Historical Review of the International Water-Resources Program of the U.S. Geological Survey 1940-70

GEOLOGICAL SURVEY PROFESSIONAL PAPER 911

Prepared with the cooperation of the Agency for International Development, U.S. Department of State, and international organizations

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By GEORGE C. TAYLOR, JR.

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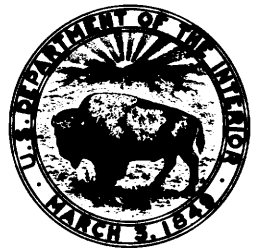

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HISTORICAL REVIEW OF THE INTERNATIONAL WATER-RESOURCES PROGRAM OF THE U.S. GEOLOGICAL SURVEY 1940-70

By GEORGE C. TAYLOR, JR.

ABSTRACT

The present review describes the history of the U.S. Geological Survey's (USGS) activities in international water-resources investigations and institutional development as well as exchange in scientific and applied hydrology during 1940–70. The bulk of these activities has been carried out under the auspices of the U.S. Department of State, U.S. Agency for International Development and its predecessors, the United Nations and its specialized agencies, and the regional intergovernmental agencies. The central objectives of the USGS' international water-resources activities have been to strengthen the administrative, staff, and operational functions of counterpart governmental hydrological and water-resources agencies; to improve the skills and capabilities of host-country scientific, engineering, and technical personnel; to exchange research specialists and publications in the sharing of advances in hydrological knowledge and methodology; and to participate in mutually beneficial international organizations, symposia, conferences, seminars, and special programs dedicated to various aspects of scientific and applied hydrology.

As the USGS is a domestic agency, its activities outside the United States must be covered by legislative authorization. Enabling legislation in force in 1970 included Public Laws 80–402, 85–743, 85–795, 87–195, 87–256, 87–626, and 91–175 of the U.S. Congress. USGS water-resources activities in the U.S. bilateral program were financed at an average level of $525,000 during 1950–70, peaking at $1,400,000 in fiscal year 1966. This funding is exclusive of counterpart funds in other currencies provided by foreign governments in support of project costs.

Between 1940 and 1970, USGS hydrogeologists, water chemists, engineers, and hydrologists completed 340 short- and long-term project-oriented international assignments in some 80 host countries. During the same time more than 428 water scientists, engineers, and technicians from 60 countries have received academic and in-service training through USGS water-resources facilities in the United States. Also in this period some 336 reports of a technical and scientific nature have resulted from water-resources projects in the U.S. bilateral program.

The USGS as of 1970 had been participating in international water-resources technical assistance projects for almost three decades and since the early 1960's also has been deeply involved in international exchange related to scientific and applied hydrology. Political events and age-old social and cultural constraints have presented many obstacles to goals of building viable hydrologic and water-resources institutions in the developing countries. Nevertheless, significant advances have been made in many of these countries which the USGS helped to achieve. Also between 1965 and 1970 the USGS played an active role in UNESCO's International Hydrological Decade, which already has had a marked impact in sparking advances of hydrologic knowledge among the developed countries as well as in the application of the scientific method to the solution of water problems in the developing countries.

INTRODUCTION

"History's highest function is to rescue merit from oblivion, and to hold up as a terror to base words and actions the reprobation of posterity."

Tacitus

Historiae, ca. 116 A.D.

The present historical review of the role of the U.S. Geological Survey (USGS) in international water-resources investigations and institutional development as well as exchange in scientific and applied hydrology is based on the writer's experience and association with the program over a period of 30 years. The review is largely descriptive and does not pretend to present an analysis of the philosophic import of technical assistance and scientific exchange—either in water-resources appraisal, development and management or in scientific and applied hydrology. Moreover, the review does not attempt to cover the full gamut of the USGS international activities but only those that pertain to water-resources investigations and hydrology. Emphasis in the review is on the participation of the USGS water scientists and engineers in the U.S. bilateral program, because this, historically, has constituted the bulk of the total overseas USGS water-resources activity and is the part with which the writer is most familiar. The review, however, describes, in somewhat less detail, USGS participation in activities of water-oriented multilateral agencies of the United Nations family and regional intergovernmental agencies; governmental scientific and technical exchange and cooperation; nongovernmental interna-

tional organizations; investigations and research abroad in extension of domestic research; foreign participant education and training; and procurement of hydrologic equipment for overseas projects. The review covers perhaps 90 percent of the USGS overseas water-resources activity during 1940–70 but not that of activities for which little or no available documentation exists.

The USGS has had in its basic charge topographic and geologic mapping and the scientific appraisal and evaluation of our Nation's mineral and water resources since its establishment in 1879. From its earliest days, moreover, USGS scientists and engineers have maintained active professional contacts and exchanged ideas, concepts, and knowledge with their counterparts in countries around the world through correspondence, publications, individual travel, and attendance at international scientific meetings. Thus, the USGS has always been internationally oriented, even though its primary mission is within the national boundaries of the United States and its possessions.

During the last years of the 19th century and the first four decades of the 20th, USGS water scientists and engineers were assigned from time to time to overseas activities under special bilateral agreements, notably in Brazil, Haiti, the Dominican Republic, Cuba, Panamá, and Nicaragua. Active involvement of U.S. Federal agencies, including the USGS, in overseas programs was first formalized, however, by President Roosevelt's creation in 1938 of the Interdepartmental Committee on Scientific and Cultural Cooperation (ICSCC) under the direction of the Department of State. ICSCC activities were authorized and financed under the terms of Public Law 63, 76th Congress, May 25, 1938, and Public Law 355, 76th Congress, August 9, 1939. The ICSCC, designed to coordinate the overseas programs of some 26 departmental and independent Federal agencies, was active throughout the 1940's until its mergence in 1950 with the programs of U.S. Technical Cooperation Administration (TCA).

Under the aegis of the ICSCC, USGS expertise in resources appraisal and evaluation was first projected overseas during World War II (1939–45), when, as a result of critical shortages of strategic mineral commodities in this country and among our allies, the USGS was authorized to undertake reconnaissance mineral exploration and appraisals in Latin America. Between 1940 and 1946 more than 60 USGS geologists in 16 Latin American countries carried out more than 100 field studies of 11 different mineral commodities that were then in short supply. Also, during the war, some 10 water geologists and engineers from the USGS entered military service and were assigned to engineering groups and water-supply battalions of the U.S. Armed Forces to study water-resources problems and to locate suitable water supplies for military installations in various places in Europe, Africa, Asia, South America, and the Pacific Islands. Little of this work, however, is documented in available form and is not included in the descriptive sections of this report.

Another forerunner of the present U.S. bilateral foreign aid program was the Office of the Coordinator of Inter-American Affairs (OCIAA) founded under the sponsorship of the Rockefeller Foundation. The OCIAA was moved under the wing of the ICSCC in the Department of State during the early years of World War II to further the objectives of President Roosevelt's Good Neighbor policy in Latin America. The OCIAA was reorganized and expanded during the post-war period in the Institute of Inter-American Affairs (IIAA) which provided technical assistance chiefly in education, public health, sanitation, and agriculture during 1945–50. Under the auspices of OCIAA and IIAA, USGS hydrogeologists were involved intermittently through the war and post-war years in appraisals of potential ground-water sources for public and rural water supply and for irrigation in Central America and the Antilles.

During the strife of World War II was born the concept of the United Nations (U.N.) system. Founded in 1945, the UN, during the next few years, gave birth to a large family of intergovernmental cultural, scientific, technical, and development agencies concerned with the social and economic betterment of mankind. Concurrently, the United States was expanding its bilateral program, under the direction of the ICSCC, of cultural, scientific and technical cooperation with friendly developing nations.

During the later 1940's the programs fostered by this committee were directed chiefly toward the Latin American nations, although cooperative projects in selected countries of the Eastern Hemisphere were also included, chiefly under the aegis of the Economic Cooperation Administration (ECA) during 1948–50.

The USGS participation in the activities of the UN and its specialized agencies during their formative years of the late 1940's was relatively small. In the U.S. bilateral program under the ICSCC, however, U.S. Geological Survey personnel worked actively with host-country scientists and engineers in improving their professional competence in miner-

als and water-resources investigations, and in building up the standards of geological and hydrological institutions in 12 Latin American countries as well as in Greece, Korea, Liberia, the Philippines, Saudi Arabia, and Thailand.

With the promulgation of President Truman's Point IV doctrine set forth in his Presidential Message of January 1949, the United States commitment to technical assistance, institutional building, and economic aid in the developing countries became worldwide, not only through a consolidated U.S. bilateral program but through the multilateral programs of the UN and the regional intergovernmental agencies as well. Since 1950 the U.S. bilateral program has continued through several transformations, resulting from shifts in the orientation of U.S. foreign policy. First launched in late 1950 as the Technical Cooperation Administration in the U.S. Department of State with emphasis on technical assistance and institutional development, the program was reorganized briefly in the Mutual Security Administration (MSA) during 1951–53, then in the Foreign Operations Administration (FOA) in 1953–55 and later the International Cooperation Administration (ICA) during 1955–61 under President Eisenhower. The most recent reorganization occurred in 1961 during President Kennedy's administration when ICA was transformed into the present U.S. Agency for International Development (US AID) with emphasis on capital development. Also, at this writing (1970) another reorganization is under consideration based on the recommendations of President Nixon's task force on foreign aid headed by Rudolph Peterson.

The multilateral programs of the UN family grew slowly during the 1950's but expanded rapidly in the 1960's owing to the increasingly pressing needs for social and economic assistance in the developing countries and to shifting emphasis from bilateral to multilateral assistance in many recipient countries. As of 1970, the programs of the UN family were operating at peak manpower and funding levels, whereas the U.S. bilateral program had shrunk to its lowest level since 1948. Historically, USGS participation in multilateral projects has been limited largely to short-term programing, consultative, or technical support assignments. The initiation in 1965 of the International Hydrological Decade (IHD) under UNESCO leadership marked the beginning of a sharp expansion of USGS participation in water-related symposia, working groups, seminars, conferences, and training courses sponsored by international agencies.

Under the aegis of US AID and its predecessors, the agencies of the UN family, other regional intergovernmental agencies, and direct government-to-government agreements, the USGS has actively participated through the years in overseas technical assistance in water-resource investigations and scientific exchange in hydrology, not only in the developing countries but in the developed countries as well. Between 1940 and 1970, USGS hydrogeologists, water chemists, engineers and hydrologists completed 340 short- and long-term project-oriented overseas assignments in some 80 host countries. These water scientists and engineers have worked with a wide variety of host-government organizations including geological surveys, hydrological investigative and research services and institutes, hydropower and flood-control agencies, agricultural and irrigation departments, water-development and land-reclamation authorities, and health and sanitation or public water-supply agencies. During the same time more than 428 water scientists, engineers, and technicians from 60 countries have received academic and in-service training through USGS facilities in the United States. Many of these former participants have assumed positions of leadership within their own governmental organizations. Others have gone into private enterprises for water-resources appraisal, development and management or university programs of hydrological research, education and training. Virtually all have continued professional contacts with the USGS as well as with related resources-oriented public and private organizations in the United States.

ACKNOWLEDGMENTS

Recognizing the mutual dependence of the various sectors of the USGS overseas and domestic programs, the writer, who as of 1971 was Chief of the Office of International Activities (OIA) for the water-resources program, gratefully acknowledges the inspiration, encouragement, and support he has received through the years from his U.S. Geological Survey colleagues. The writer is first constrained to mention those who have been most concerned continually or who have contributed perhaps most significantly to the objectives of USGS overseas water-resources investigations as well as to scientific and applied hydrology. Notable among the many individuals, who have been involved, are the late W. D. Johnston, Jr., the doyen of the USGS overseas program, who introduced the writer to the joys and mysteries of working in Chile, Haiti, Panamá, Thai-

land, and India; the late A. N. Sayre, who had the courage to select the writer as his assistant for his first foreign assignment in El Salvador; T. E. Eakin, who organized the Foreign Hydrology Section (the forerunner of OIA) and guided its course for the first 8 years of its history; F. E. Clarke, whose personal participation and enthusiasm for the OIA program have given it continuing impetus during the past 10 years; R. L. Nace, a founding father and mentor of the International Hydrological Decade, which has created a global view of scientific and applied hydrology; H. E. Thomas, whose philosophic insights into the water problems of the developing countries and their socio-economic implications have given substantial guidance to the OIA, particularly in the U.S. bilateral programs in Africa and western Asia; and last but not least A. I. Johnson, who through his sustained enthusiasm for foreign trainees and understanding of their needs and capabilities, has been a bastion of strength for the OIA foreign participant training program.

In the mundane sphere that relates to the genesis and nurture of overseas projects and foreign participant training, the writer is much indebted to J. A. Reinemund, Chief of the Office of International Geology, USGS, and to G. L. Schoechle, H. L. Fleming, Gertrude W. Brown, and Caroline A. Watkins of his staff for their continuing support and counsel in the operational problems of the OIA. To the loyal staff of OIA the writer must also express his gratitude for enduring support of the program. Those most recently involved have included G. W. Edelen, Jr., Assistant Chief, OIA; Rebecca A. Williams, Foreign Participant Assistant; G. M. Bradford, cartographic technician; and Mildred M. Dunbar and Virginia M. Briggs, secretary-typists.

Of course, many other individuals in the USGS, US AID, the Department of State, the United Nations agencies, and counterpart agencies in foreign governments, have supported and furthered the objectives of the USGS foreign water-resources program. Regrettably, their names are too numerous to mention, but to these anonymous ones the writer also expresses his great appreciation and gratitude, particularly for their help in the operations and program objectives of OIA.

GENERAL OBJECTIVES AND POLICY

During the past three decades through the U.S. Department of State, US AID and its predecessors, the United Nations and its specialized agencies, and the regional intergovernmental agencies, the central objectives of USGS water-resources work in the developing nations have been (1) to strengthen administrative, staff, and operational functions of counterpart governmental hydrological and water-resources agencies, and (2) to improve the skills and capabilities of host-country scientific, engineering, and technical personnel so that they may better direct and guide the investigation, development, and management of water resources—all in support of advancing national economies. With not only the developed nations but also with many developing nations, USGS objectives have been largely directed toward (1) exchange of research specialists and publications in the sharing of advances in hydrological knowledge and methodology, and (2) participation in mutually beneficial international organizations, symposia, conferences, seminars and special programs dedicated to various aspects of scientific and applied hydrology.

In the furtherance of these objectives the USGS (1) has trained foreign water scientists, engineers, and technicians either in USGS domestic field offices and laboratories or by on-the-job training from USGS water scientists and engineers on overseas assignment, (2) has provided hydrological experts to guide, conduct, and participate in international symposia and seminars in scientific and applied hydrology, (3) has exchanged research specialists and shared knowledge in scientific and applied hydrology, (4) has provided direct advisory services through overseas assignments of USGS personnel for the establishment or improvement of operating host-country hydrological and water-resources organizations and institutions, (5) has participated jointly with host-country water scientists and engineers in field and laboratory projects designed to appraise, explore, and evaluate indigenous water resources and water problems, and finally (6) has advised, supported, encouraged, and instructed in institutions and professional societies dedicated to programs of hydrological education and research.

Owing to the complexity and diversity of the international activities of the USGS, no comprehensive statement of policy has been formulated that adequately covers all phases of these activities. An interim statement, however, approved by the Director of the USGS in April 1963 is quoted below:

> In accepting proposals for activities in foreign areas, as well as in domestic work for other agencies, the Survey feels that among the advantages to the agency requesting the work is the ability of the Survey to apply world-wide professional perspective, to select appropriate personnel from its large reservoir of trained specialists, to make available appropriate equipment from its rather complete stock, and to be able to

support its work with such specialized professional and technical services as may be required.

The Survey is fully cognizant of the rapidly expanding responsibilities of the United States toward the development of foreign areas. This responsibility is not only toward a better economic level for the people of those areas but is a realistic effort toward obtaining raw materials and products for use by this country and other countries of the free world. Although limited by an insufficient number of trained personnel not already assigned to high-priority projects, the Survey recognizes the need for expanding part of its efforts in foreign areas and in training foreign nationals and willingly accepts appropriate responsibilities in such activities. Because of competence in its special fields, the Survey must reserve the right to appraise carefully the requirements and special advantages of foreign projects in order to balance them against domestic activity and thereby to determine relative priorities.

With respect to such work undertaken, it is Survey policy to assign experienced personnel from the domestic program on a rotation basis. In instances where particular specialists are needed which are temporarily unavailable from domestic rolls, the Survey engages, on excepted appointment, specialists from universities or private industry. Paramount to all projects, however, is the principle of transferring philosophically, industrially, and scientifically the concept of central government geological services to the public and national welfare.

LEGISLATIVE AUTHORITY

As the USGS is a domestic agency, its activities as related to surveys, investigations, and research outside the United States must be covered by special legislative authorization. Attendance at international scientific meetings is permitted under the Training Act (Chapter 41, Title 5, U.S.C.), and conferring with individuals relative to domestic program activities is permitted under the Organic Act of the USGS; all other USGS activities abroad are permitted only as a result of other enabling legislation which is described below. Under the Organic Act of March 3, 1879 (20 Stat. 394; 43 U.S.C. 31), of the USGS and in pursuance of later specific enactments, authorized activities of the USGS are restricted territorially to the "national domain," United States territories and possessions, Antarctica, and the Trust Territories of the Pacific. The Organic Act, in effect, was modified August 23, 1958, by Public Law 85–743 and again on September 5, 1962, by Public Law 87–626. These laws extend certain authority of the Secretary of the Interior, exercised through the USGS, to areas outside the national domain.

Public Law 80–402, 80th Congress, 2d Session.—United States Information and Educational Exchange Act of 1948:

A government agency, at the request of the Secretary of State, may perform such technical or other services as such agency may be competent to render for the government of another country desirous of obtaining such services *(Section 402)*. Also this law permits the sale of educational and informational material and specialized scientific equipment for dissemination to, or use by, peoples of foreign countries *(Section 801 (2))*.

This law permits the USGS, upon approval of the Department of State, to enter into an agreement with a foreign government for specific services. This requires an exchange of diplomatic notes between the Department of State and the foreign government. The foreign government advances to the Department of State, U.S. dollars to cover the cost of the services to be rendered. These funds are transferred to the USGS where they are utilized to make disbursements.

Public Law 85–743.—Antarctica; Trust Territory of Pacific Islands:

This law of August 23, 1958, modified the Organic Act (43 U.S.C. 31) and provides for the extension of certain authorized functions of the Secretary of the Interior to areas other than the United States, its Territories and possessions. The authority of the Secretary of the Interior to perform surveys, investigations, and research in geology, biology, minerals, and water resources, and mapping was extended to include Antarctica and the Trust Territory of the Pacific Islands.

