tailored to the needs of working professionals, should be strengthened substantially by academic institutions and governmental agencies where they exist and initiated where they are not.

The Work Group feels that among the most important of continuing-education programs are those directed at individuals and groups publicly voicing their opinions. Because most groups have vested or biased interests, the programs should be prepared, regardless of agency, to be

as factual and as well balanced as possible. All educational means should be used, and the programs should be tailored to the capabilities of the means for their presentation as well as for the intended participants.

> RECOMMENDATION 9: Educational programs oriented to special water problems in the public interest should be prepared by specialists in information and technology transfer so as to be as objective and understandable as possible.

The Office of Water Research and Technology, in its cooperative program with Land-Grant Universities, has the authority to organize the continuing- and public-education programs visualized here. Appropriations for implementation should be expedited. Other federal and state water agencies--especially those with planning roles--have the potential to be effective in implementing the above recommendations.

International Activities

International aspects of education and training in hydrology and the water resources fields are considered by the Work Group to be primarily a series of efforts in the exchange or transfer of information. These efforts involve fitting the technology to the scale of the problem and the capabilities of the organizations available to carry them out. Organizational arrangements, social infrastructures, and technologies themselves all have limits beyond which they cannot be easily adjusted to accommodate successful transfer. This is reflected in the growing interest abroad in "intermediate technology," technology that can be applied within existing economic and cultural constraints.

Major efforts of the United States and those of the agencies of less developed countries concerned with hydrological activities and water-resource development are oriented toward quick results. The year-to-year justification of budgets and the yearning for early economic improvement makes this inevitable. The short-term approach, however, can be wasteful and counter-productive if adequate consideration is not given to the intermediate- and long-term points of view. A three-part educational strategy is needed: first, continue

technical assistance to short-term educational projects meeting some of the immediate needs; second, seek improved means for providing U.S. assistance in education that is useful to intermediate-term needs of developing countries; and third, simultaneously strengthen the educational and research institutions and long-term capabilities of the developing countries.

The Work Group has noted that many current exchange programs dissipate their resources through fragmentation, lack of coordination, and unclear or unrealistic goals, insufficient attention to training of counterparts, and an inadequate recognition on the part of agencies of the needed balance between technical and sociopolitical objectives and capabilities.

RECOMMENDATION 10: International programs for the exchange and transfer of information should be strengthened through realistic and coordinated arrangements involving the relevant federal agencies, universities, and research and education foundations in both donor and recipient countries.

RECOMMENDATION 11: Hydrological and water resources education activities of the United States in the less developed countries should be conducted through suitably supported long-term programs carefully coordinated through staffs involving professionals and technicians on as coequal and counterpart a basis as possible. Programs must plan for follow-up studies and support until the host-country's institutional structure is able to support its programs in a suitable manner.

RECOMMENDATION 12: Existing programs to enhance the capabilities of United States and foreign professionals and professors should be expanded by bringing hydrologists and water resources experts from abroad to the United States for short-term information-exchange programs and by encouraging U.S. scientists and

experts to accept short- and long-term assignments abroad.

The Work Group suggests that Recommendation 10 and 11 should be considered by the Department of State and Agency for International Development in conjunction with water-related U.S. federal agencies that have training programs accepting foreign participants, such as the Geological Survey, the Bureau of Reclamation, and the Corps of Engineers. An example of coordinated support is the International Hydrological Program for which a U.S. National Committee for Scientific Hydrology, composed of federal agencies and nonfederal organizations, was formed to promulgate U.S. participation. Recommendation 12 should be brought to the attention of the National Science Foundation, which already has a program of international exchange of scientists, research, and information.

Education and Manpower Assessments

Because educational capabilities in hydrology and water resources fields frequently seem to be out of phase with shifting and fluctuating manpower needs, the Work Group feels that periodic analysis of both capabilities and needs are essential. Also, methods for assessing manpower requirements need to be made more effective so that the allocation of educational resources among categories of requirements may be made realistically.

RECOMMENDATION 13: Some objective body should conduct periodic analyses of, and make recommendations on, educational programs in hydrology and water-related fields, including adequacy of training with respect to needs, effectiveness of institutional structures, and relationships to manpower needs.

RECOMMENDATION 14: Periodic manpower studies should be conducted to estimate future needs in water-related fields.

Several organizations could play an effective role in implementing recommendations 13 and 14. In general, The Work Group believes that training grants should be made a part of the program of an agency with a

multimission role, such as general research support or interagency coordination. The Office of Water Research and Technology, through its cooperative research program with the land grant universities, could contribute to the assessment of existing manpower and training. Through its grant programs, it could also provide continuity and adjustment in training emphasis necessary to meet future manpower needs. The Water Resources Council, through its grant programs with state water planning agencies, is also capable of contributing to the assessment of manpower needs and to identifying resulting needs in training. The National Science Foundation and the Environmental Protection Agency also have the capabilities and resources to implement portions or all of both of these recommendations. These recommendations should be considered by all these agencies and by UCOWR and the concerned professional societies.

Institutional Needs

The Work Group finds that the existing educational institutional structure is generally satisfactory, and Recommendations 1 - 14 seek to improve or expand already accepted functions. However, the Work Group believes that institutions designed to support the educational activities could be strengthened by assessment of their present activities, increased support of basic research in hydrology, and the establishment of a central clearing house for water-related information.

On the basis of its experience, the Work Group firmly believes that the National Academy of Sciences-National Research Council should establish a committee, supported by federal and state water agencies, to make the assessments advocated in Recommendations 13 and 14. The Work Group is aware that a Committee on Water Sciences and Research has been proposed in the NAS-NRC to succeed the U.S. National Committee for IHD. It is convinced that the NAS-NRC should also accept the assessment of manpower and training requirements as a continuing need to be included in NAS-NRC concerns with water-related problems.

> RECOMMENDATION 15: The National Academy of Sciences-National Research Council should establish a committee or subcommittee for the purpose of periodically

assessing the effectiveness and usefulness of all levels of hydrological and water-related educational activities and for assessing the needs for trained manpower in water-related fields in the United States.

Several recommendations, when implemented, will require sources of financial support that now are not available, or are not available in sufficient amounts. The Work Group goes on record as supporting a 1971 UCOWR resolution recommending government-wide extramural grants (see Appendix A). One of the prominent gaps in the existing system for supporting water-related education and research is the lack of an office in the National Science Foundation specifically concerned with basic hydrological and water-resources research. When established, the office should also have the responsibility of coordinating its functions with those of other NSF offices with water-related interests and with the Office of Water Research and Technology in the Department of the Interior.

RECOMMENDATION 16: An Office of Hydrology and Water-Resources Science should be established in the National Science Foundation to give adequate attention to the research needs in hydrology and water-related problems.

By way of a final conclusion the Work Group notes that education and training activities at all school levels and in the public domain are related to university, agency, and private-sector research, all of which are, in turn, related to the intricately ramified system of agricultural, industrial, municipal, environmental and social uses of water. Yet, despite the intricate ways in which water permeates man's activities, there exists no central headquarters or clearing house for water information of all types in the United States. Such an institution could provide water information to industrial, commercial, and educational institutions and so assist the transfer of research and technological results and needs from one arena of activity to another. Such a center would in no way interfere with other data-storage-and-retrieval systems. The Work Group considered many alternative institutional mechanisms to fill this gap but was not totally satisfied with any one design. In general, they

thought that some sort of independent institute should be created jointly by governmental, university, and private-sector subscription to carry out the following functions: (1) be a general clearing house for the water-related professional activities of the nation; (2) complement existing programs designed for user groups; (3) encourage development of educational programs now falling outside the programs of other water-related organizations; and (4) mobilize scarce educational and research resources to meet needs not otherwise being fulfilled by current programs.

This need warrants the serious consideration of all sectors of the "water community." The Work Group does not know of any one organization that might be capable of implementing the proposed concept, and therefore suggests that a consortium, possible built around the activities of the American Water Works Association, National Water Well Association, American Water Resources Association and the Universities Council on Water Resources may be a starting point. The Work Group believes that the need it has perceived is real, but it will remain for others to find a way to fill it.

Introduction

The objective of the International Hydrological Decade (IHD) was to improve and extend education and research in hydrology and related fields by means of international efforts such that all countries would eventually be capable of coping with their individual and mutual water problems. The program was to operate by means of the advancement of national capabilities on the premise that international problems will be resolved as national capabilities are increased.

It was hoped that the individual nations, through participation in the Decade, would increase their cadres of professionals and technicians, both in number and in level of training, to the point of meeting local needs. Parallel to this, it was hoped that institutions would be established, developed, and enlarged to meet national and regional needs and to absorb and employ the newly trained personnel.

In most countries, and particularly in the developing countries, the IHD provided the privotal spur to the advancement of national hydrological capabilities.[1/] In recent years, the water-related technologies and methodologies used in the more developed countries have become increasingly sophisticated, particularly through the application of stochastic and deterministic processes and models, and computational techniques. During this period the IHD was instrumental in increasing the number of

1/ UNESCO/WMO, 1975, Records of the International Conference on the Results of the International Hydrological Decade and on Future Programmes in Hydrology, Paris, 2-13 September 1974, Vol. 1 Final Report, Chap. 6.5, p. 30-31.

professionals and technicians in the developing countries who are capable of handling these new techniques. The Decade also saw an increased awareness on the part of administrators and executives, both governmental and non-governmental, that sound decisions regarding the management of water could be made only with a sound knowledge of the physical, chemical, and biological controls, and with the aid of people who were adequately trained to use this knowledge.

Within the IHD program, education involved not only classroom instruction, but also participation in symposia and conferences, on-the-job training, exchange of scientists, and the preparation of a wide variety of texts, handbooks, and teaching aids. These mechanisms, coupled with the advancement and enlargement of standard educational capabilities, increased the numbers and improved the capabilities of scientists, professionals, and technicians for meeting the challenges of the water problems of the future.

As one of the principal initiators of the IHD, as well as one of the recognized leaders in the field of hydrology, the United States was expected, both at home and abroad, to take a broad view of its responsibilities in advancing educational capabilities in hydrology. Consequently the U.S. National Committee for the IHD, early in its existence, proposed an extensive program to advance overseas and domestic capabilities in hydrological education and training. In 1966, the National Committee established a Work Group on Education and Training to plan the specific projects that would implement the proposed program. The Work Group's first list of recommended projects included activities ranging from postgraduate research to the education of the public in less-developed countries. However, because of limitation in funding, only parts of the proposed program were implemented and priorities were shifted to emphasize domestic benefits.