Public Law 85–795.—Federal Employees International Organization Service Act of 1958:

The law authorizes the USGS to detail or transfer (for a period not in excess of 3 years) an employee to an international organization. A detail may be made without reimbursement, with partial reimbursement, or with full reimbursement to the USGS. The employee on detail continues to receive compensation, allowances, and benefits directly from the USGS, with the international organization reimbursing the USGS, either wholly or partly, as outlined above. However, it also permits the employee to receive directly from the international organization payment or reimbursement for allowances or ex-

penses incurred in the performance of duties required by detail.

Under this law (for details) the USGS does not retain technical supervision of the employee, but he does remain on the rolls of the USGS.

Public Law 87–195.—Foreign Assistance Act of 1961 (AID):

This law, in effect, supersedes Public Law 535 and supplements the Mutual Security Act of 1954 as amended, which governed USGS functions under the aegis of US ICA.

Section 625 (d) (1).—This section authorizes the employment or assignment of personnel to perform functions under the Foreign Assistance Act of 1961 outside of the United States by any agency of the U.S. Government. To perform such functions the USGS enters into a Participating Agency Service Agreement (PASA) with the U.S. Agency for International Development (AID) covering the services to be rendered. A General Agreement under which the participating agency service agreements are executed was signed by the Department of the Interior and the Foreign Operations Administration (FOA) in March 1954, and a new and updated agreement was signed by the Agency for International Development and the Department of the Interior on April 5, 1967. AID supplies funds to cover the cost of each agreement.

Section 607.—This section of the Foreign Assistance Act of 1961 authorizes the U.S. Government agencies to furnish services and commodities on an advance of funds or reimbursement basis to friendly countries, international organizations, the American Red Cross, and voluntary nonprofit agencies registered with and approved by the Advisory Committee on Voluntary Foreign Aid. This section requires a determination by the Administrator of AID that the requested services would be in furtherance of the Foreign Assistance Act of 1961 before the USGS can deal directly with the requesting country or international organization. The USGS retains technical supervision over the employees assigned to the project.

Public Law 87–256.—Mutual Educational and Cultural Exchange Act of 1961:

This public law provides for improvement and strengthening of the international relations of the United States by promoting better mutual understanding among the peoples of the world through educational and cultural exchanges.

Public Law 87–626.—87th Congress, Scientific Examination Authority, Extension:

This law of September 5, 1962, modified the Organic Act (43 U.S.C. 31) of March 3, 1879, and is worded as follows: "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, that the authority of the Secretary of the Interior, exercised through the Geological Survey of the Department of the Interior, to examine the geological structure, mineral resources, and products of the national domain is hereby expanded to authorize such examinations outside the national domain where determined by the Secretary to be in the national interest."

USGS participation in overseas activities related to the International Hydrological Decade program and to independent investigations and research in extension of domestic research are authorized under Public Law 87–626.

Public Law 91–175.—Foreign Assistance Act of 1969:

This law of December 30, 1969, contains amendments to Public Law 85–795. These include: increase of the allowable period of detail or transfer to an international organization from 3 to 5 years; option by employee to select the retirement system of either his domestic agency or the international agency to which he transfers; and provision for payment on re-employment of differences in pay, allowances, post differential and other monetary benefits that result from the transfer or detail. The detail or transfer also may be extended beyond 5 years under special circumstances where the Secretary of State determines it to be in the national interest.

FUNDING

Historically, the bulk of the U.S. dollar funds required to support USGS overseas personnel assignments, foreign participant training in the United States, purchase of scientific and technical equipment, and related technical and administrative support in the United States have been provided by the US AID and its predecessor agencies. Limited dollar funds, however, have been received directly from foreign governments and from United Nations and regional intergovernmental agencies, chiefly in reimbursement of costs for short-term details to projects and for participant training. Prior to fiscal year 1952 no funds were received directly by the water-resources program of the USGS, as all USGS technical assistance activities were then handled in the USGS Branch of Foreign Geology (now Office of

International Geology). After establishment of the USGS Foreign Hydrology Section (now Office of International Activities) in fiscal year 1952, transferred funds were assigned directly to USGS/OIA.

As shown in figure 1, the USGS overseas water-resources program built up rapidly in the early 1950's but stabilized at an annual level of about $450,000 during the latter half of the decade. A second period of active program growth occurred in 1960–66, but this peaked in 1966 when the funding level reached $1,400,000. Since 1966 the funding has declined to a level of $479,000 in 1971, which is comparable with that of the late 1950's. Over the 21-year term shown in figure 1 the average annual budget has been about $525,000 with a total dollar input of about $11,010,000 to the USGS foreign program in water-resources investigations.

The fluctuations in funding reflect not only the size and scope of the USGS overseas water-resources program but also year-to-year gross variations in U.S. Congressional appropriations for foreign aid and the distribution of these funds among regional bureaus of US AID (fig. 2). The marked decline in funding for fiscal year 1970, however, resulted both from limitations imposed by personnel ceilings, which have inhibited initiation of new overseas projects, as well as from sharp reductions in U.S. foreign aid, which in 1971 was at its lowest level since 1948.

The funds shown in figure 1 represent only the U.S. dollar inputs into USGS international water-resources activities. Indeed, total costs in country projects may be several times greater than the amounts indicated in figure 1. Thus, costs of housing, post allowances, in-country travel, and other miscellaneous expenses are paid directly to USGS overseas water-resources personnel by US AID country missions or other sponsoring agencies, generally in counterpart currencies. Also, vehicles and field support equipment are commonly purchased through channels other than the USGS. Other in-country costs such as office and laboratory space and equipment and salaries of host-country support personnel also are not reflected in USGS dollar budgets.

Funds allocated to the USGS for participation in the program of the International Hydrological Decade are not included in figure 1. An expanded program for USGS water-resources participation in the IHD was included in fiscal year 1967, 1968, 1969, and 1970 budget presentations of the USGS but has continued to be approved by the Congress at approximately the same annual level. The funds allocated

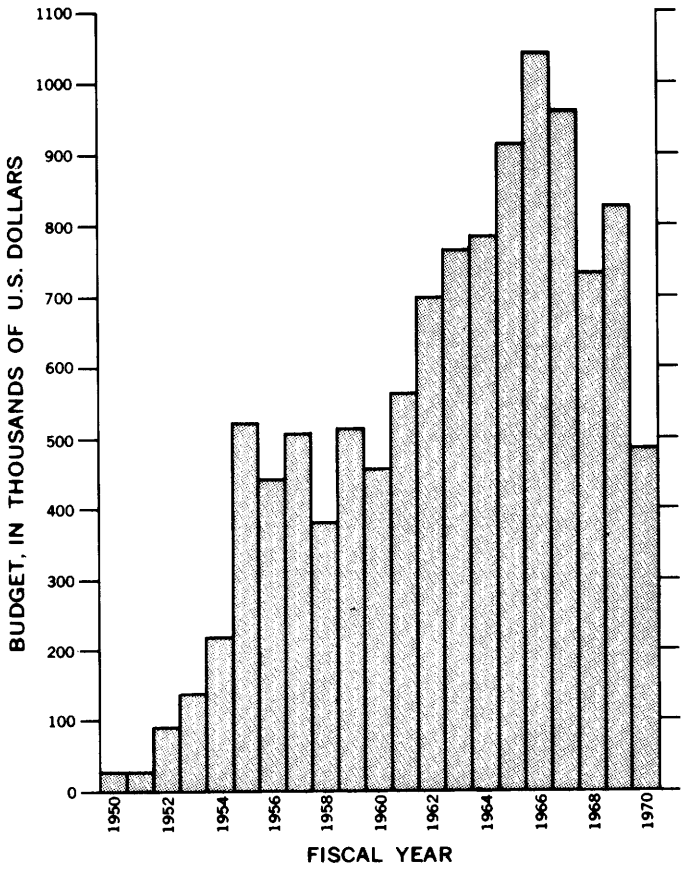

FIGURE 1.—Distribution of USGS water-resources foreign program funds by fiscal years, 1950–70.

to USGS for the IHD program by fiscal years since 1965 are as follows:

1965	$2,500	1969	$153,500
1966	$178,000	1970	$158,400
1967	$150,000	1971	$170,400
1968	$150,000		

The bulk of these funds have been expended for USGS domestic water-resources projects identified with the objectives of the IHD. A part of the funds, however, have been used for international travel related to technical support of UNESCO/IHD Secretariat activities and of the participating country programs.

As a result of the U.S. balance of payments deficits and the increasing will of many developing countries to "pay their own way," there has been an increase since about 1965 in the projects being conducted by the USGS which are financed from funds advanced by the host governments. Thus far such projects, except for the USGS minerals investigations program in Saudi Arabia, have been of short duration (for example, Kuwait, 1 month; Libya, 1 month; Argentina, 1 month; Chile, 6 months; Vene-

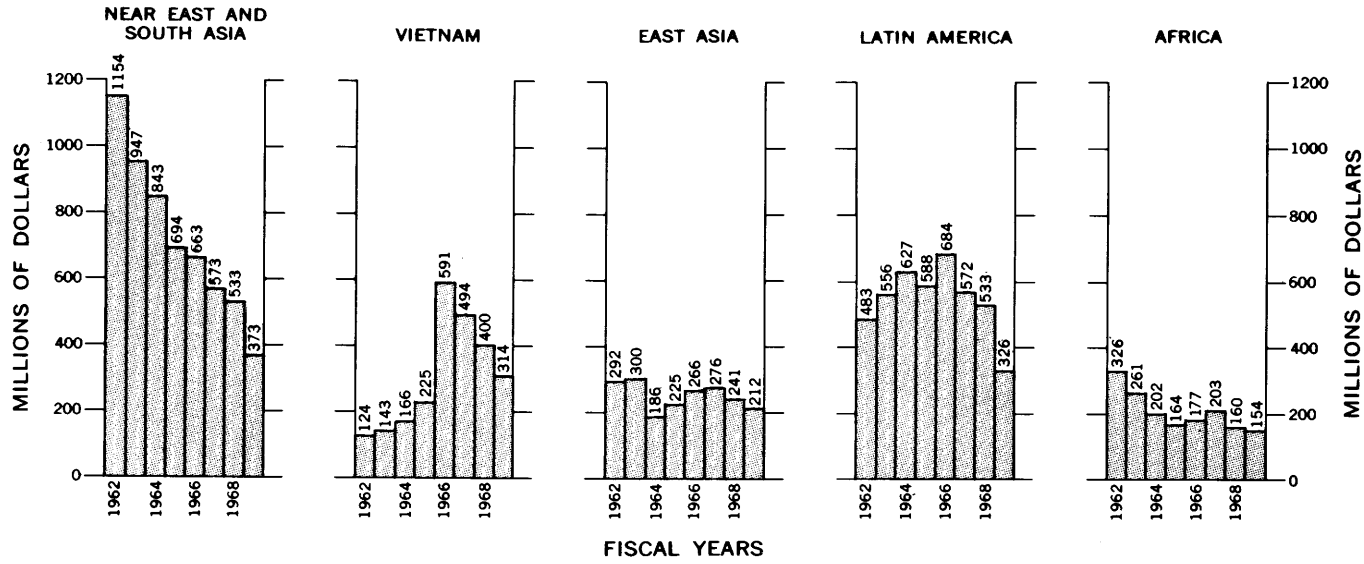

FIGURE 2.—Distribution of aid, in millions of dollars, among regional bureaus of the U.S. Agency for International Development during 1962–69. (From US AID "Front Lines.")

zuela, 1 month). It is expected, however, that such projects may increase as AID grant and loan projects are reduced.

HEADQUARTERS TECHNICAL AND ADMINISTRATIVE SUPPORT

The Office of International Activities for the USGS water-resources program had as its chief functions in 1971 the direction, guidance, and logistic support of USGS water-resources country projects under the U.S. bilateral program and foreign participant training in the United States. Beginning as a one-man effort in 1952, the OIA, formerly Foreign Hydrology Section, has since grown to a staff of two professionals, a foreign participant assistant, a cartographic technician, two secretaries, and a part-time editorial clerk.

The OIA has served as a connecting link between the domestic and overseas water-resources programs of the USGS; scheduled the bulk of the intern training as well as the study programs of visiting foreign water scientists and engineers in the USGS domestic water-resources offices; designed, negotiated, and implemented new country projects and provides technical backstopping to USGS water-resources personnel in active projects of the U.S. bilateral program; assisted from time to time in the identification and scheduling of appropriate USGS water-resources personnel for assignments to projects of the United Nations and regional intergovernmental agencies; regularly provided technical logistic support in the USA in the procurement of hydrologic equipment and supplies for overseas USGS water-resources projects and from time to time projects of foreign governments and UN agencies; reviewed and processed technical and administrative reports resulting from USGS country projects in water resources; and occasionally scheduled field reviews by USGS headquarters personnel of country projects. Prior to 1971 the OIA had not been directly involved with USGS participation in activities related to nongovernmental organizations, with hydrologic investigations abroad in extension of domestic research, nor with the UNESCO/IHD program.

Since 1965 the Chief Hydrologist's staff in the USGS under the direction of R. L. Nace has provided guidance and technical backstopping for domestic and overseas activities of the IHD.

REPORTS AND PUBLICATIONS

The diversity of USGS overseas water-resources activities results in a variety of reporting requirements. Technical and scientific reporting on water-resources investigations has not always been of priority concern in in-country projects of the U.S. bilateral program, but has been an important secondary product resulting from the primary objective of institutional development. Such reporting is, however, frequently paramount in respect of participation by USGS personnel in water-oriented international conferences, symposia, seminars, and workshops sponsored by United Nations and regional inter-governmental agencies, nongovernmental international organizations, and USGS water-resources investigations and research abroad in extension of domestic research.

Administrative reporting has been a dominant requirement for intra-agency as well as inter-agency communication in all overseas projects in the U.S. bilateral program and, indeed, has high priority in most multilateral agency activities. Such administrative reports include, among others, proposals for design and content of new projects, progress reports, project review and evaluation reports, individual end-of-tour reports, and reports recounting the history and results of completed projects.

Most reports in the administrative category are considered internal operational documents and are not available to the general public. Technical and scientific reports, however, are generally available to the public and include formal publications and open-file reports of the U.S. Geological Survey; articles published in technical and scientific journals, both in the United States and abroad; and formal publications and open-file reports of foreign governmental and international agencies. Between 1940 and 1970, for example, some 336 technical and scientific reports resulted from overseas water-resources projects in the U.S. bilateral program and were made available to the public.

Formal publications and open-file reports of the USGS and of foreign governmental agencies that have resulted from USGS water-resources projects in the U.S. bilateral program are listed with country descriptions in this report. References relating to USGS participation in water-resources projects of the United Nations and regional intergovernmental agencies, in the UNESCO/IHD program, governmental scientific and technical exchange and cooperation, nongovernmental international scientific organizations, and investigations and research abroad in extension of domestic research are not generally listed in this report.

FOREIGN PARTICIPANT EDUCATION AND TRAINING

During the past 30 years, well-trained and experienced scientists, engineers, and technicians have generally been in short supply in the developing countries; consequently, education and training of personnel is essential in any effort to help these countries attain higher levels of economic and social viability. As the principal agency in the U.S. Government concerned with geologic, hydrologic, and cartographic surveys and research, the USGS has accepted responsibility to help train scientific and technical personnel and encourage the growth of agencies with comparable functions in the developing countries. During the past three decades the USGS has provided or arranged for the training and education in the United States for some 1,100 participants from 79 countries in geology, geophysics, geochemistry, hydrology, hydrogeology, cartography, scientific and technical publication, administration, and related fields. The bulk (perhaps 90 percent) of the participant training has been sponsored and financed by the U.S. Agency for International Development or its predecessor agencies. The USGS, however, has also provided training for a substantial number of participants sponsored by agencies of the UN family as well as regional intergovernmental agencies and also by direct government-to-government arrangements through the U.S. Department of State.

USGS assistance in the education and training of foreign nationals has been carried out in three ways: (1) on-the-job training under the guidance of USGS specialists assigned to technical assistance projects in other countries, (2) in-service (intern) training of individual participants assigned to headquarters, field projects, or laboratories in the USGS domestic program, and (3) guidance or assistance by the USGS foreign participant program staff in selecting appropriate curricula and universities for academic studies in science and engineering by participants. Depending on the needs of the participant, individual programs have been designed either for intern training or for academic studies; however, many programs in recent years have been combinations of both. Also, intern training available at USGS domestic facilities has been commonly coordinated or augmented with training at other U.S. Federal agency facilities and from time to time with private companies, so as to give the participant a spectrum appropriate to his individual needs.

The USGS has been involved in foreign participant training in the water sciences and engineering since the early 1940's, but the level of activity was relatively low during the 1940's and early 1950's. Beginning in 1956, however, activity sharply increased to a high in 1962. The total level in 1971, however, promises to exceed that of 1962. The number of participants trained per year during 1956–70 ranged from 26 in 1956 to 57 in 1962. The average number trained during the 1960's was 47 per year at a relatively constant rate.

Table 1 shows the numbers of foreign participants provided intern and academic training and education programs through USGS domestic water-resources facilities and their countries of origin for 1950–70. As of the end of 1970 and since 1940 the USGS has provided training in the United States for 428 for-

TABLE 1.—*Countries for which participant education and training has been provided in the United States through USGS domestic water-resources facilities with numbers of participants from each country, 1950–70*

North and South America		Europe		Africa		Asia	
Argentina	6	France	1	Congo (Kinshasa)	4	Afghanistan	13
Bolivia	2	Germany	1	Egypt (UAR)	17	Burma	1
Brazil	37	Great Britain	1	Ethiopia	3	Ceylon	1
Canada	1	Greece	7	Ghana	3	India	29
Chile	15	Iceland	2	Kenya	2	Indonesia	7
Colombia	3	Poland	2	Liberia	1	Iran	5
Costa Rica	2	Spain	5	Sudan	11	Iraq	4
Cuba	1	Yugoslavia	2	Tanzania	1	Israel	9
Guatemala	1	Total	21	Togo	1	Japan	7
Guyana	5			Uganda	1	Jordan	19
Haiti	2			Union of South Africa	1	Korea	8
Jamaica	2			Total	45	Lebanon	1
Mexico	3					Libya	4
Panamá	1	Australia	1			Nepal	16
Peru	2					Pakistan	46
St. Lucia, W.I.	1					Philippines	28
Uruguay	1					China (Taiwan)	16
Venezuela	8					Saudi Arabia	1
Total	93					Syria	1
						Thailand	13
						Turkey	38
						Vietnam	1
						Total	268

mally scheduled and funded participants from 60 different countries. The duration of individual programs ranged from a few days to as much as a year, but most of the programs were in the range of 2 to 6 months. In addition, informal scientific and technical consultation has been provided by USGS water-resources specialists in the United States to an even greater number of unscheduled or casual foreign visitors. It is interesting to note from table 1 that the countries providing the largest number of participants correspond to those where the USGS has had intensive involvements in water-resources projects in the U.S. bilateral technical assistance program—notably Brazil and Chile in Latin America; Egypt and Sudan in Africa; and Afghanistan, India, Jordan, Nepal, Pakistan, Philippines, Thailand, and Turkey in Asia.