The IHD experience in the United States has served to identify new educational needs in water science and to emphasize old ones. Most new needs involve a balance between two objectives that are not necessarily compatible--that of a growth-oriented system and that of minimizing irreversible environmental damage. The known needs that have been emphasized concern improvements in educational methods and content.

Emerging public concern and support for clean water and a better environment has engendered a need for hydrologists with expertise in water chemistry and water managers with an appropriate balance of technological and administrative knowledge and ability. In the future, hydrologists will need to bring a broader spectrum of knowledge to the decision-making process. Such knowledge will include a greater depth of understanding of hydrological processes and far greater breadth of understanding of related sciences such as chemistry and aquatic biology. They must also be able to devise and implement programs to satisfy the already existing demand for water knowledge in the public sector.

The educational curricula of water sciences commonly focus on the need to upgrade the pursuit of present national goals and seldom are concerned with any attempt to alter the goals. The educational system obviously should continue to be responsive to discernible national goals. However, it should also educate to evaluate the hydrological effects of these goals and to lay the ground work for new ones as they become needed. Changes in national water-resource goals are inevitable but should occur as the result of informed public opinion. Plans for education in hydrology and related fields should therefore include curricula for the public as well as for students who intend to specialize in the water fields or in allied fields.

In the preparation of this report, the Work Group assumed that the science of hydrology will continue to become more complex and will increase in scope to encompass other aspects of water not now embraced by the science. It was also assumed that public knowledge and concern over hydrologic problems will continue to increase coorelative with environmental concerns and that education will be required to deal with the greater concerns.

While carrying out its program, the Work Group became broadly acquainted with many problems and opinions in the domestic and overseas practices of education and training in hydrology outside the spheres of its own projects. In this regard, it found that its relation to the Academy gave it access to a wide variety of views from all levels in government, universities, and private sectors. The opinions formed by the Work Group are based upon many individual and group discussions. The

recommendations given in this report represent a consensus based on these opinions. The purpose of these recommendations is to increase the scope and impact of water-resources education in the United States and, to a lesser extent, abroad.

Published Sources of Information

A growing need for all kinds of water scientists, and a rapidly increasing public concern with the environment developed during the years of the International Hydrological Decade. In the United States, this concern brought an increasingly sophisticated awareness of the complexity of environmental interrelations. If the level of concern continues to rise, a broadly based environmental ethic may eventually have to be considered simultaneously with concern for economic growth and social welfare.

Some hydrologists and other scientists have seen many dangers in continued economic growth and development in a world of finite, if renewable, resources. They also have recognized that the deleterious effects of ignoring these dangers can only be lessened by application of the ingenuity of man. The spreading use of environmental impact analyses as the basis of reaching conclusions further suggests the need for educational approaches that emphasize aesthetic and social, as well as earlier ecomomic goals.

The development of satisfactory curricula to meet future needs depends on the existing available educational opportunities, and the use of those opportunities should depend on manpower needs. Obviously, an optimal situation would exist if the educational capacity was able to anticipate and meet society's demands. It is equally obvious that in the Western version of the "laissez faire" society, this balance is improbable if not impossible.

Some recent summaries, described briefly here, contribute to the basis for some of the conclusions reached

by the Work Group, but they are not responsible for the content of the final recommendations.

Water-Related Education in the United States

Hydrological and water-resources education in the United States are inexorably mixed. Moreover the term "hydrology" has different connotations at different universities, and even in different departments in the same university. In contrast, water-resources education is subject to fewer internal contradictions because it is generally admitted to be broad in scope. The Work Group preferrred to discuss education in terms of water-resources education, referring to hydrology only as the term is used in referenced documents and as it is used in reference to the physical sciences.

Several reports describing water-resources education in the United States were issued during the Decade. Although these reports cannot be compared in objectives or material, in total they do present conditions at the time of their preparation and indicate some of the changes that occurred during the Decade.

UCOWR Survey of Education in Hydrology. The UCOWR Committee on the Survey of Educational Programs in Hydrology contacted 88 universities and educational institutions, 74 of which responded to questions on the status of hydrological education during the 1965-66 academic year. The report [1/] presented information on four aspects of hydrological educational programs--faculty, courses offered, degree programs, and financial support.

At the institutions surveyed, 850 faculty members were involved in hydrological education or research; 52 percent were in biological sciences, including such fields as forestry and agronomy; 22 percent were in engineering, including civil, agricultural, sanitary and petroleum curricula; 20 percent in earth sciences, including geology, geography, meteorology and oceanography; and 6 percent in

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1/ Universities Council on Water Resources Committee on Survey of Education Programs in Hydrology, 1967, Education in Hydrology, United States Universities - Early 1966, The University of Texas Press, Austin, Texas 44 p.

other fields such as social sciences, water resources, and conservation. Approximately 70 percent of those engaged in teaching some aspect of hydrology had doctorates, and about 25 percent had master's degrees in their respective fields; however, these were not in hydrology or water resources *per se*. Faculty interest was approximately divided as follows: 85 percent in scientific and engineering aspects of the hydrological cycle, 8 percent in hydrological processes, 2 percent in mathematical and computer applications, and the balance in biological aspects.

At most institutions, hydrology courses, or courses with hydrological content, were offered in several departments. Engineering departments offered a larger number (about 50 percent) of effective semester hours of hydrology per year than departments in earth, biological, and other sciences.

The maximum number of semester hours of work with hydrology content that could be included in a degree program tended to increase with the level of the degree. With the median of all institutions as the index, a student could take 12.5 semester hours of courses with hydrology content for the bachelor's degree, 15.7 for the master's, and 22 for the doctorate. Civil engineering departments gave approximately 50 percent of all degrees with emphasis on hydrology. A wide range of courses was included in the various degree programs. Among those occurring most frequently were hydrology, soil physics, open channel flow, groundwater hydrology, water-resources engineering, geophysics, geochemistry, and geomorphology. The report suggested that "it would be possible to approximately double the output of Bachelor's and Master's degree holders, and more than double the output of Doctor's degree holders with the present (1965-66) facilities, faculty, and staff."

Reliable data on financial support were difficult to obtain because hydrology figures in so many different programs. Civil engineering departments ranked first in total financial support and in support available to students. In general, the amount of student support earmarked specifically for hydrology was small in departments such as civil engineering, forestry, geology, botany, agricultural engineering, and meteorology, which produced most of the majors interested in hydrology.

University of Nebraska Survey. Four years later, in 1969, the Nebraska Water Resources Research Institute prepared a listing of universities with formal water-resources programs; those without formal programs, but that offered training through various disciplines; and those that were in the process of developing graduate programs. [1/] The report included detailed discussions of several highly developed programs, but did not present an overall summary.

UCOWR Listing of Graduate Programs in Water Resources. In 1970 the Universities Council on Water Resources (UCOWR) issued a pamphlet entitled "Graduate Studies in Water Resources." [2/] The pamphlet provides information on educational opportunities in water resources at 65 UCOWR member universities. Programs of study are described briefly. The booklet has been widely distributed and is a good source of information for students attempting to select an institution for advanced study in hydrology or water resources.

UCOWR Conference on Environmental Education Needs. At its 1972 annual meeting, UCOWR attempted to assess how well university programs were meeting the nation's training needs in water resources. [3/] One major contributor reported on the results of a personal survey in which he attempted to identify universities offering a degree in "Water Resources Management" or "Water Resources Planning." Results showed that (1) no university offered graduate degrees in "Water Resources Planning," and only two offered a degree with the title of "Water Resources Management"; (2) several schools offered degrees in firmly established disciplines, such as Civil Engineering, with "Water Resources" listed as the area of specialized

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[1/] Viessman, Warren, Jr., 1969, "A Survey of Educational Programs in Water Resources at Various Universities," duplicated paper, Nebraska Water Resources Research Institute, University of Nebraska, 20 p.

[2/] Universities Council on Water Resources (UCOWR), 1974, third edition, "Graduate Studies in Water Resources" (brochure), University of Nebraska, 38 p.

[3/] "Changing Education Needs in the Field of Environmental Resources," UCOWR, Proceedings of a Conference, Amherst, Massachusetts, July 24-26, 1972, 107 p.

study; and (3) a considerable number offered formal programs in planning and management or in water resources within a curriculum acceptable to a degree in a major discipline, but the degree did not specify areas of specialized study.

The Proceedings of the UCOWR Conference[1/] also included comments of consulting engineers and professionals in industry, government, and politics on their assessment of the adequacy of university education in water resources. Emphasis was, in general, on the need for more practical research, more experience-related instruction, more attention to the decision-making process, and more broadly based education of water-resources professionals.

Assessment. The Work Group finds that the preceding reports and its own observations indicate three general trends in hydrological education in U.S. universities since the early 1960's:

1. Increasing emphasis on water-management techniques, environmental problems, planning processes, and related topics, usually tied to computer applications.

2. Increasing emphasis on simulation techniques for educational, research, and planning purposes to integrate what is known about complex hydrological systems and the socioeconomic problems in whose contexts they are considered.

3. Decreasing emphasis on the basic physical, chemical, geological, and biological processes, and their interrelations, which characterize the systems (soil zones, unsaturated zones, exchanges between surface water and groundwater, overland flow, mass-balance exchanges, etc.) through which the hydrological cycle passes.

The Work Group also noted the increasing emphasis on water quality and the significance of the close relations between the constituents and characteristics of the water and the rock skeleton through which it passes. This trend, the Work Group believes, is to be commended both

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1/ "Changing Needs in The Education of Water Resources Planners: A State Water Planning Agency Point of View," E.A. Imhoff, P. 41-50 in UCOWR, Proceedings of a Conference, Amherst, Massachusetts, July 24-26, 1972, 107 p.

for its impacts on the use, disposal, and salvage, of water supplies, and on the improved understanding of water movement itself.

The application of sophisticated computer-based analytical and numerical methods to quantitative and qualitative water-resources problems must be commended. However, while they may be ingenious and penetrating as new tools, their usefulness still depends primarily on the validity and reliability of the underlying scientific concept. Many current formulae adapted for high-speed computer and analog applications are still based on concepts produced a hundred and more years ago. They continue to be used because they still provide useful answers within certain boundaries. However, new conditions sooner or later will force consideration of new boundaries, and the usefulness of computers will falter while programmers wait for new theoretical breakthroughs.

The Work Group recognizes that this is a time of increasing emphasis on science aimed at the solution of existing and foreseeable socioeconomic problems. Nonetheless, it urges that a small portion of the research budget should be allocated to studies that might, with luck, provide the intellectual fodder needed to fuel the next generation of problems.

The combination of increasing emphasis on socioeconomic processes and on simulation techniques permits less emphasis within the usual educational framework for attention to the physical base of the nature and occurrence of water. The Work Group observes that both management and simulation depend on facts, and that it is vital that the facts be understood if the simulation techniques are to provide reasonable approximations and if the management decisions based on the approximations are to be reasonably sound. Thus the Work Group urges that all hydrological curricula provide a firm base of physical, chemical, geological, and biological studies for any advanced studies involving simulation techniques and socioeconomic problems. The basic courses should not be all planned for the needs of the future scientists. Rather, they should be geared to the needs of the relevant disciplines--engineering, economics, municipal planning, etc. The important thing is that the hydrology that they are taught is scientifically sound, reasonably up-to-date, and applicable to their aims.

The Work Group is encouraged to see that increasing numbers of universities are offering degrees in established fields of study with indications of specialization on water-related studies. Two universities now give graduate degrees in hydrology per se. This trend of recognizing hydrology and water-resources studies as legitimate fields of study and specialization is useful because it encourages students to train for careers in these fields.

In addition to expanding curricula and providing increasingly appropriate degree programs, many universities have expanded the number and scope of water-related courses in their programs of continuing education. Short courses, evening classes, and special lectures in subjects ranging from highly technical innovations to broad generalizations related to everyday problems are now being offered, and often over-subscribed, in nearly all parts of the country. In the same spirit, many governmental agencies in the water-resources field have developed in-house training programs for their employees, and in many instances their in-house programs accept participants from outside agencies and sometimes from abroad.

The Work Group also noted the spread of water-related studies in high schools, and, more rarely, in even lower grades. It was also aware of much concern about the quality of environmental education reaching our primary, secondary, and high-school students, as well as of that given to non-science college students. Too frequently this education is reported to be a disjointed presentation of limited amounts of heavily weighted evidence prepared by a special-interest group with only narrow concerns within the broad environmental spectrum. Such instruction, the Work Group believes, can only be detrimental in the long run, regardless of how attractive individual presentations may be. Those in the educational systems responsible for environmental instruction should insist on the preparation of sound, balanced curricula that will teach the basic systems without attempting to promote any particular solutions. Moreover, environmental instruction should be introduced into the school systems as early as possible so that the students will have longer to gain understanding and appreciation of short-range needs, and long-term objectives. By being exposed for longer periods of time to the interplay between the physical and chemical sciences, political and economic demands, and social

and individual desires, students will be better equipped as adults to meet problems that today can be only anticipated.

Manpower Requirements in Water-Related Fields

It is obvious that throughout our society, hydrological knowledge needs to be applied increasingly to important decision-making processes and thus that the decision makers need to acquire a greater knowledge of hydrology. The science of hydrology, because it is central to many decisions regarding the environment and the use of natural resources, has become intricately involved in the web of political structures. With growing frequency, political decisions are affected by the science. It is assumed that this trend will continue and that it will be accompanied by growing demand for knowledge in hydrology and water sciences by people involved in public administration, planning and related fields.

Today, practically no one questions that proper water-resources management is a necessary element in any plan for the continued survival of our society and its standard of living. Such a plan requires that all levels of decisions involving water are based on up-to-date knowledge of hydrology and a clear understanding of how to institutionalize and implement the decisions thus reached.

Existing programs must be reviewed and opportunities for new or amended programs explored to ensure that manpower in water resources will be available to meet the nation's requirements. The findings of two important studies indicating major future trends in manpower requirement are reviewed here.

UCOWR Manpower Study. In 1971 a special work group on manpower was assembled by UCOWR to recommend new or improved policies for adoption by universities and governments. The purpose of the policies was to strengthen and make more efficient the production of skilled manpower needed to manage and solve the water resources and environmental aspects of the nation's problems.

The study[1/] considered the need for manpower; identified, reviewed, and appraised current programs in universities and government; and considered alternative ways by which manpower production could be improved.

The study observed that "scientists and engineers are not created on short order, and especially not from random source material. Rather, they are the product of 10 to 20 years of study and application, and they must have the technical ability to begin with." In 1971, the study noted that the percentage of college students entering the fields of science and engineering was leveling off. By 1974, the Work Group felt that the trend apparently had continued, and a shortage of scientific and engineering talent appeared likely within the next 15-20 years.

The UCOWR task force assessed university-government relationships and recommended a system of government-wide extramural grants. It also examined intramural government programs for manpower training, such as university-faculty participation, civil service training, student interactions, and employment and internship programs. Specific recommendations were made on university administration of training and research, evaluating the need for water-resources professionals, the nature of training required, and continuing education. It was also pointed out that federal agencies should be encouraged to broaden their approach in assessing manpower and training needs to include not only the numbers but also the qualities needed in people to be trained to solve environmental problems. This could be accomplished by cooperative studies involving agencies associated with environmental problems--U.S. Environmental Protection Agency, Office of Water Research and Technology (formerly Office of Water Resources Research), and other agencies in the Interior Department--universities, and professional groups such as the Universities Council on Water Resources and the American Association of Professors of Sanitary Engineering.

[1/] UCOWR, Report of Special Task Force on Federal Government-University Programs and Policies Concerned with Manpower Production in Water Resources and Related Environmental Activities, Oregon State University, Corvallis, Oregon, July 31, 1971, 83 p.

Manpower Study by the American Association of Professors of Sanitary Engineering. The 1972 manpower study of the American Association of Professors of Sanitary Engineering[1/] noted that about 1,200 students in the United States were studying water-quality control. According to the study, about 35 to 40 percent of these students would find employment with local, state and federal governmental agencies, 25 to 35 percent would go into the consulting field, 15 to 20 percent to industry, and a similar fraction would go into teaching and research. The large anticipated manpower needs in water quality control have been documented, for example, in "Manpower and Training Needs in Water Pollution Control," Document 49, 90th Congress, August 2, 1967.

More than 8,000 U.S. consulting firms were contacted during this study to inquire about their manpower needs in the water-quality area. From the responses, 268 firms (with a total 1970 waste-treatment construction volume of $4.6 billion) were selected for further analysis. These firms indicated they employed 7,600 professionals, and would need 8,700 in 1972, if conditions then current stayed the same--an increase of 1,100. For 1976 they indicated a probable need for 11,900 professionals.

Industry's needs for professional water-quality engineers were about the same.

The report saw increased demands for professionals in water quality in the near future. In the past, federal training support has been a principal means for educating needed professionals and concern was expressed that a reduction in EPA training support could have serious long-term consequences. During the past 5 years there has been a marked decline in this support. The retraining of professionals in other areas (aero-space, for example) could not be counted on to fill the void because they would not be properly prepared for such a transition without considerable reorientation and education. Total expenditures for professional training in all aspects of EPA's fiscal year 1973 program amounted to only 0.4 percent of the construction budget for water quality alone.

[1/] Middlebrook, E. J., M. F. Ettelstein, R. G. Snider, and L. M. Spiller, 1972, Manpower Needs of Consulting Engineering Firms in Water Pollution Control Federation, v. 44, n. 10, Washington, D.C.

The problem of effective development of facilities without competent professionals to design and operate them is implicit.

Future Directions—National

Society is becoming more aware of environmental problems resulting from man's activities and is beginning to place a higher value on the conservation and restoration of the environment than it has before. Among the principal concerns are increased emphasis on restoring higher quality to natural waters, simultaneous preservation and utilization of rivers and lakes, and multipurpose urban land management and use.

Although the physical processes underlying these concerns fall within the field of hydrology, most hydrologists gave these problems little attention until recently. They now recognize a need for increased knowledge specifically to deal with these problems and foresee a growing emphasis on finding solutions to and making studies of these problems in the future.

Although many scientists agree that the term hydrology can be defined broadly enough to encompass the physical processes involved in these new concerns, others prefer to use terms such as "water science and engineering" or "water-resources studies." These, they believe, more clearly reflect the interactions between physical and chemical processes and the impacts imposed on them by the economic, political, and social interplay of man's uses and demands.

When considering the direction and needs of education for the future it is necessary to realize the dynamic nature of the field and the lag time between a person's education and his productive contribution to the solution of real-world problems. A person's basic education and his continuing education efforts must keep him abreast of changing conditions and prepare him to deal with new

situations he may encounter for the next 30 or 40 years of his professional life. It is now apparent that education will need to give attention to a broader range of more complex concerns than it has in the past. In addition to the traditional emphasis on the quantitative aspects of the hydrological cycle, emphasis must also be given to problems of water quality, and related ecological and environmental factors.

Future directions for education in water science and engineering should be considered in terms of three types of programs: (1) teaching programs for both the specialists in the field and the general student, (2) continuing education for the practicing scientists and engineers and for teachers at all levels, and (3) education for public officials and the general public.

Education at University and College Levels

Specialists working in the area of hydrology professionally in the United States are usually educated in a university environment. Course work as well as research work is carried on in various colleges and departments, with 40 percent of the total in civil engineering departments, 15 percent in geology departments, 9 percent in agricultural engineering departments, and the remaining 36 percent in a variety of other departments.[1/] The university environment provides opportunity for exposure to many fields of knowledge that contribute to the understanding and study of hydrology. Opportunities for breadth in hydrological education through association with chemistry and biology, for example, are desirable, together with the opportunity for the students to become aware of the economic, social, and ecological effects of hydrological processes. Collaboration between students of hydrology and engineering is also useful to impress them with the effects of engineering on the hydrological system and vice versa.

1/ Table VII in Universities Council on Water Resources, 1967, Education in Hydrology, United States Universities--Early 1966, The University of Texas Press, Austin, Texas, 44 p.

Training of Hydrologists and Water Specialists. In the near future, many students who will work in the field of water sciences will continue to be educated within the curricular limits of established departments such as geology, civil engineering, and agricultural engineering. Some students will be educated in specially organized hydrology, water-science, or water-resources departments, but the number of students in these departments will remain relatively small in relation to the total number of students in the field. Whatever the academic structure, the education of water scientists and engineers at universities should provide training in both the scientific and applied aspects of water-related problems. This training should include a firm grounding in physics, chemistry, mathematics, and geology, and their roles in understanding the physical processes of the hydrological cycle, as well as the application of theory to real-world hydrological problems.