Most in-service training in USGS water-resources facilities during the past 30 years has been directed to the scientific and technical requirements of foreign geologists, engineers, chemists, and professionals in various aspects of the basic disciplines of general hydrology, surface-water hydrology, groundwater hydrology, and hydrochemistry. From time to time, however, training has been provided for participants of supervisory grade in administration, management, programing and planning techniques necessary to the operation of water-resources and hydrological organizations that function at national, regional, or provincial levels. The USGS has also provided group training in hydrology for foreign participants on several occasions during the past 10 years, chiefly through its Water Resources Training Course in Denver, Colo.

PROCUREMENT OF HYDROLOGIC EQUIPMENT FOR OVERSEAS PROJECTS

One of the more important functions of the OIA is provision of technical logistic support in the USA for procurement of special hydrological equipment and related supplies needed in overseas USGS water-resources projects and occasionally in hydrological investigations projects of foreign governments and UN agencies. OIA, however, does not normally become involved in common commodity procurement, which is regularly handled by the General Services Administration (GSA).

The bulk of the funds for hydrological equipment purchases in USA have been provided to OIA from US AID and its predecessor agencies. Some dollar credits, however, also have been received from UN agencies and from foreign governments for purchases of hydrological equipment. During the years 1964–69, hydrological equipment purchases for US AID-sponsored projects averaged about $70,000 per year with a peak of about $100,000 in 1966. The distribution of dollar amounts for hydrological equipment purchases for individual country projects during this 5-year period is shown below:

Brazil	$133,000	Egypt	$38,420
Afghanistan	82,880	Ethiopia	12,020
Nigeria	53,040	Jordan	10,100
Thailand (Mekong Committee)	40,000	Kenya	4,300

In addition intermittent purchases of hydrologic equipment for foreign governments and UN agencies has been in the range of about $5,000 to $10,000 a year.

INTERNATIONAL ACTIVITIES

From the foregoing discussions it is evident that the USGS activities in other countries do not constitute and cannot be a tightly integrated program, owing to the diversity of requirements of the sponsoring agencies, through which the USGS must operate. These activities can be grouped, however, in five general categories as follows: bilateral activities, multilateral activities, governmental scientific and technical exchange and cooperation, cooperation with nongovernmental international organizations, and investigations and research abroad in extension of domestic projects. Among these categories, technical assistance under the U.S. bilateral program and related foreign participant training constituted as of 1971 the bulk of USGS water-oriented overseas activity. During the past 10 years, however, there has been a marked increase in the level of USGS water-resources activity with multilateral agencies and nongovernmental international organizations. In other categories listed above, USGS water-resources activity also has been highly significant, scientifically and technically, but not large in terms of funding or intensity of involvement. USGS international water-resources activities during 1940–70 in these five categories in various countries and with various sponsoring agencies are described in the following sections but with larger emphasis on projects in the U.S. bilateral program.

BILATERAL ACTIVITIES

Most USGS long-term overseas water-resources projects and individual assignments prior to 1970 can be grouped in the U.S. bilateral program, sponsored by US AID and its predecessors and also by direct arrangements through the U.S. Department of State with foreign governments. USGS international water-resources activities in this category are authorized under terms of Public Laws 80–402 and 87–195.

Between 1940 and 1970, some 253 individual assignments, ranging from a few days to several years duration, were completed on short- and long-term projects in 46 countries (table 2) in bilateral activities. Regionally, the bulk of USGS water-resources activity in the U.S. bilateral program has been concentrated in the countries of the Near East and South Asia, where high priority has been given during the past 20 years to water-resources development and related institutional building. Generally, a somewhat lower level of activity has prevailed in Africa—with the notable exceptions of the United Arab Republic (Egypt), Libya, and Nigeria. In Latin America, USGS water-resources activities in bilateral assistance have been concentrated very largely in Brazil and somewhat less in Chile (table 2). USGS water-resources participation in bilateral activities in various regions of the world and in individual countries is described in the following sections.

TABLE 2.—*Countries to which the USGS water resources personnel have been assigned under U.S. bilateral assistance with numbers of assignments, and years during which projects were active in each country, 1940–70*

Latin America	Europe
Argentina, 3—1959; 1962	Belgium, 1—1960–62
Bahama Islands, 5—1953; 1954–55	Greece, 2—1948–50; 1966
Brazil, 26—1953; 1960; [1] 1961–75	Netherlands, 1—1958–59
Costa Rica, 1—1964	Portugal (Azores), 1—1950
Chile, 8—1945–48; 1950; 1955–62; 1969; 1970	Total number of assignments ------- 5
El Salvador, 2—1943–44	
Guyana, 1—1957	
Haiti, 2—1948–49; 1959	
Nicaragua, 3—1943; 1956	
Panamá, 4—1949; 1962; 1964–65	
Peru, 1—1955–59	
Total number of assignments ------ 56	

Africa	Asia
Chad, 1—1962	Afghanistan, 10—1952–69; [1]1971
Congo (Kinshasa), 1—1968	Cambodia, 3—1958; 1959; 1963
Egypt, 26—1953–56; 1959–67	India, 10—1950; 1951–57; 1966; 1968; 1970; [1]1971–74
Ethiopia, 4—1966; [1]1968–73	Iran, 6—1952; 1953–63; 1968
Ghana, 1—1964	Iraq, 1—1958
Kenya, 5—1967; [1]1968–75	Israel, 1—1962
Libya, 13—1952–64; 1967; 1969; 1970	Japan, 2—1951; 1964
Nigeria, 14—1961; 1962–1968	Jordan, 4—1958; 1959–60; 1962; 1966
Rhodesia, 1—1959	Korea, 5—1963; 1964; 1965; 1966–71
Senegal, 1—1965	Kuwait, 2—1947; 1965
Sudan, 2—1955; 1961–63	Nepal, 9—1961; [1]1962–74
Tunisia, 3—1958; 1959–65	Pakistan, 27—[1]1953–71
Zambia, 1—1968–1970	Philippines, 5—1955; 1957–61; 1967
Total number of assignments ---- 73	Saudi Arabia, 2—1945–46; 1952–53
Australia, 7—1963; 1966; 1967; 1969	Thailand, 8—1954; 1961; 1970
	Turkey, 8—1957; 1958–62; 1963–65; 1966; 1967
	Vietnam, 9—1964–66; 1968–70
	Total number of assignments --- 112

[1] For currently (1970) active projects final year indicated is that of planned project termination.

LATIN AMERICA

Although the USGS has a record of participation in water-resources projects of bilateral assistance in Latin America (fig. 3) that dates back before the beginning of this century, the overall level of involvement, regionally, has been somewhat less than in Africa and only about half that in Asia (table 2). Nevertheless, projects have been undertaken and completed in 12 Latin American countries since 1940 through 63 individual assignments, among which the preponderance have been in Brazil, virtually all since 1960.

FIGURE 3.—Index map of Latin America showing those countries (shaded) in which the U.S. Geological Survey has been active in water-resources projects of the U.S. bilateral assistance, 1940–70.

ARGENTINA

Argentina, land of the vast and fertile pampa, the gaucho, and some of the world's finest beef cattle, lies in southern South America and is the second largest country on the continent. Beginning its early history as a Spanish colony, Argentina gained its independence in 1816 under the leadership of General José de San Martín, the national hero. Despite its impressive human and natural resources, Argentina has experienced considerable political turbulence and economic difficulty since World War II. The United States, as one of Argentina's principle trading partners and in the interest of strengthening the economy, provided some $157 million in bilateral economic aid and technical assistance between 1957 and 1968. The USGS participated briefly in the water-resources sector of the bilateral program first in 1959 and again in 1962.

As a result of a request in early 1959 from the Argentine Dirección Nacional de Geología y Minería (DNGM) to US ICA/Buenos Aires, S. L. Schoff, USGS hydrogeologist, was assigned for a 3-month tour (July–October 1959) to evaluate the national ground-water investigations program of DNGM's Hydrogeologic Service and to recommend ways and means of improving collection and recording of data; observation well networks; areal geologic and hydrologic studies; hydraulic, geochemical and chemical studies; technical reporting; and hydrologic and geologic equipment. His report of April 1960 evaluated these needs and presented recommendations for their fulfillment. Also during his tour Mr. Schoff participated with Argentina hydrogeologists of the DNGM in reconnaissance areal ground-water studies in the Pampa del Castillo and Cañadón de El Trebol, 40 to 60 km (kilometres) west of Comodoro Rivadavia; in the Bahía Blanca area; and in the Santa María Valley, Provincia de Catamarca of northwestern Argentina. The results of these studies were released in three open-file or published reports.

For several years, ground-water users in the La Plata area along the southern margin of the Rio de La Plata estuary had been coping with declining water levels in supply wells and concurrent deterioration in chemical quality, owing to salt-water encroachment. Early in 1962 the Laboratorio de Ensayo de Materiales e Investigaciónes Tecnológicas (LEMIT) through the Buenos Aires Provincial Comision de Investigaciónes Científicas (CIC) at La Plata requested assistance from US AID/Buenos Aires for the short-term services of a U.S. specialist to formulate a ground-water program in this area. W. W. Doyel, USGS hydrogeologist, was assigned to work with LEMIT for a 6-weeks tour (July–August 1962). Based on recommendations in Mr. Doyel's administrative report of August 1962, a 4-year project designated "Ground Water in the Northeast of Buenos Aires Province" was begun in February 1966 and has since been carried to a successful conclusion. The findings of this investigation, involving the services of 10 full-time LEMIT geologists, engineers and technicians, provide a base for planning the rational utilization and management of the ground-water resources in a 20,000-km^2 (square kilometre) area in the commercial and industrial heartland of Argentina.

Between 1962 and 1971, the USGS also provided short-term specialists on several occasions, both in surface-water and ground-water investigations, to United Nations and Organization of American States (OAS) projects in Argentina. These activities are described under "Multilateral Activities."

References

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BAHAMA ISLANDS

The archipelago of the Bahamas, containing 700 low-lying islands and 2,000 rocks and keys, stretches 800 kilometres southeastward from Florida. From its former status as a British colony, the Bahamas became a self-governing commonwealth in January 1964. Since World War II the U.S. has maintained several installations in the islands for which the USGS has provided technical consultation in water-supply problems. These activities are described below.

Before 1953 the U.S. Air Force had depended almost entirely on paved rainfall-catchments to supply fresh-water requirements for its installations on the islands of Grand Bahama, Eleuthra, San Salvador,

Mayaguana, and Grand Turk in the Bahama Group. Owing to increasing demands for water at these installations, the U.S. Air Force in early 1953 requested the USGS to study fresh ground-water bodies on these islands with a view to determining their adequacy for supplementing supplies from the catchments.

In a first preliminary study of San Salvador and Mayaguana in August 1953, N. D. Hoy, USGS hydrogeologist, obtained basic data on existing ground-water supplies and selected areas for development of additional supplies. M. C. Schroeder, USGS hydrologist, made a second reconnaissance in December 1953 and directed drilling of shallow test holes on San Salvador and Mayaguana to determine permeabilities of the water-bearing coralline sand and limestone and ground-water quality near existing supply wells. A third reconnaissance was made by N. D. Hoy and Howard Klein in January 1954 of all five islands to determine ground-water quality near U.S. Air Force installations, to choose areas likely to yield fresh ground-water supplies and to select sites for exploratory drilling. Between July 1954 and April 1955, 91 exploratory wells were put down on the 5 islands for water and formation sampling and aquifer testing.

The fresh ground-water lenses on the islands generally range from 2 to 7 m (metres) thick, but on Grand Bahama, which has a relatively high rainfall, the lens is 15 m or more thick. Also the fresh-water lenses expand and contract seasonally with the flux of recharge from rainfall and subsequent dissipation of head by discharge. In their report of January 1958, Messrs. Klein, Hoy, and Sherwood recommended development of the fresh-water lenses by skimming from shallow wells with a rigorous program of water-level and salinity observations to avoid overpumping and resultant salt-water contamination.

Reference

Klein, Howard, Hoy, N. D., and Sherwood, C. B., 1958, Geology and ground-water resources in the vicinity of the Auxiliary Air Force Bases, British West Indies: U.S. Geol. Survey open-file rept., 142 p., 49 figs.

BRAZIL

Although Brazil has abundant natural resources, it has had to face tremendous social and economic problems in attempting to find, evaluate, and develop these resources. In recent years, considerable progress has been made in solving these social and economic problems, and Brazil's efforts to explore and develop its resources have greatly increased. The USGS has been privileged to cooperate with Brazilian resources agencies in these efforts, as part of the U.S. assistance program in Brazil. USGS technical assistance in mineral and geological investigations with Brazilian agencies has been continuous since the early 1940's. USGS participation in the water-resources sector of the U.S. bilateral program in Brazil is more recent, first in 1953, again in 1960 and then continuously between 1961 and 1971. The scope and nature of this work are described in following sections.

Possibly the earliest recorded USGS work on water-resources investigations in Brazil resulted from a request in 1910 to the U.S. Department of State from the Government of Brazil for advisory assistance in the establishment of a ground-water investigations section in the National Department of Mineral Production (DNPM). G. A. Waring, USGS hydrogeologist, was assigned to the work and, beginning in September 1910, spent several weeks in field reconnaissance in northeast Brazil and in office consultations in Rio de Janeiro, during which time he formulated a proposed program for DNPM. This program apparently was never implemented owing to lack of funds and organizational direction.

Dewatering and Mine Drainage in Open-Cast Mining of Phosphate Deposits at Olinda near Recife, Pernambuco, 1953

The first USGS involvement in areal water-resources studies in Brazil was a short-term investigation of ground-water problems related to the development of the phosphate deposits at Olinda, near Recife in the State of Pernambuco. This study sponsored by the US TCA at the request of the National Department of Mineral Production (DNPM) was made by G. A. Rynearson and E. W. Reed of the USGS during April and May 1953. The study included a detailed description of the stratigraphic and mineralogic characteristics of the phosphate deposits and an analysis of the dewatering and mine-drainage problems that would be related to open-cast mining of the deposits.

Appraisal of the Status of Ground Water Investigations and Development in Brazil, 1960

The first appraisal of the status of investigations and development of Brazil's ground-water resources was made for US ICA by Robert Schneider, USGS hydrogeologist, in early 1960. During his 3-month stay (February–May 1960) in Brazil, Mr. Schneider interviewed key officials in Federal, State, and local governmental agencies as well as private companies and individuals with interest or concern in ground-

water problems. Among those Federal agencies contacted were the Serviço Especial de Saúde Pública (SESP), the Departamento Nacional de Produção Mineral (DNPM), the Departamento Nacional de Obras Contra as Sêcas (DNOCS), the Departamento Nacional de Obras de Saneamento (DNOS), the Comissão do Vale do São Francisco (CVSF), and the Superintendência do Desenvolvimento do Nordeste (SUDENE). All these agencies have some degree of involvement in ground-water investigation and development.

Mr. Schneider also identified the larger ground-water provinces of Brazil and their general development potential for irrigation, public, industrial, and rural water supply. In his report of June 1960, he pointed out the particular need for systematic ground-water investigations coupled with development in northeast Brazil, in the São Paulo industrial area, of alluvial aquifers in the large river valleys and of general hydrologic networks for collection of essential basic data.

Hydrogeologic Education and Training in the CAGE Project, 1961–64, and Hydrogeologic Reconnaissance of Northeast Brazil, 1962

During July 1961 to January 1964, D. J. Cederstrom, USGS hydrogeologist, was assigned to the CAGE (Campanha para a Formacão de Geologos or Geologic Training Campaign) educational project sponsored by DNPM under US AID auspices to introduce the study of ground-water geology and hydrology in Brazil on a formal basis. Classes in these topics were held in the DNPM headquarters building in Rio de Janeiro, along with other classes in several other fields of geology. The first school year, three lectures a week were given to a class of seniors. In the following school year one course for 21 seniors was held, and in the next school year a course for junior and another for senior students was given. Enrollment averaged about 17 students in each class. Lectures were given in Portuguese.

In the latter part of the second year, the continuity of the courses was interrupted, when Mr. Cederstrom suffered an accidental fracture of his hip. During his convalescence he prepared a general text, "Agua Subterrânea," in the Portuguese language that was later published by US AID/Rio de Janeiro. This text has since received wide circulation in university and government circles throughout Brazil and elsewhere in Latin America as a basic reference on ground-water geology and hydrology.

In January–February 1962, Mr. Cederstrom made an 8,700–km reconnaissance of northeast Brazil to observe geohydrologic conditions and related socio-economic problems in the Drought Polygon of northeast Brazil. In his report of June 1962, Mr. Cederstrom pointed out the development potential of ground water in the alluvial deposits of the larger stream valleys; the possible uses of rainwater catchments (cisterns) for domestic water supply in rural areas; and the needs for continuing maintenance and proper management of earthen surface-water impoundments (açudes) and drilled wells constructed by DNOCS and SUDENE. He also suggested ways of improving the prevailing poor chemical quality of the native ground water by in-tandem use of dug wells, cisterns, and spreader dikes. Mr. Cederstrom's recommendations were subsequently included in ground-water investigations in northeast Brazil as described in the following section of this report.

Water Resources Investigations in Northeast Brazil, 1962, 1963–68

Water-resources investigations with USGS participation were begun in June 1962 in the Drought Polygon of northeast Brazil and adjacent areas, as part of a general US AID-sponsored development program. US AID/Recife provided administrative backstopping throughout the life of the program. As elsewhere, water-resources investigations in this region are essential for planning, development, and management of water resources for rural, municipal, and industrial water supply and for irrigation and hydropower. The chief counterpart agency for the USGS team during the life of the program was the Natural Resources Department of the Superintendency for the Development of the Northeast (SUDENE). Close contact, however, was maintained with the National Drought Relief Department (DNOCS); the National Department of Sanitary Works (DNOS); the National Department of Mineral Production (DNPM); and the Commission for the San Francisco Valley (CVSF), as these agencies are also involved in water-resources development and management in the Northeast.