A closely associated consideration is the breadth of experience and competence of the faculty. Universities often confine recruiting to individuals who either are just completing their education or are already teaching in universities or their equivalents. In general, such sources are inadequate to meet all the requirements of water-related curriculae because they lack practical experience. Most hydrological problems utilize approaches that require the adaptation of theory to the imperfect conditions in the field. Students must be introduced to both the applied and theoretical aspects of hydrology and its ramifications, and it is important that some members have substantial practical experience.

The detailed content of hydrology-related degree programs is not discussed in this report. However, information on the content of various existing programs in hydrology is available through UNESCO.[1/]

Interdepartmental Arrangements. The lack of hydrology or water-resources departments in most universities generally leaves the development of appropriate curricula to interdepartmental arrangements. In many instances they are ad hoc, depending on short-lived grants, local

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[1/] UNESCO/IHD, 1972, "Curricula and Syllabi in Hydrology," Technical papers in Hydrology, Bulletin No. 10, Paris, France.

pressures, and individual interests. In some institutions, interdepartmental cooperative arrangements are working well and students have water-related courses available in a wide variety of fields. Even under the most favorable conditions, however, the success of such arrangements depends heavily on the people involved and thus can change rapidly. For the same reason, such arrangements can rarely be copied elsewhere although they provide useful models and guidelines.

A few interdisciplinary degree programs are conducted under the supervision of interdepartmental committees. Again this arrangement works only so long as the people involved make it work. It should be considered as a possible solution, but there is often great difficulty in maintaining a strong program.

A majority of the Work Group considers that such arrangements are satisfactory, or at least adequate; a minority believes that they are not. However, with the institutional structure of most universities and colleges, such interdepartmental arrangements are about the best that can be expected. Improvement in most current interdepartmental arrangements was recognized as being desirable, to meet the full scope of future education and training needs in water-related fields.

Internship Programs. Over the past two decades in civil engineering and other water-related fields, practicing professionals and university faculty frequently have exchanged mutual criticisms. The universities have been criticized for failing to recognize practical problems and thus for not training students to appreciate them; the practitioners have been criticized for being slow, or failing to apply new theoretical concepts and techniques. The Work Group thinks that both sets of comments have some validity; a useful technique is available to improve the situation.

Many universities and organizations within the practicing professional community have developed "internship" programs, which have been extended to include students. They provide faculty members with the opportunity to work with the practicing community and to apply their theoretical training and research to practical problems, and in turn practicing professionals in applied fields have the opportunity to teach and share their experiences with university faculties and students. Some programs have

been extended to give undergraduate and graduate students opportunities to obtain practical experience as part of their curricular training.

Exchanges between universities and other organizations have been developed successfully in a few places, and the Work Group urges that the practice should be applied more broadly. Arrangements for student internships for summers, on a part-time basis on a work-study arrangement, also should be encouraged and expanded. These internships not only permit students to learn first-hand the art of practice, but give them an idea of employment opportunities and work activities and provide their employers with direct links to research and other university functions. Consideration by students of employment abroad soon after graduation should be encouraged as part of the training of professional hydrologists. Such experience is invaluable in developing initiative on the part of the young professional, and also the day-to-day exchange with professionals in other countries is one of the best ways to transfer modern technologies and concepts.

Training for Those not Specializing in Water-Related Matters. Courses dealing with water development and management and with related environmental, economic, social, and political issues should be available for students studying in fields other than water science and engineering.

Two major needs should be met at least on the larger university campuses. First, a "cultural" or general-information background course should be offered for students who do not expect to make professional use of water information but who desire to become well informed on the major environmental, economic, social, and political issues of the day and thus capable of making knowledgeable decisions on water-related issues. The course would provide an understanding of man's relation to his environment and of the many ways in which water affects his environment and influences his personal life. It would describe the physical, chemical, and biological systems involved and consider the many management issues to be faced in meeting the needs and desires of today's and future societies. Second, special water-resources courses should be designed to meet the professional needs of students in economics, law, political science, and

related subjects who require a basic understanding of the water system with emphasis on those aspects involved in economic, legal, and political decisions.

Education at Pre-University Levels

After examining the educational programs associated with hydrology, the Work Group concluded that the teaching of water-resources-related material in the primary and secondary schools, community colleges, and even some smaller universities should be made more general and improved. Not only do these schools represent a step in development of public understanding of the complex issues involved in water development and management, but they also shape and influence the career choices of our youth. The presentation of factual information regarding the country's environmental problems at the primary and secondary levels becomes increasingly important when it is realized that many of the students will receive no higher education, but still as voters will be faced more-and-more frequently with the necessity of making decisions regarding the environment.

The major responsibilities for presenting facts in this realm lie with the teachers at pre-university levels. Since these institutions influence future voters and taxpayers and their career choices, it is important that they offer courses with effective and balanced instruction in water problems.

The Work Group thinks that the primary and secondary schools and community colleges should develop two types of courses:

First, general-information courses to better equip the students as citizens. Such courses should present a broad understanding of the many ways in which water affects the environment and influences our personal lives. They should be as objective as possible, avoiding the excesses of the developmentalist or preservationist biases while calling attention to the full range of issues and viewpoints. Second, technical courses should be developed at community colleges and other institutions of higher education. These should equip their graduates with sufficient understanding of water science and engineering to

fill the technician and technical positions offered in a growing number and variety of employment opportunities.

Technician Training. The increased attention now being given to water treatment and disposal and to other water-related activities has swelled the need for technicians trained in water science and engineering to operate water and waste-treatment plants, and to perform a growing number of functions in agencies and organizations involved in some aspect of water management. The number of such positions will increase rapidly as government at all levels, industry, and other water users are required to give greater attention to water management, especially to water quality and pollution control.

A number of 2- and 4-year technology programs in the United States are designed to prepare personnel for working in fairly narrow fields. Graduates of these programs are commonly awarded technician certificates, associate degrees, or in the 4-year programs, bachelors' degrees. Normally, following these programs participants have no interest in further training. Indeed, the programs do not prepare them for graduate study. Consulting firms, and federal, state, and local government units have a serious need for personnel to work on routine problems in water resources. Thus, practical programs in water-resource technology would provide an important source of staff for these organizations. It is important that these courses establish a base in engineering and in the sciences, including biology, adequate for a reasonable understanding of changing problems and technology. The students also should be given some general understanding of the environmental issues and of the economic, social, and political aspects of water-management decisions.

Training for Teaching Environmental Studies. From their own observations and experience, the Work Group members feel that there is legitimate cause for concern over the adequacy of environmental education, including water and related problems, as now offered in schools and in undergraduate courses in some community colleges and small universities. Although the situation has improved since the late 1960's, many instructors still lack objectivity in their presentations. Of particular concern to officials charged with water development and management are inaccuracies and bias in the information as presented.

This problem is particulary acute in the primary and secondary schools. In recent years, many state and local departments of education have initiated instruction in ecology and environmental matters, resulting in a sudden increased demand for teachers in this area. Many inadequately prepared teachers have found themselves dependent on the limited teaching material obtainable.

Often the available material has been prepared by outside sources with strongly biased points of view. Some water agencies offer speaker's and teacher's kits of pamphlets and visual aids that subtly or blatantly present the development ethic. At the same time, some preservationist-conservation groups, alarmed by the developmental view offered freely for use in schools, have held field trips and teachers' institutes that stress their views on resource issues. A reasonable degree of objectivity is difficult to achieve if teacher educational materials or programs are provided or financed by special-interest groups, and inexperienced teachers cannot be expected to recognize the biases contained in their teaching materials.

Not enough has yet been done through the normal educational channels to provide teachers with a better insight into the complexity of water problems. It is important that teachers, who daily face a multitude of demands on their limited time, have available information that includes lists of topics, references, visual aids, and other teaching material. Such information in the form of a syllabus and teacher's kit can be quite effective as a guide for those who do not have the time to do the necessary research and to organize the balanced and informative course, especially where the teacher's educational background is in some other area. One approach to preparing such syllabi and teacher's kits would be to organize special short-period workshops or institutes at universities. These could be scheduled for a few successive weekends, during short vacations, or as night courses. Participants would discuss water and other special environmental problems with professors specializing in hydrological education and with hydrologists and water-resources experts experienced in facing practical situations. The technical content would come from the university group, and the format necessary to make the information most useful would be developed by the science teachers on the basis of their experience.

Summer Study, Work, and Research Programs. Most primary- and secondary-school teachers and community-college instructors must periodically attend summer schools to take general courses in education. These study periods alternate with summers during which the teachers either work or vacation.

Summer courses in environmental studies are being offered increasingly in universities, and many do an excellent job in helping teachers prepare their course work for the school months. The universities have a responsibility to ensure that such studies present a useful balance of academic and practical matters, and that the material they offer has been reviewed, if not prepared, by experts in the respective fields.

Working on real-world problems in the environmental area, especially in water-related activities, also would greatly improve the ability of teachers to offer meaningful instruction in hydrology and water resources.

Valuable professional development could come from work-experience programs designed to allow teachers to participate in the activities of water-supply agencies, water-treatment and disposal plants, water-related fish and wildlife programs, etc. Agency programs in these areas, which typically expand during the summer months, would offer good opportunities for useful work-experience programs for teachers. Such work programs would also benefit the older students who could be placed in jobs suitable to their age, experience, and maturity. Upon their return to the classroom, students with work experience would provide an incentive and challenge to their instructors to improve and expand the scope of their curricula.

The National Science Foundation has had a program that provides funds for high-school teachers to work during the summer on research projects in universities. Because of the importance of water resources, this program should be expanded to provide more opportunities to gain experience in hydrology. Working with an experienced researcher on a meaningful project would be an excellent experience on which to build future teaching. It appears that comparatively few teachers have used this program to add to their knowledge of water-resources problems.

Where possible, the educational value of summer employment could be substantially increased by organizing groups of teachers to work on a variety of activities and arranging for weekly seminars under the leadership of an experienced water scientist or engineer; these seminars would afford opportunities to discuss issues and share experiences. Financing such group arrangements and seminars might be handled as were the numerous summer institutes for high-school teachers sponsored by NSF in the mid-sixties.