As identified by US AID/Recife, the water-resources program included two components, (1) hydrologic data collection and analysis on streams of northeast Brazil (surface-water investigations), and (2) exploration of ground-water resources for improved land use in the Drought Polygon (ground-water investigations). Financed by US AID grant funds, the program was continued over a 5-year term and phased out in November 1968.

Surface-water investigations.—U.S. Geological Survey technical support of surface-water investigations in northeast Brazil began in January 1963 with

the arrival in Recife of L. J. Snell, USGS hydrologist, who was assigned as project chief and advisor to the Hydrology Division, Natural Resources Department of SUDENE. The general objectives of the hydrologic investigations included: (1) expansion and improvement of the field network of streamflow, rainfall, and evaporation stations, (2) field and office training of SUDENE hydrologists, (3) annual compilation and publication of hydrological data, (4) computation, evaluation, and publication of a backlog of 30,000 station years of rainfall and 1,700 of streamflow data. From March 1964 to March 1966, the late R. O. R. Martin, USGS hydrologist, was assigned to the project to guide the work of computation and evaluation of rainfall and streamflow data; he was assisted in this work for 3 months in early 1965 by G. E. Philipsen, also a USGS hydrologist.

Mr. Snell concentrated his efforts in guiding the overall direction of the project, in assisting SUDENE to form an effective organization for collection of hydrological data, in working out operating methods and procedures to be used by SUDENE and in training SUDENE hydrologists. Mr. Snell returned to the USGS domestic program in October 1965.

In August 1966, W. F. Curtis, USGS hydrologist, was assigned to the project to continue the work of Mr. Snell in advising SUDENE on technical problems related to hydrologic-data collection, in working out operational procedures to be used by SUDENE, and in training personnel. Mr. Curtis also oversaw the final stages of publication by SUDENE of the rainfall and streamflow data compilation, which had been brought near completion by Mr. Martin. USGS technical support of SUDENE's program of surface-water investigations ended in December 1967, when Mr. Curtis was transferred from Recife to Rio de Janeiro. At this time the SUDENE Division of Hydrology was functioning well in the field collection of basic hydrologic data. A network had been established of 120 operating streamflow measuring stations in northeast Brazil. The network had 31 stations equipped with modern continuous water-stage recorders, 1,930 rain gages, 78 maximum and minimum temperature stations, and 37 evaporation stations. Staff and facilities for computation and publication of streamflow records were still, however, inadequate. In addition, 40 hydrologic technicians and engineers had been given individual and group training in the basic field and office methods and observational techniques of surface-water hydrology.

As of March 1970, 60 streamflow stations out of 120 were considered to have excellent records that were being computed and compiled on an annual basis. Also efforts were being made to improve records at the remaining 60 stations through better definition of stage-discharge relationships.

Ground-water investigations.—The technical base of USGS support of ground-water investigations in northeast Brazil was established by S. L. Schoff, USGS hydrogeologist, in a 3-month reconnaissance in mid-1962. His report of October, 1962 evaluates in considerable depth the needed scope of ground-water investigations in northeast Brazil, including types of investigation, organizational needs, staffing, equipment, and reporting. The long-term project was implemented in June 1963 with the arrival of Mr. Schoff in Recife as project chief and advisor to the Hydrogeology Division, Natural Resources Department of SUDENE. In December 1963 and June 1964, respectively, W. C. Sinclair and H. G. Rodis, both USGS hydrogeologists, were assigned to the project. Mr. Rodis remained until August 1966 and was not replaced owing to curtailment of funds. Mr. Schoff returned to the U.S.A. in September 1967. Mr. Sinclair, however, stayed on in northeast Brazil until November 1968, when he returned to the U.S.A. and reassignment in the USGS domestic program. The objectives of the project were (1) to train SUDENE hydrogeologists in methods and techniques of areal ground-water investigations and (2) to carry out actual field investigations of representative or critical areas as demonstration projects.

Mr. Schoff directed his efforts toward group training of the SUDENE hydrogeology staff, in preparing Portuguese language training materials in hydrogeology, in general liaison between US AID/Recife and SUDENE's ground-water program, and in special studies of ground-water salinity in the Upper Paraíba basin, the results of which were published in USGS Water-Supply Paper 1663–H.

Messrs. Sinclair and Rodis concentrated their efforts in individual field training of SUDENE hydrogeologists and personal participation in ground-water investigations in the Upper Capibaribe Basin, the Açu Valley, the Teresina-Campo Maior area, and the Irece area of the Northeast. The technical results of the first three investigations were published in USGS Water-Supply Papers 1663–E, 1663–C, and 1663–G, respectively.

By the time the USGS support was terminated in December 1968, the USGS hydrogeology team had actively participated in and completed ground-water investigations of some six areas of the Northeast

and had advised, intermittently, SUDENE hydrogeologists working in several other areas. Also, the Hydrogeology Division staff had been increased from 3 to 24 professional hydrogeologists, most of whom had been trained to competence by the USGS team.

Overall, both the surface-water and ground-water segments of the USGS-supported water-resources program in northeast Brazil achieved perhaps 80 percent of original objectives in water-resources investigations and institutional development. Both the Hydrology and Hydrogeology Divisions of SUDENE were functioning organizations in 1970 with competent staffs of hydrologists and hydrogeologists, most of whom are personally interested in increasing their knowledge and capability. Also the USGS has continued, since 1968, active participant training programs for young Brazilian hydrogeologists and hydrologists newly recruited to SUDENE.

Hydrologic Investigations in the Araguaia-Tocantins River Basin, 1964, 1965

At the request of the Interstate Commission for the Araguaia-Tocantins Valley (CIVAT) to US AID/Recife, L. J. Snell, USGS hydrologist, was assigned in June 1964 to review hydrologic-data activities in the Araguaia-Tocantins River Basin which covers 770,000 km² in east-central Brazil and to recommend a program to meet the needs for feasibility studies of proposed large-scale developments for hydroelectric power, navigation improvements, and drainage and for industrial and municipal water requirements. Mr. Snell's report of June 1964 described the streamflow (fig. 4) characteristics at seven gaging stations on the Tocantins and Araguaia Rivers, for which records beginning in 1961 were available, and he suggested locations and instrumentation needs for 33 primary additional stations as well as requirements for precipitation and evaporation stations in the basin.

In April 1966, Mr. Snell's recommendations were incorporated, with some additions and modifications by F. F. LeFever, USGS hydrologist, in a report outlining the needs for implementation of geologic mapping, mineral resources evaluation, topographic mapping, basic geodetic control, and hydrologic investigations in the CIVAT region.

Amazon River Investigations, 1963–69

When the International Association for Scientific Hydrology (IASH) began, in 1957, a program for assessment of river-borne dissolved solids from all sources carried to the oceans, the investigators found little published information on the Amazon River. This situation led in May 1961 to a joint proposal by

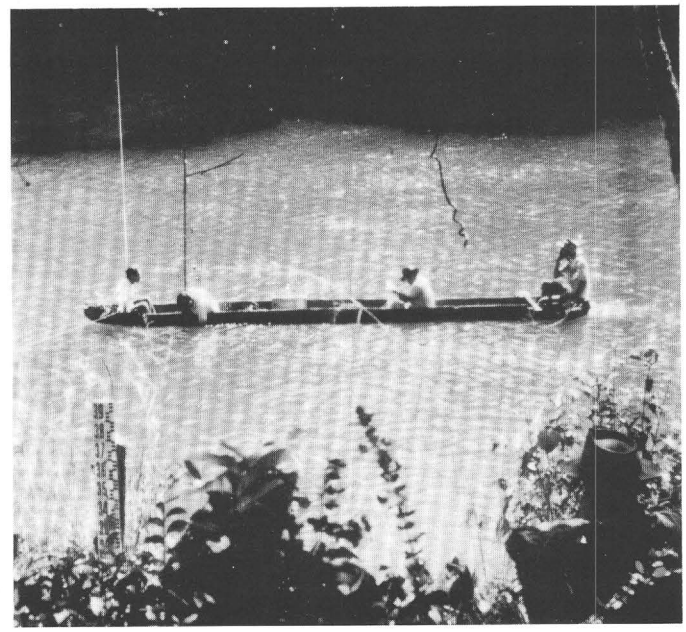

FIGURE 4.—Brazilian engineers measuring flow of the Rio Araguaia near Alto Araguaia with guidance from L. J. Snell, USGS hydrologist. Staff gage for measurement of river stage in foreground.

L. B. Leopold, Chief Hydrologist of the USGS, W. B. Langbein, USGS Staff Scientist, and Professor H. O'R. Sternberg, Director of the Brazilian Center for Geographic Research at the University of Brazil, for measuring the flow, solute load, and sediment concentration of the Amazon River. Professor Sternberg gained the backing of Vice Admiral Helio Garneir Sampâio, Director of Hydrography and Navigation, Brazilian Ministry of the Navy, who agreed to provide a suitable gaging vessel, while, at the same time the USGS agreed to provide an expert hydrologic team (fig. 5), and equipment.

R. E. Oltman, as team leader, and F. C. Ames, L. C. Davis, and G. R. Staeffler were designated as the USGS hydrologic team to carry out the work. They were ably assisted by several Brazilian naval officers, by Professor Sternberg, and by L. J. Snell, also a USGS hydrologist. In all, three hydrologic reconnaissance expeditions were completed by the USGS team in July 1963, October–November 1963, and August 1964 at high, low, and medium river stage, respectively. The measurements (fig. 6) of 1963–64, plus antecedent stage records, indicate well-supported mean annual water discharge of the Amazon River at Óbidos of 157,000 m³/s (cubic metres per second). The Amazon River is indeed the largest river in the world with more than 10 times the average flow of the Mississippi. Another fact of interest is the surprising purity of the water of the

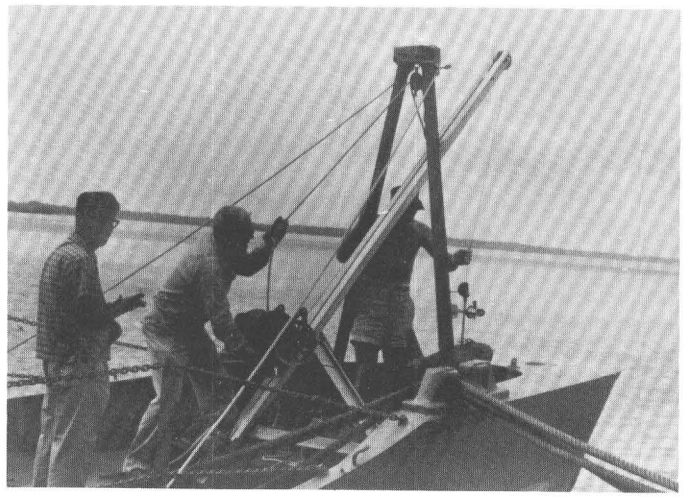

FIGURE 5.—R. E. Oltman (center), USGS hydrologist and team leader regulating the cable while his colleague, L. C. Davis (right), guides the current meter and water sampler over the side of the ship. A Brazilian hydrologist (left) stands by to provide assistance. A typical Amazon sailing smack passes to the left.

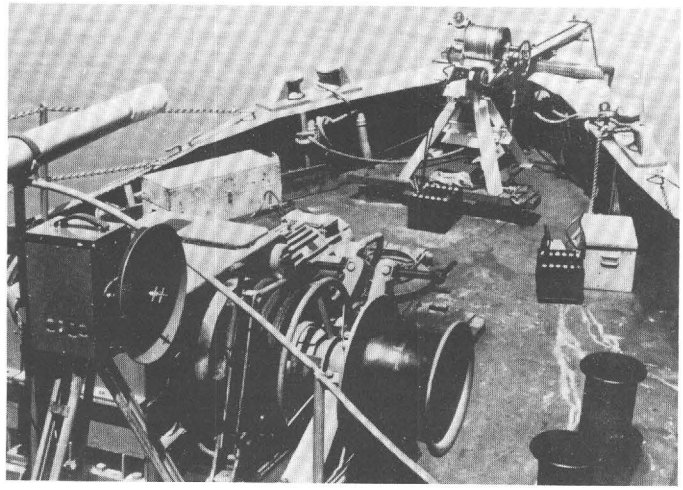

FIGURE 6.—Bow of the Brazilian Corvette, *Mearim*, which plied the Amazon River in July 1963 carrying the USGS team investigating the hydrology of this, the world's greatest river. At the left is the tellurometer unit used for ship-to-shore control measurements. The winch at the bow railing was used for flow measurements, soundings, and water samples.

Amazon River. The dissolved-solids concentration ranged from only 20 to 51 mg/l (milligrams per litre) during the 1963–64 period of observation. The technical results of these investigations were published in USGS Circular 552.

Between 1964 and 1969 the Amazon River was measured three times under the direction of the National Department of Water and Electrical Energy (DNAEE) and with the assistance of USGS hydrologists attached to DNAEE under US AID auspices. Most recently on November 27, 1969, G. F. Smoot, USGS hydrologist, demonstrated the "moving-boat" method of streamflow measurement on the Amazon River at Óbidos with the assistance of DNAEE hydrologists. Past individual measurements of the river at this gaging station by conventional methods have required 1½ to 2 days to complete. Individual measurements by the "moving-boat" method, of comparable accuracy, required only about 20 minutes each.

NATIONAL WATER RESOURCES PROGRAM, 1967–70

Although the regionally oriented water-resources investigations program in northeast Brazil had been operating successfully through USGS support to SUDENE and other agencies and under US AID grant financing, a policy decision was made in 1966 (1) to de-emphasize support of regional development programs and increase support of national programs and (2) to change over the financing of technical assistance in Brazil from grant to loan funding. As a result of this decision, the USGS in concert with US AID and the Brazilian agencies concerned designed a 10-year master plan for a long-term program of minerals and water-resources investigations, based on US AID loan financing, and successfully negotiated an agreement with the Brazilian Ministry of Mines and Energy (MME) as the counterpart. The loan agreement was signed in December 1967. The loan agreement included provision for water-resources projects with two departments of the MME, one in surface-water investigations with the National Department of Water and Electrical Energy, and the other in ground-water investigations with the National Department of Mineral Production (DNPM). The surface-water project was identified as "Hydrologic Data Collection and Analyses (DNAEE no. 1)" and the ground-water project as "Ground-Water Project-Northeast Brazil (DNPM no. 5)."

Surface-water investigations.—Preliminary formulation of technical support needs in Brazil's national program of surface-water investigations was first made in July 1964 by L. J. Snell, USGS hydrologist, who reviewed the activities of the former Division of Waters of the DNPM. (This division subsequently was changed into the National Department of Water and Electrical Energy or DNAEE in December 1965.) The organizational needs for functions and operations in surface-water hydrology of the newly established DNAEE were studied in depth by A. H. Williams, USGS hydrologist, during the

first 3 months of 1966 and described in detail in his report of March 1966.

Active USGS technical support of the new DNAEE was begun under interim US AID grant funding in February 1966, when F. F. LeFever, USGS hydrologist, arrived in Rio de Janeiro to take up his duties as senior advisor in hydrology to DNAEE. The principal project objectives included (1) expansion and improvement of the field network of streamflow, sediment, rainfall, and evaporation stations, (2) field and office training of DNAEE hydrologists in 10 active regional districts, (3) computation, evaluation, and publication of a backlog of streamflow and other hydrologic data, and (4) annual compilation and publication of hydrologic data. Mr. LeFever remained in Brazil until September 1966, when he returned to the U.S.A. During his tenure, however, he concentrated on strengthening the headquarters organization of DNAEE in Rio de Janeiro and counseling DNAEE on organizational, staffing, equipment, and publication needs.

In April 1967, G. N. Mesnier, USGS hydrologist, was assigned to the project to continue the work of Mr. LeFever. He completed his assignment, returned to the U.S.A. in February 1969. In April 1967, C. L. Lawrence, USGS hydrologist, also was assigned to advise DNAEE on technical problems in hydrologic-data collection, in improving operational procedures used by DNAEE, and in training personnel. Mr. Lawrence completed his assignment and returned to the domestic program of the USGS in July 1969. W. W. Evett, USGS hydrologist, arrived in Rio de Janeiro in July 1969 to take up the duties of senior advisor in hydrology to DNAEE and to carry on the work of Mr. Mesnier, and in July 1970, D. C. Perkins, USGS hydrologist, arrived in Brazil to take up the work of Mr. Lawrence.

On termination of formal USGS technical support of SUDENE surface-water investigations in December 1967, W. F. Curtis was transferred from Recife to Rio de Janeiro to begin work on the hydrologic program of the DNAEE. During the remaining 7 months of his 2-year tour in Brazil, Mr. Curtis visited the district offices of DNAEE in Niterói, Belo Horizonte, Salvador, Belém, and Manaus to demonstrate the use of hydrologic field equipment previously provided DNAEE under US AID grant funding. He also designed a new Sediment Analysis Laboratory for the DNAEE at Belo Horizonte and selected equipment for the laboratory. Mr. Curtis returned to the USGS domestic program in September 1968. He again visited Brazil on a 1-month assignment in November 1969 to assist in the inauguration of the laboratory on November 17, 1969. The laboratory has a regional function, processing sediment samples for DNAEE from south-central Brazil.

In August 1969, L. J. Snell returned to Brazil on a 3-month assignment to review current operations of the Division of Waters in 10 of the 12 operating DNAEE districts. Mr. Snell's report of December 1969 described in depth the specific staffing, operational and quality-control problems in the stream-gaging programs of the DNAEE district offices and at the Rio de Janeiro headquarters, and presented nine recommendations for improvements. Mr. Snell returned again to Brazil in February 1970 on a 4-month assignment to assist on an intensive on-the-job training emphasizing computation of streamflow data in the individual DNAEE districts. He returned to the U.S.A. in June 1970.

Also in November 1969, G. F. Smoot, USGS hydrologist, spent 2 weeks in field seminars and demonstrations of the moving-boat method of stream gaging to Brazilian hydrologists of the DNAEE. During his stay in Brazil, Mr. Smoot gave field seminars with the participation of 25 DNAEE hydrologists at Pirapora on the Rio São Francisco in Minas Gerais and also at Óbidos on the Amazon River.

Ground-water investigations.—Under the loan agreement a "Ground Water Project-Northeast" (DNPM No. 5) had been identified for implementation in the Ground Water Section of DNPM's Fourth District, whose activities in 1971 were directed toward drilling production water wells for private individuals and companies as well as for municipalities and other governmental agencies in northeast Brazil. This activity is carried on in competition with the drilling operations of 28 or more other public and private agencies. DNPM project No. 5 was designed to build within DNPM a competence and capability for areal ground-water appraisal and investigation coupled with guided exploratory drilling for hydrogeologic data. The leadership of the DNPM Fourth District, however, proved largely interested in production well drilling; consequently, the project was not implemented.

Owing to administrative delays, technical support of the national surface-water program was slow in gaining momentum. Not until July 1969 did the program become fully operative. As of 1971, however, the program was well underway and moving toward the goal of a national hydrologic network on all the major rivers in Brazil. A national program of areal ground-water investigations was still an unattained goal in 1971 in Brazil but is much to be desired. As

of 1971, SUDENE in northeast Brazil was the chief governmental organization that was actively conducting systematic ground-water investigations of the type that are needed in many other critical areas of Brazil for proper appraisal of the needs and limits of irrigation, public, industrial, and rural water supply.

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CHILE

Extending north-south for 4,270 km along the Pacific Coast of South America and averaging only slightly more than 160 km wide between the crest of the Andes and the ocean, Chile is a land of tremendous climatic and geographic diversity. It ranges from the bleak and barren Atacama Desert in the north through the mild and sunny valleys of central Chile to the icy fiords of Tierra del Fuego in the south. For the past 25 years the USGS has participated in the U.S. bilateral program of economic aid and technical assistance in Chile, which aggregated more than $1 billion prior to 1969. Beginning first with reconnaissance-type ground-water studies in the middle and late 1940's, the USGS assistance evolved to more intensive hydrogeologic investigations and institutional development in the 1950's and early 1960's. In recent years (1969–70), the USGS assisted in designing a national water-data system and a computerized total water-resources evaluation of the Río Aconcagua Valley, which is typical of the transverse valleys of central Chile. The scope, objectives, and accomplishments of the assistance during 1945–70 are described in following sections.

Ground-Water Reconnaissance in Central and Northern Chile, 1945–48

Owing to restrictions on imported foodstuffs engendered by shipping shortages during World War II and to economic stagnation in northern Chile resulting from the decline of the nitrate industry, the Government of Chile, in the postwar period, embarked on an extensive program of agricultural and water-resources development aimed at broadening the economic base and agricultural self-sufficiency of the region. This program, financed by loans from the Export-Import Bank to the Chilean Corporación de Fomento de la Producción (CORFO), gave considerable emphasis to pump irrigation from wells, particularly in central and northern Chile.

To establish guidelines for ground-water exploration and development and to evaluate ground-water potentials in various parts of central and northern Chile, the CORFO (Chilean Development Corp.) requested technical assistance of the U.S. Government through the Department of State. S. S. Nye, USGS hydrogeologist, was assigned to the Irrigation Section of CORFO to undertake the work in late 1945 under the program of the Interdepartmental Committee on Scientific and Technical Cooperation. Owing to illness, however, he was compelled to return to the United States and was replaced by G. C. Taylor, Jr., also a USGS hydrogeologist, who arrived in Chile in May 1946.

Mr. Taylor continued in Chile until January 1948 and during his stay completed surveys and appraisals of the ground-water resources of 26 valleys and basins in northern Chile. These included: studies of the Lluta, Azapa, Chaca, Camarones, and Tana Valleys, the Pampa del Tamarugal, Pica Oasis, Río Loa Valley, and the San Pedro de Atacama area, all in the "Norte Grande" region; and the Domeyko, Algarrobal, Paipote, Chañaral Alto, Aucó, Quilimarí, Lagunillas, and Los Choros Valleys, the Tongoy area, Pocuro, Putaendo, Catemu, Melón, Puchuncavi, La Ligua and Petorca Valleys, all in the "Norte Chico" region. In addition, ground-water surveys were made of the Casablanca, Chacabuco, Yali, and Pangué valleys in central Chile. USGS open-file reports on all these surveys and appraisals were also translated into Spanish for more effective use in Chile. Since their release in 1946–47 these reports have formed an important base of departure for more recent and more intensive ground-water exploration and development by CORFO, other Chilean government agencies, and private companies.

Ground-Water Investigations in the Río Elqui Valley and the Huachipato-Talcahuano Area, 1950

Engineering feasibility and cost-benefit ratio studies made in 1949 by the Frederick Snare Corp., consulting engineers of New York, pointed up the lack of good dam and reservoir sites in the Río Elqui Valley (fig. 7), owing to the considerable thickness and permeability of the valley fill, the steep stream gradients, and the high rate of siltation. Test drilling for foundation studies indicated, however, a high permeability of the valley fill and a probable potential for ground-water development.

To evaluate this potential, the Chilean Corporación de Fomento de la Producción through the Department of State requested the services of a USGS ground-water hydrologist. P. H. Jones, hydrogeologist assigned to the project, made a detailed field examination of the Río Elqui Valley and the adjacent area in the "Norte Chico" region of Chile in March and April 1950. In his report of January 1951, Mr. Jones recognized (1) that quantitative studies were needed before intensive development of the ground-water resources could be undertaken, (2) that the ground-water resources were indeed large and capable of much greater exploitation than that then (1950) extant, and (3) that the best approach to optimum development of the water resources of the valley was through use of the ground-water reservoir in the valley fill to balance surface-water inflow and outflow.

Mr. Jones in March 1950 also made a brief reconnaissance of the Huachipato-Talcahuano area in central Chile to outline requirements for ground-water

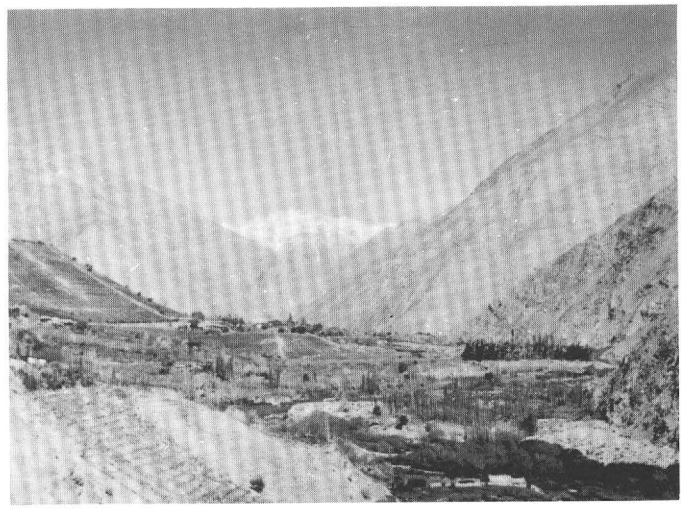

FIGURE 7.—Valley of the Río Elqui from point east of La Serena. Snowcapped Andes Mountains in the background. Terraced irrigated vineyards on the left.

exploration for the industrial water supply of CORFO's Compañía de Acero del Pacífico steel mill and submitted a report on his findings.

National Ground-Water Investigations Program, 1955–62

A long-term program of ground-water investigations and related institutional development in Chile was begun in May 1955, as part of countrywide geological, minerals, and ground-water investigations, technically supported by the USGS and under the sponsorship of US AID and its predecessor agencies. The principal Chilean counterpart agencies during the life of the program were the Corporación de Fomento de la Producción, which traditionally has been concerned with the exploration and development of the nation's ground-water resources, and the more recently established (December 1957) Instituto de Investigaciones Geológicas (IIG), which has been concerned chiefly with surveys, appraisals, and investigations of mineral and ground-water resources and geologic mapping. The Dirección de Riego and the Dirección de Obras Sanitarias, both in the Ministerio de Obras Públicas, were also involved at times in ground-water exploration related to project activity. Financed by US AID grant funds, the USGS support of the ground-water investigations program was continued over a 7-year term and was phased out in June 1962.

R. J. Dingman, USGS hydrogeologist, arrived in Chile in May 1955 to begin the ground-water program and during the following few months moderately intensive ground-water investigations were begun near the Pica Oasis, in the Pampa del Tamarugal, in the San Pedro de Atacama region (fig. 8), and the Santiago basin, all of which had been assigned priority for investigation and development by CORFO and later IIG. After a decision in 1958 to expand the scope of the ground-water investigations, W. W. Doyel and R. J. Devaul, USGS hydrogeologists, were assigned to the program. They arrived in Chile in February 1959. Mr. Devaul returned to the United States in December 1961 and Mr. Doyel in April 1962.

Active fieldwork continued in the Pica area under Mr. Dingman's direction until December 1956. The report on the area, published in Spanish by the IIG in 1962, presents a detailed geologic map of the area, a description of the geology, the results of exploratory drilling, a complete well inventory, a semiquantitative evaluation of the ground-water resources, and recommendations for their development. Fieldwork on a similar but somewhat more intensive investigation in the San Pedro de Atacama region was

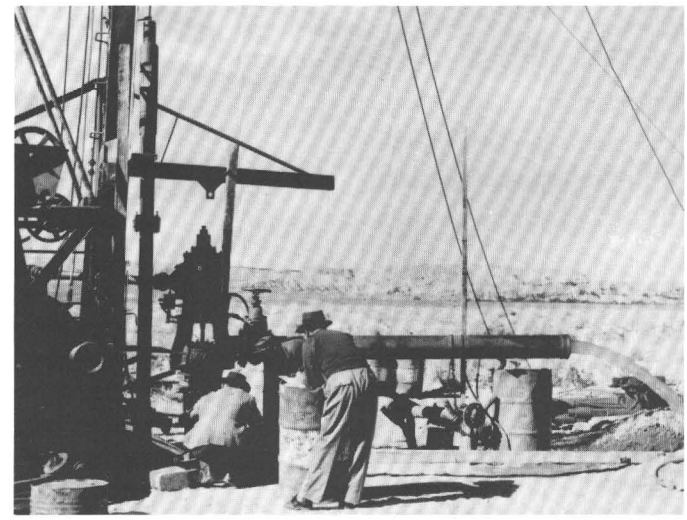

FIGURE 8.—Chilean engineers making observations at well 6, about 2 km northeast of San Pedro de Atacama. The well drilled to a depth of 246 m flowed naturally, but discharge has been increased by the installation of a pump. This well is one of several put down to explore an artesian system in the northern part of the Atacama Basin under the guidance of R. J. Dingman, USGS hydrogeologist.

continued until June 1962, and two reports were published on this region by IIG in 1963 and 1965, respectively. A ground-water reconnaissance of the Pampa del Tamarugal basin under Mr. Dingman's guidance was completed by Octavio Castillo U., IIG hydrogeologist, in June 1957, and the results were published in IIG Bulletin 5 in 1960. This report contains a complete well inventory, a water-table map, an evaluation of ground-water quality, a semiquantitative analysis of the probable rates of recharge and discharge from the ground-water reservoir, and recommendations for further ground-water development in the basin.

Fieldwork on an intensive and continuing investigation of the ground-water resources of the Santiago Basin, begun by Mr. Dingman in 1955, was later continued under the guidance of Mr. Doyel until the termination of USGS technical assistance in 1962. Two reports on the Santiago Basin were published by the IIG covering the 7-year term of USGS technical support. The first report, of a preliminary nature and released in 1958 as IIG Bulletin 1, covers an area of some 720 km^2 in the vicinity of the city of Santiago. This report contains a brief description of the hydrogeology of the Santiago area, tables of well records, a well location map, and chemical analyses of the ground water. The second report released in 1963 as IIG Bulletin 15, described in detail the ground-water geology and hydrology of the Santiago

Basin. This report pointed out that, as of 1961 and with an average rate of withdrawal of 3.2 m^3/s, ground-water levels were declining at an average of 1 m per year in the central part of Santiago. At the same time the ground-water reservoir in the peripheral areas of the basin was underdeveloped. The report recommended limited development of those areas but legislative control of further well drilling in the central part of the city. As of 1961, withdrawal of ground water for municipal and industrial purposes amounted to 32 percent of the water use in the Santiago urban area. Throughout the 1960's Chilean engineers (fig. 9) and hydrogeologists continued detailed studies of the geology and hydrology of the Santiago Basin that led in 1970 to publication of a comprehensive atlas entitled, "Hidrogeología de la Cuenca de Santiago" under the auspices of IIG and CORFO with Señores Falcón, Castillo, and Valenzuela as principal contributors.

Mr. Dingman also began hydrogeologic studies and exploratory drilling in the Arica area, which covers 125 km^2 in the lower Lluta Valley, the lower Valle de Azapa and the Concordia just south of the Peruvian border. The work, continued and completed under Mr. Doyel's direction, included collection of lithologic and water-quality data and aquifer tests at 14 exploratory wells, a well inventory of the Azapa Valley, and an observation-well program. A report on the Arica area by Mr. Doyel was published by the USGS in 1964.

FIGURE 9.—Chilean engineers and technicians preparing to set pump on new well near the Río Maipo southeast of Santiago.

Messrs. Dingman, Doyel, and Devaul also directed preliminary hydrogeologic studies and exploratory drilling by IIG and CORFO personnel in the Calama area; Copiapó Valley; Chillán (fig. 10), Temuco, and Tongoy areas; and Aconcagua Valley during their stay in Chile, but these studies were not carried to the stage of formal reporting during the life of the support program.

During the last 2 years of his stay in Chile and until the phaseout of USGS support and his return to the United States in June 1962, Mr. Dingman served as chief-of-party of the combined USGS geological, minerals, and ground-water team. Mr. Doyel in this period gave leadership to the USGS support in ground-water activities. With the assistance of CORFO and IIG personnel, he completed a Spanish-English glossary of 700 ground-water and related hydrologic terms and began an observational program of ground-water levels in the developed areas of Chile. He directed a pilot-type inventory of the industrial and public water supplies of Coquimbo Province, which was released as an IIG open-file report in 1962. He also participated in ground-water studies in the Puntas Arenas region of southern Chile, the Quebrada de Los Choros, and Quebrada de Tarapacá and in special hydrogeologic studies of damage in the Valdívia area caused by the major earthquake of May 22, 1960, in south-central Chile.

Throughout their stay in Chile, considerable attention was directed by Messrs. Dingman and Doyel toward the education and training of Chilean geologists and engineers through a 4-year series of seminars and formal courses in ground-water geology and hydrology in the Schools of Geology and of Engi-

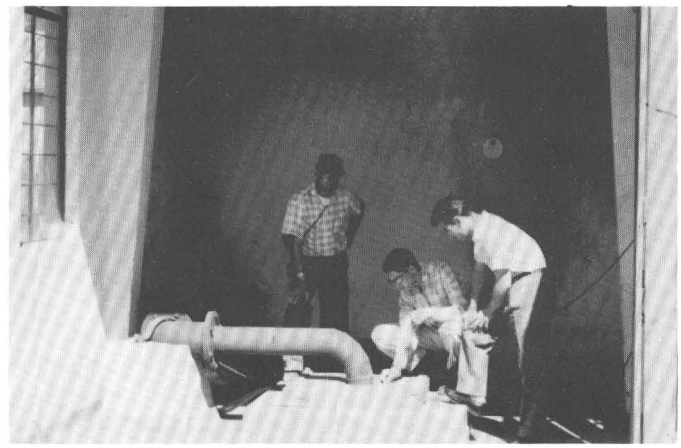

FIGURE 10.—Chilean engineers making water-level measurements in municipal well at Chillán under the guidance of R. J. Devaul, USGS hydrogeologist.

neering at the University of Chile in Santiago. They also trained IIG and CORFO personnel in techniques and methodology during the progress of fieldwork in areal ground-water investigations. At the phase-out of USGS support in June 1962, the ground-water staff of IIG had been increased to five trained professionals and to eight professionals in CORFO's Ground Water Section, all of whom had been trained to a high level of technical competence by the USGS team.

Overall, the USGS ground-water group in its 7-year term (1955–62) of technical support was markedly successful in building a strong and viable scientific and technical base for ground-water investigations and development in Chile. This success is measured by the fact that Chile in 1970 was playing a leading role in this field among the Latin American nations and was moving ahead effectively in ground-water development and management at a rate commensurate with its general economic growth. The Hydraulic Resources Section of CORFO with a staff of 22 professional engineers, geologists, and technicians currently is the most active governmental agency in Chile in ground water as well as in overall water-resources investigations and development. The Direcciónes de Riego and Obras Sanitárias, each with a staff of several professional engineers, also had moderate involvement in this field as of 1970. The IIG, however, has relinquished somewhat its former position in ground-water investigations in favor of concentration on minerals investigations and geologic mapping, and some of its personnel in the ground-water sector have moved to the CORFO staff.

A further measure of the success of the USGS technical support since 1946 is CORFO's record in ground-water discovery and development in Chile. Between 1949 and 1962, for example, CORFO put down 357 production wells for an aggregate depth of about 25,000 m and a total tested yield of 19.55 m^3/s. This development resulted in a potential increase in irrigated land of 17,000 ha (hectares), the solution of the water-supply problems for 67 industries, and the provision of potable water supplies to 300,000 people. In addition, the success of exploratory drilling in unproven areas has created a new field for private well-drilling contractors and has resulted in the establishment of several competent well-drilling contractors. Since 1962 and through 1970 this rate of growth continued. Also, the prolonged drought of 1967–69 greatly accelerated ground-water exploration and development particularly in the valleys of central Chile where, traditionally, irrigated agriculture has been sustained mostly by diversions from streams.

National Hydrologic Data System, 1969

During 1967–69 most of central Chile suffered from a prolonged drought that was perhaps the most severe in the recorded history of the region. To cope with the problems induced by the drought, the Chilean government organized an interdepartmental Special Drought Commission composed of representatives of all the governmental agencies concerned with water resources and related problems. Among others, this commission recognized a compelling need for a National Hydrologic Data System to optimize water-resources investigation, development, and management. To assist in the formulation of this system the commission requested expert U.S. assistance from US AID/Santiago, and W. W. Doyel and M. E. Moss, USGS hydrologists, were assigned to the work. Messrs. Doyel and Moss arrived in Chile early in August 1969 and remained until early in November 1969, at which time a draft of their recommendations was submitted to US AID/Santiago and the Government of Chile.

In their USGS open-file report of November 1969, they (1) outlined in detail the needs for a national hydrologic data system in Chile, including organizing, controlling, and testing the system, and (2) presented 19 recommendations for implementing the system.