Programs in Continuing Education and Technology Transfer

Continuing education and technology transfer may be considered as the two sides of a single coin. Technology transfer is the process of translating research results and technological advances into practical application or of making such results available for use as quickly as possible by practicing professionals and technicians. Continuing education is one of the more useful means for effective technology transfer because it makes information available at times and in forms compatible with the needs of the student.

The Work Group believes that every possible avenue should be exploited to enhance the capability and knowledge in water-related fields of educators, practicing professionals, technicians, managers, decision-makers, and the public. Continuing education should be expanded greatly, and should be directed toward two specific goals. The first is to advance and update the technical capability of, or transfer technology to, educators, professionals, technicians, and all others already engaged in the practice of their water-related professions. The second is to enhance the understanding of water problems among adults whose principal interest in water is how it affects their personal lives.

Continuing education programs may consist of courses and workshops, special seminars, and field trips. Whatever the type of instructional vehicle, it should be tailored to the needs and schedules of the working group for which it is intended. They also should be supplied with state-of-the-art manuals, syllabi, educational films, and other educational aids, again appropriate to

the needs of the group being taught. Programs of continuing education should be developed regionally and locally through the cooperation of teachers, hydrologists and water-resources experts from state and federal departments of public and environmental instruction, continuing education centers, and appropriate research and science foundations.

Courses should be offered in a variety of forms. Particularly because the professional often must continue working while learning, it may be desirable to organize some workshops along the lines followed by the Institute of Traffic Engineers, which distributes its sessions one night per week for a period of 6 weeks. Universities and agencies also should be alert to organize seminars and workshops around the visits of outstanding foreign visitors who are able to bring foreign developments to the attention of U.S. water scientists and engineers.

Practicing Professionals in the Water Field. Although there are funds for retraining the unemployed and for educating undergraduate and graduate students, virtually no provision is made for the continuing education of the professional whose knowledge is falling behind. For example, hydrologists working for agencies or companies generally are over-committed and only rarely have they the time to learn some new method that for lack of time they have been unable to glean from the research literature.

The short courses that are available are frequently at a distance or scheduled inconveniently for interested people and their employers. As a result, the practitioner fails to receive the postgraduate education he needs to update his formal training. The dissemination of information to this group is a major requirement.

In general, the Work Group believes that universities should foster programs that involve the development and dissemination of new knowledge, while governmental agencies should focus on in-service training programs directed to better understanding of the operational aspects and relationships of agency activities in the environmental field. The need for exceptions in both directions is recognized. The Work Group also suggests that within a locality or region, as well as on a national basis, academic institutions should collaborate with professional groups to devise continuing education programs that will be mutually reinforcing.

Although most university educators are familiar with the literature related to their areas of research, like all other professionals, they are unable to keep up with all advances in their respective disciplines. Their own areas of research may be presented in their courses almost completely up to date, but other areas that must be covered may be a few to several years behind current practice or the most recent thinking. The continuing education activities for practicing water scientists and engineers already mentioned should also be available to and used by college and university professors.

Some of the workshops or seminars recommended in the previous section would be of special value to college and university professors in their selection of workshop topics of interest to primary and secondary school educators and provide for adequate discussion of educational topics.

The General Public and Public Officials. The need to provide opinion-shapers and decision-makers at all levels with balanced information on hydrology and water problems is perhaps the most important and difficult educational challenge of all. These groups include the personnel of agencies and organizations that in some way affect or are affected by water development and management, and public officials at all levels of government, especially city and county. Misunderstanding of physical and chemical factors and differences in social and political values among these groups contribute to public confusion, stagnation of decision-making, and increasing resort to injunctions, suits, and other court actions. The Work Group believes it is especially important to improve means for informing public officials and providing them with a better understanding of the principles governing hydrological processes and water-resources development.

Society has reached a stage of technical development at which man's living conditions are significantly affected by public actions concerning hydrology and water resources. At the same time the planning agencies are adopting policies different from those used in the past. Once it was possible for a planning agency to develop a single plan and submit it to the public for adoption or rejection; now it frequently is necessary to prepare

alternate plans and related environmental-impact statements and to involve the public in making choices.[1/]

For most practical matters, however, the public is composed of small vocal groups who at most constitute a small minority of the population. Of special importance in influencing public opinion are the League of Women Voters, service clubs, PTA's, labor unions, sportsmen's clubs, homeowners associations, watershed associations, wilderness clubs, and others organized around their vested interests in water. It is the concerned citizens who form these small groups who must be taught to understand the hydrology and water-resources systems so that they may exert their influence for constructive and rational policies. To increase citizen knowledge and understanding of hydrology and water-resources systems, special educational programs should be devised for the general public. These should include public-service broadcasting over national, regional, and local TV and radio stations.

Also, special seminars and open forum discussions should be organized to present selected aspects of water science and engineering to public officials and people publicly voicing personal opinions. Such seminars must be carefully prepared to meet the special needs of the public officials invited to the seminar. Two or three key public officials should be involved in the planning of the seminars to keep them directed specifically at the right targets. Other disciplines besides hydrology should be included in the planning and conduct of the seminars if they have a contribution to make toward the solution of problems facing the public officials.

Technology Transfer. Whether it is an industry that must develop a resource within more-and-more stringent environmental constraints, or a legislative or county commission trying to perfect a public policy, the requirement for shorter and shorter response times between problem identification and solution is being thrust upon the hydrological community, educational facilities, public officials, and public. This implies the need to improve and accelerate the process of transferring an understanding

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[1/] White, G. F., 1973, Prospering with Uncertainty in Transfer of Water Resources Knowledge, Water Resources Publications, Ft. Collins, Colorado 80521, p. 22-28.

of the technology available to solve society's problems from the academic and scientific communities to the economic and political decision-makers.

The transfer of information and technology among adults has turned out to be a far more complex process than was originally believed.[1/] Many other groups faced with the problem of technology transfer have turned to an intermediary who became a specialist in being able to translate scientific into applied terms and put practical problems into scientific contexts. Probably the best example of specialists in technology transfer in our country is that of county extension agents encouraging and speeding farmers to apply the results of agricultural research. A similar information program has been developed with the Sea-Grant program.

The Work Group believes a similar specialization appears to be needed to bridge the gaps between researcher and manager-planner and between the planner-manager and the public. Many new research developments and concepts of water supply, flood protection, waste disposal, pollution control, and planning are waiting "in the literature" to be tested and applied by governmental and private operating groups and individuals. To accelerate the testing and application of research calls for organizational arrangements that deal explicity with the transfer mission and function. To make it effective it must be distinguished from either classroom teaching or academic research and from design by the practitioner.

The Work Group is not making a new suggestion, but simply reinforcing what has been well recognized but insufficiently developed or applied. The gap in communication necessary to accomplish technology transfer is well known. The water manager needs assistance to identify and define problems accurately to specify the most appropriate technology to effect a solution. Then the specified technology must be adapted to the problem, while institutional and organizational adjustments are made to apply the technology successfully. The Work Group feels that the communication gap can best be closed

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1/ White, G. F., 1973, Prospering with Uncertainty in Transfer of Water Resources Knowledge, Water Resources Publications, Ft. Collins, Colorado 80521, p. 22-28.

by specialists in translating scientific and technological advances into timely and practical applications--in short, in technology transfer.

Hydrologists who are skillful and successful at technology transfer owe their abilities to talent, proclivity, and opportunity rather than to a programmed and purposeful training effort. The Work Group believes that the need for technology transfer in the water-resources field is so great that the profession cannot depend on chance to provide it with the transfer services it needs. Specialists should be trained, given professional recognition, and employed; their task would be to bridge the gap between researcher and practitioner, particularly by assisting them to identify the problems and relevant solutions and by participating in the development and presentation of continuing education programs.

Universities are being expected to and are expecting to assume the role of specialists in technology transfer in hydrology and other fields. However, because universities are structured around research and classroom teaching, the ability to transfer technology of this speciality needs to be developed if universities are to play their desired role in this regard.

Future Directions—International

The international aspects of education and training in hydrology and the water-resources fields are considered by the Work Group to be primarily a series of problems in the exchange or transfer of information. These problems are receiving increasing attention because of the constantly growing demand for information from countries with developmental problems, and because of the benefits to be gained at home and abroad by the advancement of science and technology. The demand grows in spite of criticism of current and recent efforts in international information exchange and transfer.

Three international aspects present difficulties to which the solutions are at best still in experimental or trial stages. The first is that U.S. participation in information exchange or transfer is both a technical--i.e., educational--and a political--i.e., foreign policy--operation, and that both sides must be considered in the development of successful programs. Second, the conditions of exchange and transfer among more-developed countries are different from those between industrial and less-developed countries. And last, recognizable benefits must accrue to both parties involved in the exchange or transfer if the process is not to collapse completely or fall far short of meeting its original objectives.

For the United States, two major objectives exist in international exchange or transfer of information. The first is increasing U.S. awareness of foreign advances pertinent to domestic programs, and the second is furthering of U.S. endeavors to maintain friendly relations with other countries. To meet these objectives, exchange-and-transfer-of-information programs must be strengthened through coordinated arrangements involving the Department

of State, federal mission-oriented agencies, research institutes, universities, scientific and professional societies, and individuals.

Information Distribution

The Work Group is aware of the generally recognized discrepancy between the tremendous effort expended by the United States to transfer water-related information to developing countries and the limited amount of success achieved. Much of the discrepancy results from the dissipation of effort through fragmentation or lack of coordination, unclear or unrealistic goals, and an inadequate recognition of the needed balance between technical and social or political objectives. Whether made privately or publicly, for science or for humanity, every international contact this country makes affects the manner in which other countries see us and how we see conditions abroad.

The Work Group has come to the conclusion that particular attention should be given to dissemination of information to those responsible for water-related education abroad. Most scientific information is distributed in format and syntax oriented to the professional scientists. When it reaches its intended readership, it serves the purpose of transferring information among peers. However, most of these are primarily research oriented and the new information seldom is put into terms useful to scientists working in closely related fields, and even more rarely into terms understood by the practitioner and technician. The Work Group suggests that the scientific communities in industrial countries have a responsibility to see that their new information is put into format readily understood by a cross-section of educators in different disciplines and countries. This is a significant task, quite apart from that of making scientific work understandable to those working in the same discipline.

Several mechanisms are currently in use for the dissemination of information among various sectors of the professional communities. These include large conferences, seminars, workshops, journals, and lectures. The workshop, organized to examine some specialized scientific advance and to prepare a document that makes that information

understandable by a larger audience, is felt by the Work Group to be one of the better means of preparing scientific information for distribution for broader use. Workshops should be small and specific in nature. Participants should show a balance between scientists, professionals working in the field, and educators aware of the problems of communication. The objective should be a document that can be used to inform less-sophisticated practitioners, technicians, and students.

Progress in Hydrology Abroad

Hydrological practices, concepts, and educational methods in other countries frequently are sufficiently different to provide a new insight into domestic practices, if not new information itself. Presently, direct contact between American educators and hydrologists and their counterparts in other nations is far less than is considered desirable by the scientific and professional groups involved. Much could be done to improve this situation by bringing leading foreign hydrologists to the U.S. for series of five to six regional workshops conducted at centrally located universities. Costs could be absorbed by participants in the workshops.

The workshops would be given during the summer for 3-5 days at each location, and invitations to attend would be sent to all hydrological researchers, professionals and educators in that region. The individual leading the workshop would prepare detailed notes and provide other appropriate documents necessary for the proper presentation of his subject. At the completion of the series of workshops, the notes and other written material should be revised and turned over to an executive secretary who would then get them into a proper form and make them available to the entire hydrological educational community. This program would be similar to the popular AGU-sponsored visiting-scientist program, which directs hydrologists, among other scientistis, to small colleges for 1- or 2-day visits.

Conferences focusing on educational problems, similar to the three International Seminars for Hydrology Professors held during the IHD provide another excellent mechanism. These seminars resulted in excellent exchanges of ideas and their proceedings were widely disseminated. All

three were considered to be useful to both the U.S. and international educational communities. Although the benefits of too-frequent meetings can be questioned, an occasional, large, well-planned conference has the advantage of direct contact among many practitioners. The Work Group suggests that international conferences for professors of hydrology should be held at approximately 4-year intervals. They could be organized under the auspices of UNESCO, the International Water Resources Association, the International Association of Hydrological Sciences, and other appropriate bodies. Each conference should be held in a different country and on different continents to ensure maximum opportunities for participation, particularly by developing countries.

U.S. Educational Assistance

Many hydrologists now working in developing countries were educated in the United States and many more who are called in as consultants by international agencies and the countries themselves are members of U.S. consulting firms. Thus, the role played by the U.S. educator in the solution of hydrological problems in developing countries is a major one.

The charge has been raised in a number of quarters, however, that most U.S. educators do not really understand the problems in developing countries. It is commonly acknowledged that U.S. educators do lack continuing communication with the professionals in developing countries. To overcome this deficiency, the Work Group feels there is need for a long-term program encompassing mission-oriented projects of several years' duration each. The program would (1) require repeated visits by U.S. educators to a specific country; and, (2) assign foreign professionals to U.S. universities for periods of 1-2 years. Its ultimate result would be improved development overseas; improved understanding of other countries' problems in the United States leading in many instances to improved understanding of our own problems; and finally, a better understanding and appreciation of the United States and its problems abroad.

Also under this program, U.S. educators and practicing hydrologists, in cooperation with local other-country institutions, would set up a series of short courses

abroad. These would be designed to raise the level of competence of the technicians working in the field. Such courses, carefully coordinated with appropriate local authorities, and institutions operated at field installations, universities, or other centers, and including training of counterpart instructors, would require a minimum of interruption of the lives of the students involved. Instruction materials, teaching aids, and instruments used in field problems would be left for host country counterparts use and maintenance. Finally, a follow-up device would assure that the counterparts and institutional development were indeed able to function on their own.

Selected hydrologists and educators from developing countries also should come to the U.S. for short orientation and training periods. During these periods, they would spend part of their time at universities studying approaches to hydrological education and part of their time at field stations, such as river-forecast centers or research watersheds.

Some past programs of this nature have left negative impressions on all parties involved, because visitors were shuttled from one place to another with attendant lost time and breaks in continuity. To avoid this situation, the Work Group suggests that coordinators should be assigned to schedule and monitor individual visitors' itineraries, or that some sort of coordinating center be established. Furthermore, if commonality of interests can be established beforehand, visitors should be brought in as a group and kept together as much as is appropriate to their purposes. In this way, they could compare notes, sustain each other during moments of cultural shock, and be better able to screen the ideas appropriate for their needs.

Another problem for U.S. participants in educational assistance programs is that of availability and knowledge of educational materials and technical publications. Several commercial and governmental clearing houses prepare newsletters and abstracts of publications appearing in a specific field. Many of these are at least partially oriented toward hydrology. Many U.S. hydrologists going abroad are unaware of the existence of some of these clearing houses or the services they provide. This is especially true of clearing houses located outside the United States. To alleviate this problem, a document should be prepared (1) itemizing abstracting and newsletter

services; (2) describing the services available; and (3) explaining how to obtain their services. To be of maximum use, this document should be updated regularly.

Any program designed to provide information to the hydrological community of a developing country must be carefully designed to ensure that it is meeting the real needs of that country. Coordination between professionals in the developing and industrial countries is required to ensure that the information provided is suitable for its intended technological and institutional purposes. This was made clear during the IHD when members of the U.S. Work Group collaborated with members of the corresponding work groups of several nations to prepare a series of manuscripts covering a range of hydrological and teaching problems. Some have argued that these documents are oriented too much toward conditions and problems in industrialized rather than developing nations. In general, it was concluded that increasing efforts must be made to develop a broad range of materials specifically for use in developing countries.

Before any new educational assistance programs are implemented, the strong and weak points of past efforts should be analyzed and reported. In support of future U.S. assistance abroad, a continuing centrally coordinated program should be established for conducting educational activities at technical, staff-support, and professional levels abroad in the less-developed countries. They should be organized around career staffs and designed for long-term participation in the host-country activities.

Education and Manpower Assessments

The appropriateness and reliability of any recommendations for education and training are apt to be short-lived and uncertain under the rapidly changing conditions expected in the near future. Consequently the Work Group believes that periodic, detailed surveys of educational programs and manpower needs in hydrology and water-resources fields are essential for the timely and proper design of subsequent activities.

Educational Reviews

The surveys of water-resources education summarized earlier are representative of the limited kinds of information currently available. Analysis of these surveys supports the need for periodic consistent reviews of educational programs. The existing studies were broad in that they examined the complete field of water-resources education. They also were limited because most of them were undertaken with specific, limited, and different objectives and in most cases not all universities and colleges were included in the sampling. Thus they are not directly comparable. Another deficiency is that most of them were restricted to collecting data rather than attempting in-depth analyses of the programs. While it is important to know who is doing what, an interpretation of how useful current programs are in terms of meeting professional and manpower requirements in the water-resources field would be more meaningful.

Future assessments should determine the adequacy of training related to needs, effectiveness of institutional structures, improvement of public understanding, and

relationships to manpower needs. Surveys could be carried on cooperatively with organizations such as UCOWR, AGU, and ASCE which have many common interests. All educational institutions engaged in training in the hydrology and water-resources field should be included in future efforts of this type. An analysis that meets the objectives previously described would be an extremely useful instrument for those engaged in water-resources education or those interested in recommending or engaging in educational programs. Assessments should be updated with regularity, perhaps once every 3 or 4 years, to provide the basis for a continuing evaluation.

Manpower Studies

Most manpower studies have been conducted at an unsophisticated level and tend to provide only superficial results. In many cases, they are little more than a listing of generalities related to the needs of state and federal agencies, industries, and others. More effective programs of education and training in hydrology and water resources could be provided if those engaged in the development of such programs had explicit definition of the real opportunities existing for trained professionals in these areas and the nature of training required to equip them to serve adequately.

The manpower problem is complex because it involves a great many variables, such as the general economic state of the nation, supply and demand for personnel, manpower price, convertibility of existing trained manpower, and technological advances. Because of this complexity, assessing future manpower needs is difficult and the results of such studies can never be exact. Nevertheless, a continuing reevaluation of needs is important if the effects of over- and under-production of professionals are to be minimized.

Manpower studies should include: a continuing critical analysis of the market for manpower; evaluation of particular manpower requirements of state and federal agencies, consulting firms, industry, and others employing professionals in hydrology and water resources; future trends in technology, planning, and social goals that dictate modification of present training formats; and sources of support for training programs. Studies of the training of professionals in formal university programs,

retraining of individuals with other skills and updating the education of practicing professionals all need exploration concerning the degree of effectiveness and importance of these approaches in the total manpower picture. Manpower surveys must be dynamic and should be revised at least every 3 or 4 years if they are to reflect the rapid changes of the country as it becomes increasingly concerned with the ramified interrelations of economic, environmental, and social problems.

Institutional Needs

Insofar as possible, the Work Group has tried to structure its recommendations so that they would be within the capabilities of existing educational institutions or of institutions designed to support educational activities. The presentation of so broad a spectrum of recommendations, however, implies that either existing institutions should consider some reorientation of priorities or that new institutions are needed. The Work Group feels that recommendations for action will only be as effective as the means available for their implementation.

A Committee on Water-Related Matters

Primary in many considerations is the need for a body with continuing responsibility to evaluate and provide leadership in overall educational and manpower needs in hydrological and water-resources activities. During the past few years this function was accepted by the U.S. National Committee for the International Hydrological Decade, and its Work Group on Education and Training, in the absence of any other group. One advantage of the Committee and its Work Group was that they represented the full spectrum of institutions composing the hydrological and water-resources community.[1/]

[1/] Groups such as the University Council on Water Resources and the Office of Water Research and Technology also have strong interests in water-related education. However, UCOWR represents only universities and OWRT is a Federal agency; thus neither represents as broad a spectrum of interests as did the National Committee.

The National Committee is the first constituted body, so far as known, composed of representatives of the federal, state, university, and private sectors of the hydrological and water-resources community of the nation. In furtherance of its obligations to the international program, it found itself having to examine national capabilities and national responses where water was concerned. Two closely related observations stem from this examination. The first was the tremendous size and scope of water-related activities in this country and the pervasiveness of the interrelations of water resources to national, state, and local activities of all types; the second was the looseness of the system under which all the diverse activities operated. Its effectiveness appeared to be derived from a great many institutions doing with varying degrees of competence only that which they considered to be their designated or self-appointed missions. The system works, but it is complex, difficult to come to grips with, and it has gaps. With its limited resources, the Committee and Work Group applied themselves to closing a very few such gaps as were within their commitment and resources. What was apparent from the beginning, however, was that the gaps were far greater than the Committee's available or potential resources.