Water Resources Investigations in the Aconcagua River Valley and Other Areas, 1969, 1970

The great drought of 1967–69 gave compelling impetus to the exploration and development of ground water in the river valleys of central Chile that traditionally have been irrigated from "run-of-the-river" diversions. The drought, moreover, brought into focus the great potential for utilizing subsurface storage by pumping water from the permeable alluvial fills of these valleys to balance seasonal variations in surface-water runoff and availability. To evaluate these potentials, the Government of Chile established a joint study team composed of members from the Dirección de Riego, the Servicio Agrícola y Ganadero, the Empresa Nacional de Electricidad, S.A., and the Instituto de Investigaciones Geológicas to undertake a pilot water-resources systems study of the Aconcagua River Valley under the leadership of the Hydraulic Resources Department of CORFO. This study began in 1967, and since that time engineers and geologists of the Chilean study team have obtained a large fund of information on the configuration of the water table, the shape of

the bedrock surface of the valley thalweg, and the thickness and transmissivity of the aquifer.

In mid-1969, the Chilean Government requested US AID/Santiago to provide technical assistance in setting guidelines for systems analysis studies of optimum conjunctive use of the water resources of the Aconcagua Valley. J. E. Moore, USGS hydrologist assigned to the project, arrived in Chile in October and remained until the end of December 1969. In his USGS open-file report of December 1969 he recommended a 2-year study program under CORFO leadership that included collection and analysis of all available hydrologic and hydrogeologic data, construction and calibration of a digital simulation model of the valley, and use of the model to evaluate alternative plans for development. These recommendations provide sound guidelines for optimizing water management in other river valleys of central Chile and the "Norte Chico" region. While in Chile, Mr. Moore also made reconnaissance of water resources in the Limarí, Chimbarongo, and Yali Valleys where the Dirección de Riego is currently (1970) developing ground water for supplemental irrigation.

During October 1969, J. D. Winslow, USGS hydrologist, visited Chile and the Aconcagua Valley project. During his stay he reviewed applications of USGS digital-model studies of hydrologic systems to the problems of the Aconcagua Valley. He also conferred with Mr. Moore and Chilean hydrologists of CORFO on compatibility of USGS digital-model programs with computers installed in Chile.

Following Mr. Moore's work, the CORFO in early 1970 again requested US AID/Santiago to provide short-term USGS assistance in the Aconcagua Valley project. O. J. Taylor, USGS hydrologist, was assigned from August to October 1970 to demonstrate applications of digital modeling for simulation of the effects of recharge and discharge on streamflow and ground-water storage in a selected reach of the valley, known as Hijuelas. In his USGS open-file report of October 1970, Mr. Taylor presented the results of preliminary digital-model studies of the Hijuelas reach. These model studies demonstrated that (1) withdrawals from wells reduced ground-water storage, (2) return flows to the river peaked at or shortly after the end of the irrigation season, and (3) return flow was less after conjunctive use of surface water and ground water. Mr. Taylor recommended preparation of comparable calibrated digital models of the entire Aconcagua Valley to analyze the effects of additional ground-water development, to evaluate the effects of proposed surface-water reservoirs, and to plan optimal utilization of the total water resources.

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COSTA RICA

A major and prolonged eruption of Irazú Volcano northeast of San José, Costa Rica, which began in March 1963, caused considerable loss of life, heavy ash accumulations over an area of more than 2,400 km^2, and extensive damage to agricultural lands, roads, and, particularly, vulnerable surface-water supplies. Based on preliminary studies in September 1963, the Government of Costa Rica requested technical assistance of US AID/San José, and the USGS was asked to undertake long-term investigations, beginning in April 1964, of the volcanic phenomena of the Meseta Central Occidental and their immediate and potential hazards to the economy of the region.

As a phase of these investigations, the Costa Rican government requested the short-term services of a ground-water expert to advise the Servicio Nacional de Acueductos y Alcantarillado (SNAA) or National Water Supply and Sewerage Service on problems related to ground-water development and water-supply protection and to design a program of ground-water exploration and investigations. W. D. E. Cardwell, USGS hydrogeologist, was assigned to the work and during his stay (August–October 1964) in Costa Rica completed a ground-water reconnaissance of the Meseta Central Occidental and advised engineers and geologists of the SNAA, the Instituto Geografico Nacional, and the Oficina de Defensa Civil on special development problems in several parts of the meseta. Mr. Cardwell also advised SNAA on hydrogeologic problems related to exploratory drilling for ground water in the Nicoya Peninsula and in the environs of Las Cañas, Limón, Siquirres, and Puntarenas. He pointed out the development potential of large springs at La Libertad, Ojo de Agua, Potrerillos, and Puente Mulas for municipal water supplies. These springs were subsequently developed by SNAA. His report of November

1964 recommended a 2-year program of hydrogeologic investigations, including requirements for extensive exploratory drilling and related geophysical surveys and institutional development in the SNAA.

Mr. Cardwell's recommendations were incorporated and implemented in a project that began in September 1965 under the auspices of the United Nations (U.N.) with United Nations Development Programme (UNDP) financing. This project included work by four international hydrogeologists assisted by Costa Rican engineers and geologists, drilling of some 30 deep exploratory wells, hydrogeologic training in SNAA, and detailed groundwater development plans for the San José region and two other areas in Costa Rica.

CUBA

Cuba, the "Pearl of the Antilles," lies about 145 km south of the Florida cays. The republic of Cuba includes the main island, which is about 1,190 km long, with an average width of about 95 km, and also some 1,600 smaller offshore isles and cays. U.S. Geological Survey personnel have been assigned for short periods to water-supply investigations in Cuba on several occasions during the past 75 years; where documentation is available, these activities are described in the following sections.

The earliest recorded work from a USGS source on water resources in Latin America was M. L. Fuller's brief paper on the general hydrology of Cuba, with descriptions of the water supplies of the principal towns and cities, and the occurrence of springs and ground water in karstic limestone terranes of the island. Mr. Fuller's paper, published in 1904 in USGS Water-Supply and Irrigation Paper 110, was compiled from miscellaneous field observations of the U.S. Corps of Engineers and USGS geologists during 1899–1902.

Water Resources Investigations in the Guantanamo Bay Area, 1915–16, 1925, 1959–60, 1962–64

With the exception of Fuller's early work and hydrogeologic and hydrologic reconnaissance in the Nicaro area, USGS activities in Cuba have apparently been concentrated in the environs of Guantanamo Bay which is on the south coast about 95 km west of the east tip of the island. Here as a result of a treaty in 1903 with the Republic of Cuba, the United States acquired a 115-km^2 reservation on which was established a U.S. Naval Station. Since its establishment, the USGS, at the request of the U.S. Department of the Navy, Bureau of Yards and Docks, has evaluated water-supply problems and related geologic and hydrologic conditions on several occasions and recommended solutions appropriate to the changing needs of the station.

The earliest work in the Guantanamo Bay area was that of the late O. E. Meinzer, considered by many to be the doyen of ground-water geology and hydrology in the United States. Mr. Meinzer completed a hydrogeologic field reconnaissance of the Naval Station and its environs in November–December 1915. His report released in mid-1916 described in detail the geologic, topographic, and hydrologic framework of the region and included well records and chemical analyses of typical water samples. The report concluded that the ground-water sources were small and recommended emphasis on surface-water reservoirs for day-to-day water-supply requirements. During the spring of 1916, N. H. Darton, USGS geologist, also made brief observations on water-supply conditions in connection with a study of the geology of the Guantanamo Bay region. Mr. Meinzer also returned to Cuba in February 1925 to examine briefly and evaluate geohydrologic problems at a reservoir site in karstic limestone terrane on the Guaso River near Guantanamo Bay.

In 1959, the Navy Department requested the USGS to undertake a detailed assessment of the water resources of the station reservation itself, particularly with reference to the availability of ground water for emergency needs in the event of interruptions of the supply from the Yateras River, 6.4 km northeast of the station. Horace Sutcliffe, Jr., and L. W. Hyde, USGS hydrogeologists, completed this assessment between September 1959 and June 1960. In their report of 1961, they concluded that existing ground-water sources are adequate for short-time emergencies but that no fresh surface-water sources and no deep artesian ground water are available within the reservation boundaries. Also they discovered no new shallow water-table aquifers in the small alluvial valleys in the reservation. Based on recommendations made in October 1962 by Messrs. Sutcliffe and Hyde, the Navy Department constructed eight infiltration galleries tapping the shallow ground water in the alluvial valleys. Later, during January to April 1963, Mr. Sutcliffe, together with S. M. Lang, USGS ground-water hydrologist, returned to the station to study the hydraulic response of the shallow alluvial aquifers to the operation of the infiltration galleries. In their report of 1964, Messrs. Lang and Sutcliffe described in detail the storage capacity of the highly permeable valley fill and recommended further ground-water development in the Cuzco area. They also recommended artificial recharge to build up the

hydraulic head in the alluvial aquifers and to flush out poor quality ground water near the shore.

Water-Resources Investigations in the Nicaro Area, 1953–56

Because of deficiencies in water supply and proposals for operational expansion, the U.S. General Services Administration in early 1953 requested the USGS to undertake a reconnaissance of the water resources of the area adjacent to the government-owned nickel mine and processing plant at Nicaro on the north coast of eastern Cuba. As a first phase of the survey, N. H. Hoy, USGS hydrogeologist, completed a field reconnaissance in March–April 1953 to evaluate possibilities for supplementing the existing supply from the Rio Levisa from ground-water sources and to recommend measures for their effective development and management. His report of April 1953 concludes that ground water is available in surficial sand and gravel deposits of the narrow coastal plain and in permeable zones in the underlying limestone. He recommends a followup program of water-level observations, water-quality monitoring, exploratory drilling, and aquifer testing prior to full development.

A second phase of the water-resources survey was undertaken by A. A. Fishback, USGS hydrologist, who visited the Nicaro area in February–March 1955 to study the Río Levisa, Río Culebra, Arroyo Blanco, and other streams of the area and to install a water-stage recorder near the point of a proposed diversion on the Río Culebra. He returned in September 1955 to make high-water observations on these streams, and in April 1956, J. H. Hartwell, USGS hydrologist, visited the area to complete low-water observations. Their work was summarized in J. K. Searcy's administrative report of June 1956.

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El Salvador

The Republic of El Salvador, smallest of the mainland American Republics, faces the Pacific side of the Central American isthmus. Except for a narrow coastal plain, El Salvador is largely a dissected upland plateau surmounted by an east-west chain of volcanoes, some of which are active and others intermittently so. Since its establishment as an independent republic in 1829 following the dissolution of a short-lived Federal Republic of Central America, El Salvador has provided strong leadership in the cultural and economic affairs of the region and has maintained a long tradition of friendship with the United States, its principal trading partner.

One of the earlier USGS involvements in overseas bilateral technical assistance was in 1943–44 when A. N. Sayre and G. C. Taylor, Jr., USGS hydrogeologists, were assigned to the Institute of Inter-American Affairs to study critical problems of water supply in El Salvador, as part of the cooperative program of IIAA's Health and Sanitation Division with the Salvadorean Directorate of Sanitation. Mr. Sayre spent 3½ months in El Salvador from June until September 1943 and Mr. Taylor, 7 months from July 1943 to February 1944.

During the course of the fieldwork, geologic and hydrologic studies were made of the water-supply problems of about 35 towns and cities in the republic. Individual reports were prepared both in Spanish and English by Messrs. Sayre and Taylor as well as by Mario Pacheco and Carlos Alemán, Salvadorean engineers, for each of the localities visited and a summary report was published as USGS Water-Supply Paper 1079–D. These reports described the geologic, hydrologic, sanitary, and economic features of existing and potential water supplies and made recommendations for their development or improvement.

Geologic and hydrologic studies were also made along the Pan American Highway in the 290-km stretch across the country from Guatemala to Honduras. About 50 sites were selected for the development of springs or the construction of wells as roadside watering places along the highway for travelers or livestock.

Most of the recommendations made by Messrs. Sayre and Taylor were subsequently put into effect in some 200 public water-supply development projects sponsored by the Directorate of Sanitation during the 1940's and 1950's and with technical assistance from the IIAA, US AID and predecessors, and the Pan-American Health Organization. In 1962, an autonomous agency, the National Administration of

Waterworks and Sewerage (ANDA) was established and as of 1970 planned, financed, constructed, operated and maintained water-supply and sewerage systems for virtually all the cities and towns in the country, or about 25 percent of the total population.

The United Nations also provided large inputs of technical assistance to El Salvador during the 1960's. These included surveys of the geothermal energy resources of active volcanic areas and the groundwater potentials of the San Miguel Valley and the San Salvador metropolitan area for irrigation and municipal water supply.

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GUYANA

Guyana, situated on the northeast coast of South America, includes an inland forested plateau covering some 85 percent of the country and a coastal plain 15 to 65 km wide facing the ocean. Cultivation of sugar cane on the coastal plain provides the agrarian base of the country, and sugar accounts for about one-third of the country's exports. The United States has maintained a modest technical assistance program in Guyana since 1954, and the USGS participated in water-resources studies on one occasion in 1957.

Following observed declines in pressure heads and resulting concern over possible failure of the artesian water supply in the coastal zone of Guyana, the Government of Guyana requested US ICA in late 1956 to porvide the services of a U.S. expert to evaluate the problem. Accordingly, G. F. Worts, Jr., USGS hydrogeologist, was assigned from February until April 1957 to make a reconnaissance of the ground-water conditions in the coastal artesian basin and to design a long-term program of ground-water investigations directed toward conservation and management of the artesian basin. During his stay, Mr. Worts worked closely with scientists and engineers of the Guyanan Geological Survey, the Drainage and Irrigation Department, the Transport and Harbours Department, the Meteorological Laboratory, and the Pure Water Supply Scheme.

His report, published in 1958 as Guyanan Geological Survey Bulletin 31, described the general ground-water geology and hydrology of the coastal artesian basin, including related surface-water and water-quality features. Mr. Worts concluded: (1) that the decline in head and flow of the artesian wells was due to mutual interference and not to depletion of the supply, (2) that decline in head along the coast could result in seawater intrusion in the future, and (3) that pumping from wells near the coast is undesirable because the threat of seawater intrusion would be increased. The report also presents detailed recommendations for scope of work and for organization and interdepartmental cooperation in ground-water investigations—including collection, recording, and compilation of basic data; equipment needs; aquifer testing; water analyses; well logging; and surficial and subsurface geologic studies.

Since this work, the Guyana Government with technical and economic assistance from US AID, the U.N. agencies, and private U.S. engineering consultants, has pursued effectively the goals recommended by Mr. Worts. As a result, the ground-water resources of Guyana's coastal plain, where some 90 percent of the population is concentrated, have since been carefully monitored and managed for rural irrigation and industrial and public water supply.

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HAITI

The Republic of Haiti, second oldest independent nation in the Western Hemisphere, gained its independence from France in 1804. Haiti occupies the western third of the island of Hispaniola in the Caribbean Sea. The country is largely mountainous with semiarid conditions prevailing in the lowland arable areas. Irrigation in these areas, the so-called "tradewind deserts," has been practiced, both from stream diversions and from wells since French colonial times, mainly for cultivation of bananas, sisal, and sugarcane.

A bilateral agreement for economic aid and technical assistance was concluded in 1919 between the U.S. Department of State and the Government of Haiti. As a part of the technical assistance program a four-man USGS team was assigned to Haiti and completed between October 1920 and April 1921 a nationwide reconnaissance of the geology and the mineral and ground-water resources. A comprehensive report on this reconnaissance was published in English and French in 1924 by the Haitian Geological Survey, Direction Generale des Travaux Publics (DGTP). In this report, J. S. Brown, USGS hydrogeologist, described the ground-water resources of some 15 arid lowland plains and valleys and evaluated their extant and potential development for irrigation and public water supply.

During October–November 1921, N. C. Grover, then Chief Hydraulic Engineer of the USGS, made a field reconnaissance of the surface-water resources of Haiti to determine requirements for a countrywide stream-gaging network. Based on recommendations in his report of January 1922, a Hydrographic Division was established in August 1922 with a technical staff of engineers and 24 gage observers. Also, a countrywide program of regular streamflow measurements began at some 81 regular and partial-record gaging stations, distributed in 10 hydrographic districts. The measurements were continued systematically, and the results were published from 1922 until 1936 in an annual series of 14 Hydrographic Bulletins released by the DGTP. By the end of 1936, some 8,995 individual streamflow measurements had been made. Since 1936, publication of streamflow records has languished, owing chiefly to lack of financial support. Nevertheless, actual streamflow measurements have been continued with some interruptions, for the past 35 years by the

Service des Eaux et Forêts, and unpublished data have been retained in the files of the DGTP.

After World War II and before 1963, the United States provided $105 million of technical assistance and economic aid of all types to the Government of Haiti. As part of this program, the Food Supply Division of the Institute of Inter-American Affairs in mid-1948 requested the USGS to provide the short-term services of a hydrogeologist (1) to evaluate ground-water conditions in certain of the arid lowlands, (2) to determine the feasibility of extending ground-water development for irrigation and other purposes, and (3) to define suitable sites for drilling production wells to irrigate pilot agricultural projects. G. C. Taylor, Jr., USGS hydrogeologist, was assigned to the work between September 1948 and March 1949 and was assisted by Remy C. Lemoine, Haitian engineer-geologist of the Service Cooperatif Interamericaine de la Production Agricole (SCIPA). Together Messrs. Taylor and Lemoine studied the Cul-de-Sac, Gonaïves, Arcahaie, and Moustiques Plains; the Jacmel-Meyer Bench; and the Forêt des Pins region and prepared six reports describing their findings and recommendations for each of these areas. During the 1950's, Mr. Lemoine continued and participated in this work and, together with US TCA, FOA, ICA, and AID engineers, guided several ground-water exploration and development projects in Haiti.

In response to a request from the Government of Haiti to US ICA, H. A. Waite, USGS hydrogeologist, was assigned during August–September 1959 to undertake a reconnaissance of: (1) the sources of water supply for the city of Port-au-Prince and (2) the water supplies of 12 towns and villages in the Department du Nord and to recommend ways of improving, extending, and increasing these supplies. During his stay in Haiti, Mr. Waite worked closely with engineers of the Haitian Service Hidraulique, Department des Travaux Publics; of the US ICA; of Metcalf and Eddy, consultants to U.S. ICA and the Government of Haiti; and of the Haitian-American Sugar Co. In his report of August 1960, Mr. Waite recommended a comprehensive ground-water investigation in the Plaine du Nord; the assignment of a U.S. ground-water specialist to Haiti for a 2-year period; and the training in the United States of two or three Haitian technicians for a 6-months study of ground-water problems, procedures, and investigations. Most of Mr. Waite's recommendations for improving the water supplies of the 12 towns and villages in the Department du Nord involved captation of springs and delivery of the water by gravity pipeline to public fountains or other water services. For the city of Port-au-Prince, he suggested importation of water from the Rivière Froide by extension of the Diquini Tunnel, appropriation and addition of new springs to the existing gravity system, and drilling of wells for municipal supply in the Cul-de-Sac Plain near Port-au-Prince.