The Work Group feels there is a need for a mechanism for reviewing educational activities in the water field and for carrying out these recommendations that fall outside the mission-oriented programs of governmental agencies, universities, and private operations. Because the Work Group believes it is more effective to separate the function of assessment and advice from the function of its implementation, it recommends that these functions be put into two different bodies assigned to separate institutions. To carry out the educational aspects, a committee on water-related education and training should be established in the National Academy of Sciences-National Research Council (NAS-NRC) on a continuing basis. This activity could be made one of the responsibilities of the Committee on Water Sciences and Research that has been approved within the NAS Assembly of Mathematical and Physical Sciences. 1/ This committee would be responsible for assessing the effectiveness and usefulness of all levels of educational activities in the United States, from educating fully trained scientists to providing for an adequately informed public.

1/ Not implemented by early 1976.

Financial Support for Water Education

Education for professional work in hydrology and water-resources activities requires both classroom instruction and participation in research efforts. At present, the financial support for classroom teaching in these fields competes on the same basis as other subdisciplines for available departmental funds: financial support for water-related education comes from several sources, with little central control and little budgetary security for long-range planning. Water-related courses are taught in several departments making it necessary to repeat the competitive exercise several times, further depleting the effectiveness of the limited manpower available for water-related educational activities. Because the water-related instruction is split-up among independent administrative units, there is no assurance that all pieces of a balanced program will receive the planned, or proportional, level of support, thus further confusing the water-related educational program.

Financing for instructional programs in state universities comes principally from state funds, whereas for private universities, tuition and endowment funds are the most significant source. In a few instances some federal support may be available through special programs or through the use of land-grant funds. This diversity of financial sources generally results in underfinanced operations, but it has a degree of stability that is not present when activities are dependent on single sources.

Research in hydrology at most universities is supported largely by federal funds that include those coming from the land-grant college allotments, the Office of Water Research and Technology (OWRT), formerly the Office of Water Resources Research, and to a lesser extent from projects sponsored by state and other federal water agencies.

Federal agencies should consider the impact of the existing financial system on the university's educational structure in the water resources field and on the country's future requirements for trained personnel. Federal agencies should develop financial-support programs that will involve a minimum of organizational and long-term commitments on the university while assuring the government and nation of continuing cadres of professionals and scientists to meet future demands.

The process of supplying adequately trained manpower when and where it is needed has for years been handled on either panic response or jury-rig basis. The advent of the Office of Water Resources Research saw universities scrambling to find trained hydrologists and water-resources specialists, and accepting the services of applicants who often had little background in water-related activities. At the same time, many state agencies were expanding their programs and faced the same manpower problem as the universities. Often the infusion of new ideas and outlooks was stimulating, but often it resulted in wasted time, money, and effort. The Environmental Protection Agency (EPA), in carrying out its mandate to develop and regulate practices affecting the environment, found itself similarly confronted with a shortage of trained manpower at critical times in its expansion to meet new responsibilities.

During the same general period, and in part in response to the same needs, some federal programs aimed at providing manpower were either drastically reduced, phased out, or terminated. Specifically, the NSF programs in support of continuing education and development of departmental activities were dropped in favor of expanding research applied to national needs, and EPS drastically reduced its support of training programs in universities in favor of in-house, on-the-job programs.

The Work Group considers these cutbacks to have been too drastic; with some critical modifications, the basic concepts and premises remain sound, and the need which they were attempting to meet remains unfulfilled. The substitution of in-house education, however competently presented, has always carried the stigma that it may be so oriented to its particular mission needs and agency policies that it precludes presentation of technically and factually balanced instruction. As a result, it may have excellent short-term benefits but end up strangling thought and progress.

The Universities Council on Water Resources, in 1971, passed a resolution urging that a system of government-wide extramural grants should be made available for the water-resources field (see Appendix A).[1/] The extramural grants,

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[1/] Universities Council on Water Resources, The Role and Relevance of University Water Research, Proceedings of a Conference held August 2-4, 1971, Corvallis, Oregon; Water Resources Research Institute, Lincoln, Nebraska, p. 84.

it was resolved, should provide for research, training, demonstration, and facilities, and should be designed either to provide direct assistance for training manpower or, indirectly, to provide valuable opportunities for increasing the number of professional workers in the water-resources field.

Moreover, the Work Group recommends that federal programs in support of professional training, and departmental development in support of professional training, be reconstituted to assist university and similar educational institutions to meet the need for trained personnel. The participating institutions should be made responsive to the spirit and purpose of the arrangement so that the objectives of the programs are achieved.

NSF Office of Hydrology and Water Resources Science

At the upper division and graduate levels in universities, training in hydrology and the water-resources disciplines is virtually unthinkable without parallel training and experience in related research. At this time, a significant proportion of the research in hydrology and the water-resources fields is funded through the Office of Water Research and Technology (OWRT) in the Department of Interior and the National Science Foundation (NSF). Additional sources of research funds are available through the National Oceanic and Atmospheric Administration (NOAA), the Office of Naval Research (ONR), a few other, mostly mission-oriented, agencies such as the Environmental Protection Agency (EPA), Tennessee Valley Authority (TVA), Corps of Engineers (CE), Energy Research and Development Administration (ERDA), and United States Bureau of Reclamation (BuRec). Although the adequacy of the total amount of funding available may be argued, the point under discussion here is the emphasis of the current programs.

The Office of Water Research and Technology is concerned with research that is oriented to state, regional, and Department of Interior needs. In the past few years, it has rightly stressed the need for research in the relations between the application of physical principles and the pressures of diverse economic, political and social stresses. Water-related research in EPA and, to a less critical extent, in the NOAA and ONR programs, is

also closely tied to the agency missions. Often the research conducted to meet mission objectives contributes something new, original, and stimulating, but it is relevant to the solution of narrowly defined problems, and broad aspects of hydrology remain untouched.

The National Science Foundation supports some research in the field of water through programs in the Divisions of Environmental Sciences, Engineering, and to a lesser extent, Biological and Medical Sciences. And the NSF support of U.S. participation in the IHD is gratefully and fully acknowledged. However, nowhere in NSF, is there a central office to concern itself solely with hydrological research and water-resources studies. Proposals for research on water are only considered in their relations to core disciplines, such as atmospheric studies, geology, oceanography, engineering mechanics, and ecosystem analysis. As a result, there is no central focus on the basic research needed in the field of water.

This is particularly regrettable because our understanding of the physical principles underlying the movement of water is not so far advanced that it can be considered complete. And yet these principles are the key to the distribution of water nationally and around the globe. Moreover, these physical processes underlie the problems faced by planners, developers, and managers in their efforts to obtain an optimum use and distribution of the water resources available to this country.

The National Science Foundation is well aware of this situation, but people in key agency positions have maintained that the Foundation is able to take care of the research needs of the field through the channels that now exist. This conclusion is questioned by many engaged in research in this field. The experience of the U.S. National Committee for IHD was that many good proposals for hydrological research were considered to be of secondary importance when placed in competition with proposals closer to the core of the disciplines which had offices established for their support.

NSF argues that many of water-related proposals have been reviewed and turned down by the same hydrologists who complain about NSF's lack of focus on hydrology. This argument neglects to assess the effect of using review criteria on proposals that are outside the matters for which the criteria were established. The NSF system

leads to geological proposals being sent to geologists or hydrologists with a geological background, and engineering proposals being sent to engineers or hydrologists with an engineering background. Thus, proposals that do not fit neatly into the framework of geological or engineering studies are reviewed by scientists who, because of their training and tradition, look at water problems through the filters of their parent disciplines of geology and engineering, and the hydrological persepective is bypassed.

Water, however, remains one of the essential elements for the continuation and growth of all activities in this country. The National Science Foundation's lack of a center to focus on them seems to be an incontrovertible gap. The Work Group believes strongly that an Office of Hydrology and Water Resources Science should be established within the National Science Foundation as soon as possible.

Independent Comprehensive Water Institute

Educational and training activities in schools at all levels and in the public domain are related to university, agency, and industrial research; all of which in turn are related to the intricately ramified system of agricultural, industrial, municipal, and social uses of water. Yet there is no central point at which a real attempt is being made to assist existing forums to remain aware of developments and needs relevant to their own activities and future plans. Because of these facts the Work Group believes the water resources community should consider the usefulness of an independent institute established jointly by governmental, university, and private subscription for the purpose of providing a general clearing house for water information. Such institute would assist existing programs to perform more effectively relative to each other's programs, and to assist those interest groups whose needs are not met.

The Work Group considered such models as the American Petroleum Institute, the American Geological Institute, the Information Service at the Medical Library of the National Institutes of Health, the National Water Well Association, the American Water Works Association, the American Water Resources Association, and some of the professional, commercial and industrial service associations. No one organization appears to have all the good

features that the Work Group had in time: a clearing house of scientific, technical, industrial, and commercial information concerned with water-resources activities; a capability to transfer the information into terms appropriate to different segments of the water-resources fields; a service to identify problems and bring them to the attention of appropriate bodies or individuals; and an active program of promoting interprofessional communication among all groups involved in water-resources information, use, development, and conservation. The Work Group recognizes that this is an ambitious, expensive, and possibly unpopular proposal. Nonetheless, the current facilities do not provide adequately for the transfer of information that should be available, although large sums are expended annually in the preparation of all types of water information for dissemination and distribution. What is far less well known is where to obtain the information when it is needed and whether the sources explored really represent all the information that exists. Something must be done to speed the exchange of water-related information among the many disciplines, professions, and activities involved in providing water for this country's needs. The Water Institute may not be the ultimate solution, but it should be a starting point for discussions.

Appendix A

UCOWR 1971 Resolution R-8

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UCOWR 1971 Resolution R-8

RESOLUTION PASSED AT THE 1971 ANNUAL MEETING
UNIVERSITIES COUNCIL ON WATER RESOURCES
CORVALLIS, OREGON AUGUST 4, 1971

RESOLUTION ON FEDERAL GRANTS FOR EDUCATION AND TRAINING OF PROFESSIONAL MANPOWER IN WATER RESOURCES AND ENVIRONMENTAL PROGRAMS [1/]

WHEREAS, Federal agencies responsible for the implementation of water resources and environmental programs need to have a wide variety of research and training mechanisms available for successful accomplishment of their missions; and

WHEREAS, Federal agencies should utilize research grants, fellowships, internships, contracts and training grants, demonstration grants, facilities grants and other forms of financial support to obtain the assistance of universities; and

WHEREAS, there is a lack of adequate financial aid for education and training apart from the research process;

NOW, THEREFORE, BE IT RESOLVED that the Universities Council on Water Resources should petition appropriate committees of the Congress to enact legislation which will authorize broad support for the development of education and training programs within universities for the purpose of achieving national goals in water resources and the related environment.