Following on Mr. Waite's recommendations, John Logan, a US AID hydrogeologist, was assigned to Haiti to carry out ground-water investigations throughout the country and to train Haitian technicians in the field and office methodology. During his stay (October 1960–February 1963) in Haiti, Mr. Logan worked closely with Mr. Lemoine. Together, they compiled a report released in August 1962, which describes the geologic and hydraulic characteristics of some 100 exploratory and production wells put down during the 1950's, largely in the Cul-de-Sac, Archaie, and Gonaïves Plains and the Plaine du Nord near Cap Haïtien.

The US AID program in Haiti terminated in August 1963, and since then and as of 1970, virtually all U.S. assistance has been channeled through multilateral programs.

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NICARAGUA

Nicaragua, largest of the Central American Republics, established its independence in 1838 after the break-up of a short-lived Federal Republic of Central America. The United States has provided continuous inputs of bilateral technical assistance and economic aid to Nicaragua during and since World War II. Between 1960 and 1968 this aid totalled $138 million.

Perhaps the earliest recorded involvement of the USGS in Nicaragua was the work of A. P. Davis, USGS hydrologist, who was attached to the Nicaraguan Canal Commission in 1897–98. In the commission's report of 1898, Mr. Davis described observations on the fluctuations of Lakes Nicaragua and Managua as well as the hydrology of the Río San Juan along a proposed trajectory of a transisthmian canal.

In August 1943 and at the request of the Nicaraguan Dirección General de Sanidad to the Division of Health and Sanitation, Institute of Inter-American Affairs, A. N. Sayre and G. C. Taylor, Jr., USGS hydrogeologists, were assigned for 2 weeks to evaluate the water-supply problems of the city of Managua and of Las Sierras plateau to the southwest. Mr. Sayre in his report of August 1943 reviewed the economic, geologic, hydrologic, and sanitary problems of the extant (1943) municipal water supplies from a pumping station on Lake Asososca and from private wells and recommended improvements and alternatives, including possible pumping from an infiltration gallery adjacent to Lake Tiscapa and five or six properly spaced and constructed wells 150 m or more deep in the environs of the city. Mr. Taylor in a separate report, also of August 1943, reviewed the water-supply problems and ground-water conditions in the volcanic rocks of Las Sierras plateau southwest of Managua, particularly near Diriamba, Jinotepe, and Masaya, and recommended exploratory drilling and ground-water development in the vicinity of Casa Colorado and elsewhere on the plateau to provide needed municipal, domestic, and stock water supplies.

At the request of US ICA/Managua, S. L. Schoff, USGS hydrogeologist, was assigned for 19 days in September 1956 to evaluate the results of exploratory drilling in 1954–55 at the La Calera Agricultural Experiment Farm near Managua. Mr. Schoff concluded in his report of October 1956 that the aquifers in the vicinity of the farm were sufficiently productive to provide water for irrigation but that carefully drilled and properly screened wells would be needed to extract the water.

Most of the recommendations of Messrs. Sayre, Taylor, and Schoff were subsequently put into effect in the progress of the Nicaraguan government's water-supply development programs. More recently these recommendations were included in a yearlong comprehensive feasibility study of water-supply development needs for the Managua area completed in January 1964 by Hazen and Sawyer, consulting engineers. Another detailed feasibility study for water supply and sewerage for 10 towns in western Nicaragua was completed in November 1969 by Gilbert Associates, consulting engineers. This work included the cities of Masaya, Jinotepe, and Diriamba.

Beginning in 1966, areal ground-water investigations in western Nicaragua were undertaken by a private concern, the Development and Resources Corp., under a US AID development loan for national natural resources surveys. Since 1967 the United Nations with United Nations Development Programme financial support also has sponsored ground-water investigations in selected areas of western Nicaragua.

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PANAMÁ

The Republic of Panamá, occupying the narrowest part of the mountainous isthmus between North and South America, gained its independence from Colombia in 1903. Since completion of the Panamá Canal in 1915, Panamá's economy has been closely tied to servicing the transit trade through the canal. Also, with the United States as its principal trading partner, Panamá has received U.S. bilateral aid for more than 50 years. During 1961–68, U.S. aid amounted to about $110 million. As part of the U.S. aid program the USGS provided short-term technical assistance to the Panamanian government on four occasions—1949, 1962, and 1964–65.

As part of a cooperative program with the U.S. Department of Agriculture, the Panamanian Ministry of Agriculture, Commerce, and Industries in early 1949 requested the short-term services of a U.S. specialist to evaluate ways of developing and improving water supplies for livestock in the range-

lands of central Panamá. G. C. Taylor, Jr., USGS hydrogeologist, was assigned to the work and during April and May 1949 completed a reconnaissance of ground-water conditions of Herrera Province and adjoining areas in Coclé, Los Santos, and Veraguas Provinces, all in the northern part of the Azuero Peninsula. His report of May 1949 described the general hydrogeology of the volcanic rocks of the region, occurrence of ground water, characteristics of existing wells, and the then-current ground-water problems. He also pointed out that the water-bearing rocks, which are largely of volcanic origin, will generally provide yields of 0.1 to 1.0 l/s (litres per second) (sufficient for livestock) to 152- to 203-mm (millimetre) wells 30 to 60 m deep in most of the region, but that total well failures, because of geologic factors, could be anticipated with about a 5 percent frequency. Moreover, he indicated that other failures could result from careless drilling practices or poor well construction.

In response to a request from the Panamanian Instituto de Recursos Hidraúlicos y Electrificación (IRHE) to US AID Panamá, J. T. Callahan, USGS hydrogeologist, was assigned to Panamá in February 1962 to evaluate the needs for a long-term program of ground-water investigations focused particularly on the water-short central region and the Azuero Peninsula. Mr. Callahan's report of April 1962 recommended, as a first measure, a 2-year pilot study on the Azuero Peninsula, including needs for coordination among Panamanian government agencies; exploratory drilling; geologic and hydrologic field activities; personnel training; and scope, methods, and timing of study.

In 1963, Mr. Callahan's proposals for ground-water investigations were incorporated in a comprehensive 5-year "Cadastro Rural de Tierras y Aquas de Panamá" implemented by a private contractual consortium (CATAPAN), with US AID loan funds and with counterpart participation of several Panamanian government agencies, including IRHE. As part of this program, US AID/Panamá in mid-1964 requested the short-term services of a USGS specialist in ground-water geology and hydrology. To carry out this work, R. J. Dingman, USGS hydrogeologist, was assigned to Panamá for a 3-month period (October 1964–January 1965) to train five IRHE geologists and engineers in the operation of an electric logger; interpretations of resistance, self-potential, and gamma ray logs; field methods of collecting ground data; and identification of common rock types and well cuttings. He also identified areas of moderate to large ground-water potential near La Flora and Las Flores in the Azuero Peninsula. His report of February 1965 recommended a 5-year program of ground-water field investigations, participant training, and institutional development centered in the Panamanian Department of Mines. Although not all the administrative recommendations of Messrs. Callahan and Dingman were implemented as originally proposed, many of the technical recommendations have been effected, notably by F. L. Doyle, CATAPAN hydrogeologist, as part of the ground-water phase of the Cadastro Rural, which was completed in 1968.

At the invitation of the Secretary, Permanent Planning Commission for Water of IRHE and under the auspices of US AID, H. E. Thomas, USGS hydrologist, was assigned in July–August 1962 to consult with and assist Panamanian officials in hydrologic and legal problems related to national water law. During his stay in Panamá, Mr. Thomas developed a Proposed National Water Code for inclusion in a new Agrarian Code. A few years later through two governmental decrees of September and October 1966, respectively, all water uses and rights were brought under governmental supervision, and an inter-agency National Water Commission was established to control and protect all the national water resources.

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PERU

Legendary home of the Inca empire and later seat at Lima of the viceroyalty of Spanish America, Peru has filled a centerstage position in the cultural and political affairs of South America for more than 400 years. Occupying the western bulge of the continent, Peru has climatic regimens ranging from the cool deserts of the Pacific coastal zone to the high barren páramos of the Andes and the tropical rain forests of the upper Amazon basin in the trans-Andean region. Because of perverse geography and other factors, Peru had suffered for many decades from economic stagnation. Since World War II, however, the Government of Peru with the help of international donors has made strong efforts to modernize its institutions commensurate with the demands of the times. In support of Peru's efforts to raise national living standards and to strengthen the economy, the United States provided some $619 million of bilateral aid between 1945 and 1969.

As a part of U.S. aid to Peru during the 1950's, the Peruvian Comisión de Colaboración and US FOA/Lima sponsored a long-term program of technical assistance in minerals and ground-water investigations with USGS participation. In this program, S. L. Schoff, USGS hydrogeologist, was assigned in February 1955 to carry out ground-water evaluations and appraisals of critical areas and problems throughout the arid coastal region of Peru. Mr. Schoff's assignment in Peru continued until July 1959, when he returned to the USGS domestic program. Shortly after his arrival, Juan L. Sayán M., Peruvian engineer-geologist with the Servicio Cooperativo Interamericano de Irrigación, Vías de Comunicación e Industrias (SCIIVCI), was assigned to work with Mr. Schoff and continued in this capacity until Mr. Schoff's departure from Peru.

One of the first activities of Mr. Schoff and Engineer Sayán was a 3-months' ground-water survey of the Lima area undertaken as part of a "Study Commission for Improvement of the Distribution System for the Water Supply of Lima" sponsored by the Peruvian Ministry of Development and Public Works. Their report, included as an appendix in the general report of the Study Commission, was released in January 1956. The Schoff-Sayán report described the general geology and hydrology of the Río Rimac basin and the ground-water potential of the valley fill and estimated withdrawals from wells and infiltration galleries at approximately 160,000 m^3/d (cubic metres per day).

Together with Engineer Sayán, Mr. Schoff also began in September 1955 a comprehensive investigation of the ground-water geology and hydrology of the Lambayeque Valley in northern Peru which was continued intermittently until April 1958. A report on the investigation, first released in 1959 and later formally published as USGS Water-Supply Paper 1663–F, describes in detail the hydrogeology and the occurrence, chemical quality, temperature, and the then-existent as well as potential development of the ground-water resources of the valley.

A severe drought that affected southern Peru in 1955–56 gave compelling impetus to the need for comprehensive planning in the economic development of the region. Accordingly, and by Presidential decree, an inter-ministerial committee was formed in the Government of Peru to organize a "Plan Regional para el Desarrollo del Sur del Perú (PRDSP)" (Regional Plan for the Development of Southern Peru) and to mount with the technical and financial assistance of US ICA a study team of some 60 national and foreign experts charged with field investigations, research, and evaluations required for the plan. As a phase of this work, Mr. Schoff and Engineer Sayán completed between August and November 1958 a general reconnaissance of ground-water conditions in the seven provinces of southern Peru. Their findings were published in 1959 as volume 3 of the general 30-volume PRDSP report. They described the general hydrogeology of the region and concluded that ground water in some areas, such as near Tacna and in the lower part of the Moquequa valley, may be overdeveloped but that other areas, such as the valleys of the Majes, Tambo, and lower Sama with good potential had not been fully developed. They also pointed up the need for conjunctive use and management of both surface water and ground water in the extensive irrigated area near Arequipa.

During his stay in Peru, Mr. Schoff also completed brief ground-water studies at La Granja San Jorge, near Huancayo, in the Pampa de La Joya, at Ilo, in the Pampa de Sihaus, in the Tacna Valley, at Matarani and Mollendo, in the Pampa de Ñoco, near Puno, and near Tumbes. The results of these studies were released in 10 USG open-file reports.

Since 1960 the ground-water investigations and studies of Mr. Schoff and Engineer Sayán have provided an important and useful base for further reconnaissance under UNESCO's technical assistance program and for development-oriented feasibility studies of the Inter-American Development Bank (IADB) and the U.N. Food and Agriculture Organization (FAO), as well as in regional development planning of the Government of Peru.

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EUROPE

USGS water-resources bilateral activities in the European countries have been limited to long-term assignments in Belgium, Greece, and the Netherlands and to short-term assignments related to water-supply problems at U.S. installations in European countries or their offshore island possessions. Also, water-supply site studies were carried out by USGS water-resources personnel in several European countries while on duty with the U.S. Forces during World War II. As little or no documentation is available on this work, it is not herein reported.

BELGIUM

Through a bilateral agreement between the U.S. Department of State and the Government of Belgium and under the auspices of the U.S. Atomic Energy Commission, E. S. Simpson, USGS hydrogeologist, was assigned in December 1960 to assist the Belgian Center for Nuclear Studies (CEN) in developing long-term hydrologic and hydrogeologic investigations at Mol, about 80 km north of Brussels, related to radioactive waste treatment, control, and disposal. During his stay in Belgium, Mr. Simpson began, in cooperation with CEN scientists, a continuing investigation of the microhydrology of the ground-water system in the Mol area—including studies of infiltration rates, permeabilities, velocities, and dispersion; hazard evaluations; electric-analog-model simulation; and laboratory and field studies in the application of radioisotopes to ground-water problems. Mr. Simpson completed his assignment and returned to the U.S. in August 1962.

GREECE

Greece, homeland of western classic tradition, occupies a semiarid and largely mountainous peninsula jutting southward from southeastern Europe and includes also numerous islands in the eastern Mediterranean Sea. The U.S. provided more than $3.8 billion in military and economic aid between 1946 and 1962. As a part of the aid program, the Economic Cooperation Commission requested the USGS to provide the services of a hydrogeologist with expertise in well drilling and well-construction methods for work with the American Mission for Aid to Greece. H. F. Haworth, USGS hydrogeologist, was assigned to this work, and he arrived in Athens in February 1948. Mr. Haworth worked in Greece during the following 2 years where he supervised the countrywide operations of some 25 drilling rigs supplied to the Greek Ministry of Agriculture by the United Nations Relief and Works Agency. These rigs were used to put down water-supply wells for towns and villages, both on the mainland as well as in the Greek islands.

During the First International Symposium on Water Desalination held in Washington, D.C., in October 1965, the Secretary of the Interior offered technical assistance in water surveys to several country delegations, including Greece. Availing itself of this offer, the Greek delegation requested assistance of a U.S. specialist team to evaluate the water problems of the Athens area and particularly the feasibility of desalting sea water to meet Athens' growing water requirements.

A five-man team was organized, including representatives from the Bureau of Reclamation, the Atomic Energy Commission, the Office of Saline Water, and the Geological Survey. T. G. McLaughlin of the USGS was designated as the specialist in

hydrology to evaluate conventional sources of fresh water in the Athens area. During September and October 1966, the U.S. team completed its field study in cooperation with counterpart experts from the Government of Greece. The team considered the relative merits of hypothetical single- and dual-purpose desalting plants as well as nuclear versus fossil fuel power. They also looked into the economics of developing conventional ground-water and surface-water sources versus desalting and also jointly with desalting. Mr. McLaughlin provided essential hydrologic appraisals of conventional fresh-water sources for the economic evaluations.

NETHERLANDS

Funded by a Rockefeller Foundation Public Service Award for research in coastal paleohydrology, J. E. Upson, USGS hydrogeologist, was stationed at the Hague, Netherlands, for 10 months between July 1958 and July 1959. The principal objectives of his tour were: (1) to observe Dutch methods of fresh ground-water utilization and management in coastal areas proximate to salty ground water from the sea, (2) to study little known techniques of ground-water investigations in coastal zones that might be applicable in the U.S.A., and (3) to study fresh and salty ground-water zones in the Netherlands as they relate to glacial and post-glacial fluctuations of sea level.

During his stay in the Netherlands, Mr. Upson worked closely with the Netherlands Geological Survey, the Government Institute for Water Supply, the Rijkswaterstaat, and also the Universities of Utrecht and Leiden. After his return to the U.S.A. he undertook research in coastal areas of northeast U.S.A. collateral with his technical and scientific findings in the Netherlands.

PORTUGAL (AZORES)

The Azores Group includes eight main islands and numerous smaller islets and reefs about 1,600 km west of Lisbon. Because of seasonal shortages in water supply for the Lagens Air Force Base on Terceira Island in the Azores, the U.S. Air Force's Military Air Transport Service in early 1960 requested the USGS to provide the services of an expert to review the problem and to recommend ways of providing an adequate and assured supply for the base. G. F. Worts, Jr., USGS hydrogeologist, was assigned to the work and during April and May 1950 studied the geology and ground-water conditions in the volcanic terrane of the east end of Terceira Island.

His report of December 1950 pointed out that the extant gravity supply of 4,000 m^3/d from five developed springs dwindled to as little as 400 m^3/d during the summer dry season and that no perennial streams are available for development. He recommended a ground-water exploration program, including test drilling, water sampling, and aquifer testing, and based on this information the installation of production wells to supplement the spring supply. In order to contain potential salt-water encroachment in the vicinity of the base, he further recommended recharging the aquifer through the production wells during the winter months with surplus water from the developed spring supply.

AFRICA

Practically all USGS water-resources activity in the U.S. bilateral program (fig. 11) in Africa has followed, often closely, the regeneration of older independent nations during the post World War II period or the establishment of new nations during the 1950's and early 1960's. Although there has been a relatively wide geographic distribution of assignments (74 in 14 countries), most activity has been concentrated in the United Arab Republic (Egypt), Libya, and Nigeria, all since 1950 (table 2).

CHAD

In September 1962, the Secretary General of the Commission for Technical Cooperation in Africa (CCTA) invited the U.S. Agency for International Development to furnish a hydrologist-observer at a CCTA sponsored Meeting of Hydrologists from Countries bordering Lake Chad held at Fort Lamy, Chad, October 23–25, 1962. At the request of U.S. AID to the USGS for a well-qualified observer, A. H. Williams, USGS hydrologist, was assigned to attend the meeting. Mr. Williams' report of November 1962 appraises in some detail the scope, objectives, and discussions of the meeting, which was primarily directed to problems of coordination of development of the Lake Chad basin among the riparian countries (Niger, Nigeria, Chad, and Cameroon), particularly with respect to water supply and use.