[1/] Universities Council on Water Resources, 1971, The role and Relevance of University Water Research, Proceedings of a Conference held August 2-4, 1971, Corvallis, Oregon. Water Resources Research Institute, Lincoln, Nebraska, p. 84.

Appendix B

Accomplishments of the US/IHD Program in Education and Training

APPENDIX B

Accomplishments of US/IHD Program in Education and Training

When it became obvious that the original proposals of the U.S. National Committee for participation in the IHD Program for education and training would not be funded directly by the U.S. Congress, it became necessary to reduce the program objectives to fit within the scope of existing federal programs and the foreseeable capabilities of the U.S. National Committee. The strength of the Committee, and its Work Group on Education and Training lay in its having the support and good wishes of the Universities Council on Water Resources (UCOWR), the interest of federal agencies in education and training both here and abroad, and in general, the widespread recognition by the hydrological community of the need for improvement in hydrological education and training in all parts of the globe. Reviewing the field of potential activities, the Work Group recommended to the National Committee that the US/IHD program concentrate on fellowships, short courses, on-the-job training, and science exchange.

Fellowships and Assistantships

With the full cooperation of the Universities Council on Water Resources and the generosity of the participating universities in the United States, the National Committee established and organized the UCOWR/IHD Program of Fellowships and Assistantships in Hydrology. The fellowships and assistantships were not separately funded in the universities but were allotted to the IHD out of existing university research, teaching, and scholarship programs. All were established for foreign graduate students whose purposes in furthering their education were clearly in line with the purposes of the Decade. One of the stipulations of the fellowships was that the recipient agreed to return to his country to practice the techniques he had learned and the education he had acquired under the program.

The program began with the academic year 1968-69, during which 49 fellowships and assistantships were offered by 25 universities. The immediate international response

was overwhelming--more than 900 individual applications were received. Qualified candidates were found for 23 of the available openings. During the academic years 1972-73 and 1973-74, M.S. and Ph.D. degrees were awarded to or approved for 45 students from 24 countries, by 10 U.S. universities. Two other students, from two other countries, completed nondegree graduate studies.

The program reached a peak of 62 openings in 1971. Generally, about forty percent of the available openings each year were filled by qualified students. The balance, the Work Group believes, was unused because many qualified applicants were short of funds for travel to and from the United States and many more applicants could not meet graduate-school entrance requirements. The program was terminated at the end of the 1973-74 academic year although some students who began their studies under the UCOWR/IHD program were not scheduled to graduate until 1975.

It has been difficult to keep track of the number of students who have received training under this program. After the first year, applications and admissions were entirely in the hands of the individual universities concerned. Nonetheless, on the basis of the years for which records are available, it is estimated that between 150 and 175 students came to the United States under the program and completed at least one year of graduate study.

A useful by-product of the program was the compilation of a list of foreign universities with recognized capabilities in hydrology and related fields. This list, based on a survey of opinions among hydrogeologists in the United States in 1967, is now out of date and has presumably been superseded by more-recent compilations made by UNESCO.

Short Courses

In support of its programs on short courses, the Work Group undertook to make annual surveys of short courses in hydrology and to issue an annual guide to their availability. Surveys were made in 1966 and 1967. During the middle 1960's, however, the number of short courses offered increased rapidly and, as a result, the original surveys

were out of date by the time they were compiled and ready for publication. Nonetheless, a summary of 85 planned and proposed short courses was published in the IHD Bulletin[1/] in January 1970, and subsequent short courses were announced regularly in the quarterly issues of the IHD Bulletin.

Additionally, the Work Group initiated and helped to organize three short courses under the general title of "International Seminars for Hydrology Professors." These will be discussed under science exchanges.

On-The-Job Training

The early attempts to develop a program of on-the-job training were explored in cooperation with the Agency for International Development (AID) and the Bureau of Cultural Affairs of the Department of State. Although both offices had great experience in on-the-job training and short-course programs, their operating procedures precluded their being able to adapt to the IHD program.

For one thing, there was no new money for IHD activities, and these activities became dependent on existing programs. Under these conditions, the initiative for exchanges in hydrology had to come from AID Missions and National Commissions abroad. Furthermore, these exchanges could only be made in competition with other disciplines seeking to use the comparatively limited available funds. Hydrology was in competition with established arrangements and received no special priority.

The Bureau of Cultural Affairs, although interested in the IHD in general, felt that its programs were designed to assist students in the humanities, rather than the sciences. There also seemed to be a tacit assumption, that still persists, that the sciences had ample funding sources for technical and scientific scholarships, although many of the Bureau officers recognized that it was fallacious.

1/ The IHD Bulletin, a quarterly report on national and international activities in the IHD, was published as part of the American Geophysical Union (AGU) Transactions in 1967 and 1968 and was subsequently published in the AGU EOS through 1975.

In 1969, exploratory conversations were held with the U.S. office of the International Association for the Exchange of Students for Technical Education (IAESTE), a private nonprofit organization. The purpose of IAESTE is to promote technical education by the exchange of students at the undergraduate level. This operation interested the Work Group because it would broaden the existing program to include undergraduate students, who were not covered by the UCOWR/IHD Program. The IAESTE staff enthusiastically cooperated, and shortly a U.S. IAESTE/IHD Program for on-the-job training was initiated.

This effort began to bear fruit only as the Decade came to a close. Business in the United States in 1969 went into a moderate slump, and in the following year there was tremendous pressure on all types of organizations to find job openings for the underprivileged and for those in minority status. During the 2 years during which there was an active effort to interest the water-related business, consulting, and industrial community into supporting the IAESTE/IHD On-the-Job Training Program, three exchanges were effected for U.S. students abroad. Although the program was shelved by the Work Group in anticipation of the end of the Decade, the interest in the IAESTE organization has not diminished. It is actively seeking to increase its contacts with firms interested in water resources and to develop an active program of exchanges in this field. Although the Work Group's accomplishments with on-the-job training were limited during the Decade, it is probable that the groundwork was laid for many exchanges in the coming years.

Scientist Exchange

The Committee promoted this part of the program through three International Seminars for Hydrology Professors. These were attended by 62 different participants from 29 foreign countries and by 194 different participants from the United States. Exchanges between foreign and domestic professors in the hydrology and water-resources fields occurred both during the seminars and also during many pre- and post-seminar visits at many institutions in the United States and Canada.

These Seminars were made possible through the cooperation of the Universities Council on Water Resources, the

National Science Foundation, UNESCO, and the World Meteorological Organization. The three seminars were held successively during the summers of 1969-1971, at, respectively, the University of Illinois in Urbana, Utah State University at Logan, and Purdue University at Lafayette, Indiana. Additional seminars were planned, but a change in support policy on the part of the National Science Foundation forced termination of the series after 1971.

The first Seminar provided a valuable overview and assessment of the state of the art of the whole field of hydrology. The results of this Urbana Seminar were published in The Progress of Hydrology (three volumes), [1] and widely distributed both in the United States and abroad. The second Seminar, "Systems Analysis of Hydrological Problems", [2] was concerned with the application of computer capabilities to hydrology, and the third, "Biological Effects in the Hydrological Cycle--Terrestrial Phase", [3] dealt with the interrelations of hydrology and biology. Proceedings from the second and third seminars have also been widely distributed.

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[1] The Progress of Hydrology, Proceedings of the First International Seminar for Hydrology Professors, University of Illinois, Urbana, Illinois, Vol. I-III, July 13-25, 1969, 1295p.

[2] Systems Analysis of Hydrologic Problems, Proceedings of the Second International Seminar for Hydrology Professors, Utah State University, Logan, Utah, August 2-14, 1970, 452p.

[3] Biological Effects in the Hydrological Cycle--Terrestrial Phase, Proceedings of the Third International Seminar for Hydrology Professors, Purdue University, West Lafayette, Indiana, July 18-30, 1971, 391 p.

Syllabus

In 1970 the Work Group undertook to prepare a syllabus of references for use in courses in hydrology and the water-resources fields. The Syllabus 1/ was initiated in response to a widely expressed need for information on hydrology and water-resources problems for use in the rapidly increasing number of courses in environmental studies. The lack of general texts in the field of water was voiced by many instructors who suddenly were faced with the responsibility of teaching subjects in which they were untrained. They had little to guide them as to what constituted the field and where to find appropriate and reliable materials describing it.

The Syllabus was built around a thorough outline of the field of scientific hydrology and the even broader field of the interaction of hydrology with economic, political, and social factors. The outline was designed to be used in support of (1) a 2- or 3-hour lecture series, (2) full semester courses on the scientific aspects of hydrology, or (3) a combination of the scientific and socioeconomic aspects. Six thousand copies of the Syllabus were distributed to professors and instructors who teach, or are interested in teaching, such courses. The international distribution was minimal but sufficient to bring the volume to the attention of countries who might be able to use it.

International Activities

In addition to the efforts made by the Work Group in support of the domestic program, it also supported the work of the corresponding International Work Group. Prof. Walter L. Moore was the U.S. representative on the international group, and he and Prof. R. M. Ragan worked on

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1/ Work Group on Education and Training of the U.S. National Committee for the IHD, Hydrology and Water Resources: A Syllabus of References for Teaching Introductory Courses in the Water Environment, 1972, National Academy of Sciences, Washington, D.C. 73p.

international task forces, providing large amounts of information regarding U.S. textbooks, films, curricula, syllabi, and teaching equipment. The information from the United States and from other countries is available in documents published by UNESCO. [1, 2, 3, 4]

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[1] UNESCO, Textbooks on Hydrology, Analyses and synoptic tables of contents of selected textbooks, Technical papers in hydrology, No. 6, Paris, France, Vol. I-II, 1970 & 1974.

[2] UNESCO, Curricula and Syllabi in Hydrology, Technical papers in hydrology, No. 10, Paris, France, 1972.

[3] UNESCO, Teaching aids in Hydrology, Technical papers in hydrology, No. 11, Paris, France, 1972.

[4] UNESCO, The Teaching of Hydrology, Technical papers in hydrology, No. 13, Paris, France, 1974.