CONGO (KINSHASA)

The Democratic Republic of the Congo (now Zaire), occupying the greater part of the vast Congo River basin, lies astride the Equator in south-central Africa.

Early in 1968 the Congo Government requested US AID/Kinshasa to provide the services of a ground-water specialist to reconnoiter ground-water

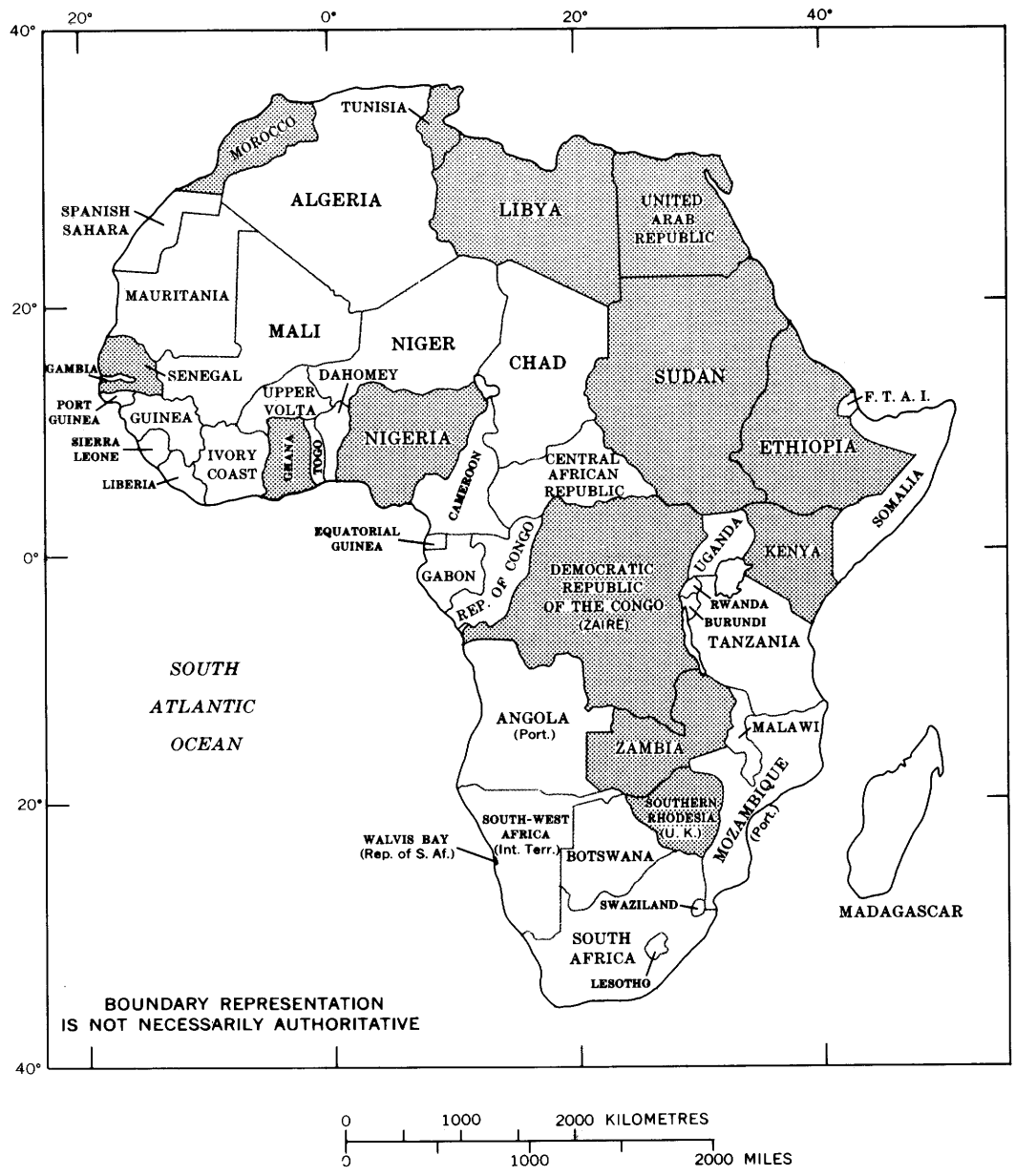

FIGURE 11.—Index map of Africa, showing those countries in which the U.S. Geological Survey has been active in water-resources projects of the U.S. bilateral program, 1940–70.

problems in several areas of Congo (Kinshasa). G. C. Tibbitts, Jr., USGS hydrogeologist, was assigned to the project, and during March–April 1968 he studied ground-water conditions in the Batéké Plateau, some 35 km northeast of Kinshasa (formerly Léopoldville); the Kimpese area, 70 km southwest of Kinshasa; the Mbaji Mayi (M'buji Mayi) area in Kasai-Oriental Province; and the Congo River terraces directly east of Kinshasa.

In his report of April 1968, Mr. Tibbitts concluded that possibilities are poor for obtaining yields from wells in sufficient quantity for irrigation in the Batéké Plateau because of the deep water table and the relatively low productivity of Cretaceous and Tertiary sandstone aquifers underlying the plateau. To solve the water-supply problem of Kimpese and vicinity, Mr. Tibbitts recommended the captation and sanitary protection of the several orifices of Kimwana Spring (flow 100 l/s) and pumping the flow to an elevated tank for gravity distribution. In the Mbaji Mayi area an extensive water-bearing zone occurs along the contact of Triassic sandstone with an underlying Precambrian dolomite. This zone supplies moderate to large yields to dug and drilled

wells and to springs. Mr. Tibbitts recommended sanitarily protected dug wells for village water supplies in the area.

Mr. Tibbitts pointed out in his report that buried gravel-filled channels underlying the Congo River terraces and extending 32 km east from Kinshasa have the potential to yield 75 to 100 l/s to individual wells 25 to 30 m deep. He recommended a 2-year project of ground-water exploration and pilot development directed toward providing irrigation water for rice and vegetable crops needed to supply the Kinshasa urban market. The project was not implemented, however, because subsequent reconnaissance of the terrace soils indicated poor suitability for irrigation.

Reference

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EGYPT (UNITED ARAB REPUBLIC)

Egypt, later known as the United Arab Republic (UAR), lies in a nearly rainless desert region at the northeast corner of Africa. Moreover, with its ancient hydraulic culture in the Nile Valley, Egypt has a continuous recorded history of some 5,000 years, the longest on Earth. The USGS participated in the water-resources sectors of the U.S. bilateral technical assistance programs in Egypt on two occasions, first in 1953–56 and again in 1959–67, with the largest aggregate input of manpower and technical support effort among the countries in Africa. The scope, objectives, and achievements of this input are described in following sections.

Underground Water Survey, 1953–56

In 1953 Egypt embarked on a program to increase the agricultural and industrial production of the country with economic aid and technical assistance from foreign donors. As part of this assistance, the Government of Egypt (GOE) requested the U.S. Foreign Operations Administration (FOA) in Cairo to provide the services of an expert to appraise needs for a long-term program of ground-water investigations and pilot development of selected critical areas in the country. P. E. Lamoreaux, USGS hydrogeologist assigned to the work, visited Egypt during September–November 1953. Based on Mr. Lamoreaux's recommendations for a project of long-term technical assistance with USGS support under US FOA auspices, C. R. Murray, USGS hydrogeologist, was assigned as chief of the project, designated "Underground Water Survey," arriving in Cairo in November 1953. In March 1954, W. W. Doyel, USGS hydrogeologist, and in April 1954, R. L. Cushman, USGS ground-water engineer, arrived to work with Mr. Murray.

The dual objectives of the Underground Water Survey were (1) to evaluate the ground-water resources of areas outside the Nile Valley that had been selected by the GOE for early irrigation development from ground-water sources and (2) to study the feasibility of pumping from wells (vertical drainage) to lower the water table and to provide supplemental water for irrigation in the Nile Delta. The chief counterpart agencies for part I of the project were the Desert Institute and also the Desert Irrigation Inspectorate in the Ministry of Public Works and for part II the Drainage and Irrigation Inspectorate in the same ministry. Project elements identified in part I included studies of the ground-water resources of (1) the Mediterranean littoral west of the Nile Delta, (2) Al Wāhāt al Khārijah (Kharga Oasis) in the Western Desert, (3) the Wādī el Ārīsh-Rafah area in the Sinai Peninsula, (4) the desert areas adjacent to the Nile Delta, and (5) the Wādī 'Araba and the Wadi Laquita in the Eastern Desert. Activities included in part II, which concentrated on the southern part of the Nile Delta and was also known as the "Well Irrigation and Drainage Pilot Project," were an inventory of wells, construction of observation wells (fig. 12) near the Rashid (Rosetta) and Dumyat (Damietta) distributaries of the Nile River (fig. 13), evaluation of the drainage and irrigation capabilities of deep and shallow wells, and training of the staff of the Drainage and Irrigation Inspectorate.

The project was terminated in late 1956. The Underground Water Survey fell short of achieving its initial goals and never reached a stage of formal reporting. Nevertheless, several worthy accomplishments can be identified. Notable among these were (1) the training of the 27-man staff of the Drainage and Irrigation Inspectorate through field, office, and laboratory seminars in quantitative methods in ground-water hydrology as applied to the problems of the Nile Delta, (2) the construction and electric logging of 38 observation wells and 9 pilot irrigation and drainage wells and completion of 50 pumping tests in the southern part of the delta, (3) the partial completion of the well inventory in the delta, (4) the completion of hydrogeological and geophysical reconnaissance in the Fūkah (Fuka), Ra's el Hikmah and Matrūh (Mersa Matruh) (fig. 14)

FIGURE 12.—Drilling of observation well by light rotary rig in the Nile Delta south of Ziftá.

FIGURE 13.—Egyptian feluccas on the Nile in the Delta.

areas of the Mediterranean littoral region (fig. 15) west of the Nile Delta and in the Wādī el Ārīsh-Rafah area of the Sinai Peninsula; (5) the completion of hydrogeological and geophysical reconnaissance and the beginning of ground-water exploration and development in Al Wāhāt al Khārijah through construction, electric logging, and aquifer tests at some 20 pilot wells; and (6) the exchange of scientific and technical knowledge with Egyptian counterparts and the resulting stimulation of ground-water development need for increased agri-

FIGURE 14.—Egyptian hydrologist measuring water level in ancient Roman well near Matruh (Mersa Matruh). Local cultivators are interested observers.

FIGURE 15.—Egyptian camel driver watering his animals at natural seep in the Wadi Naghamish near the Mediterranean coast west of the Nile Delta. Water table is within 2 m of land surface and water is drawn by hand from shallow pit in buckets and skin bags.

cultural and industrial production in Egypt. Much of the substantive data obtained from part I of the

project were later incorporated in the New Valley Project, 1959–67, which is described in the following section.

New Valley Project, 1959–67

Recognizing the pressing need to accommodate the food-supply requirements of its growing population and to provide a socio-economic base for relief of population pressures in the Nile Valley, the Government of the United Arab Republic (UAR) established in July 1959 the General Desert Development Authority (GDDA) and charged it with the task of reclaiming the lands and developing the natural resources of desert areas outside the Nile Valley. Paramount in this charge was the investigation and development of water resources, particularly ground water, for irrigation and other beneficial use. Soil surveys also were given high priority with respect to feasibility for irrigation of desert soils and for selection of appropriate crops. The problems of relocating agricultural families from the Nile Valley to newly developed lands also were assigned priority attention in demographic studies.

Shortly after the establishment of the GDDA, the UAR government requested the U.S. International Cooperation Administration to provide the services of a U.S. expert to design a long-term program of ground-water investigations in the four large oases (Kharga, Dakhla, Bahariya, and Farafra), known as the "New Valley," in the Western Desert of Egypt. P. E. Lamoreaux, USGS hydrogeologist assigned to the work, arrived in Cairo in mid-November 1959 and during the following month designed a comprehensive two-phased project, which, in the first phase, emphasized ground-water investigations (exploration) of the Nubian aquifer system of the Western Desert and, in the second, recommended a continuation of the investigations coupled with pilot development (exploitation). Both phases concentrated activities in Al Wāhāt al Khārijah (Kharga) (fig. 16) and Wāhāt ad Dākhilah (Dakhla) Oases where investigations were to be carried out by Egyptian scientists and engineers with the technical assistance of USGS advisors. Other ground-water investigations were undertaken subsequently and completed in Al Wāhāt al Bahrīyah (Bahariya) and Al Wāhāt al Farāfirah (Farafra) Oases by the Ralph M. Parsons Co. under direct contract with the UAR government. Mr. Lamoreaux's report of December 1959 identified the activities and developed a full scope of work and time table for the GDDA input, private contractual, and USGS support. The identified activities included: collection, recording, and evaluation of geologic and hydrologic data; geological mapping; subsurface geologic studies; surface resistivity, magnetic and gravimetric surveys; exploratory test drilling and production drilling of pilot-development wells; analysis of drill cuttings, cores, electrical logs, and drill-stem tests; aerial photography and air-borne magnetometric surveys covering 86,000 square miles; periodic measurements of discharges and artesian pressures in representative wells; photo-interpretation of geology, soils and hydrology; flow and pumping tests to determine aquifer characteristics of the Nubian system; studies of hydrochemical quality and of well-corrosion problems; research on proper well design and well construction practices; reservoir engineering and interpretive studies based on water-level information from an observation well program; detailed soil classification studies; agricultural pilot development studies to evaluate the adaptability of soils to different methods of irrigation and cropping; and preparation of reports embodying the results of investigations. Mr. Lamoreaux returned to Egypt in March 1961 to review the first year's progress on the investigation and several times thereafter on a yearly basis in his capacity as a private ground-water consultant to the UAR government.

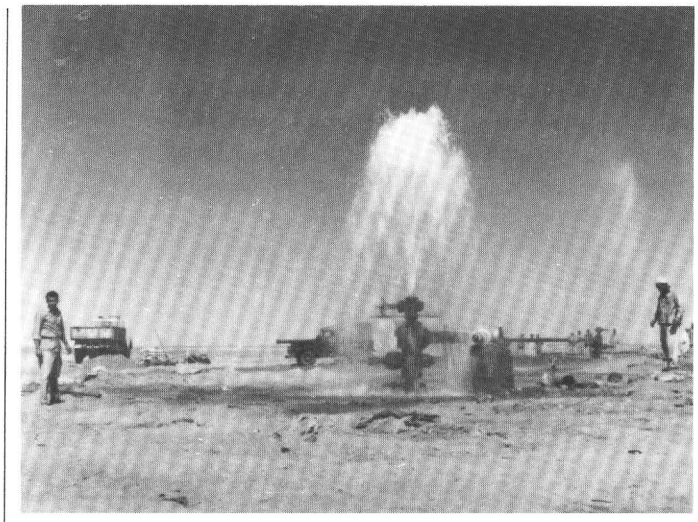

FIGURE 16.—Two flowing artesian wells put down in Al Wāhāt al Kharijāh as part of the New Valley pilot ground-water development project. Nasser no. 3 at the left is 650 m deep and flowed initially 5,100 m^3 per day; Nasser no. 1 at the right is 400 m deep and flowed initially 8,000 m^3 a day. Both wells tap sandstone aquifers in the Nubian Series.

Formal USGS technical support of the New Valley Project, designated by US AID as "Ground Water Investigations in the Western Desert," began in June 1960 with the arrival of H. A. Waite, USGS hydro-

geologist, in Cairo as principal project advisor to the GDDA and US AID/Cairo. Active USGS support of the project continued until a planned phase-out in May 1967. Mr. Waite continued in Egypt until August 1962, and, during his tenure four USGS specialists were assigned for brief terms to assist the GDDA, which in late 1961 was renamed the Egyptian General Desert Development Organization (EGDDO), in various phases of the project activity. The USGS specialists included J. P. Minard (March–May 1961), who trained the EGDDO geologists in the principles of photo-interpretation for geologic mapping; R. W. Sundstrom (June–October 1961), who trained EGDDO hydrologists and engineers in quantitative methods of aquifer evaluation; L. P. Sudrabin (February–March 1962) and F. E. Clarke (May–July 1962), both of whom advised the EGDDO on problems of corrosion of metals used in well construction and pumping equipment. Also, the late P. R. Bieber, USGS hydrogeologist, arrived in Egypt in January 1962 to assist Mr. Waite and, subsequently, Mr. Sundstrom, when he returned to Egypt on long-term assignment. Mr. Bieber returned to the U.S. in July 1964.

In June 1962, R. W. Sundstrom, USGS groundwater engineer arrived in Egypt to succeed Mr. Waite as principal project advisor and continued in this capacity until his return to the U.S. in September 1964. During this period seven USGS specialists were assigned for short terms to assist the EGDDO in several aspects of the project activity. The specialists included H. R. Feltz (March–June 1963), who evaluated facilities and investigational activities for the assessment of water quality; L. A. Heindl (June–August 1963), who made an evaluation of problems of report preparation and publication by the EGDDO; J. T. Long (June–August 1963), who advised EGDDO on geodetic control and topographic mapping in the New Valley Project; A. F. Holzle (June–October 1963), who continued the training begun by Mr. Minard in photogeology and photo-interpretation; F. E. Clarke, who in May 1963 made an additional appraisal of the corrosion characteristics of waters from the Nubian aquifer system and again in May 1964 advised on the selection of metal components for long-term development of the ground water; G. A. LaRocque (October–December 1963), who provided training to EGDDO engineers in quantitative methods of aquifer testing and analysis; H. E. Skibitzke and R. H. Brown (March 1964), who advised EGDDO on aquifer analyses and analog modeling; and A. E. Robinson (March–June 1964), who assisted EGDDO in the construction of an analog model of the New Valley Project.

In mid-1964 R. L. Cushman, USGS ground-water engineer, was named as Mr. Sundstrom's replacement and J. S. Gates, USGS hydrogeologist, to succeed Mr. Bieber. Owing to delays in processing administrative clearances and to prior commitments in the USGS domestic program, it was not possible for Messrs. Cushman and Gates to report for duty in Egypt until March 1965. Consequently, in the 6-month interim between September 1964 and March 1965 there was no on-the-ground USGS support of the project. By energetic endeavor, however, Messrs. Cushman and Gates were soon successful in re-establishing the previous momentum of project activity. They both continued to serve on the project with the planned phaseout of USGS support in May 1967, when Messrs. Cushman and Gates returned to the U.S. During this period, three USGS specialists were assigned for brief terms to assist the EGDDO in its project goals. These included F. E. Clarke (March–April 1965), who on his fourth visit to the project evaluated previous corrosion studies and EGDDO's efforts toward solving its well materials design problems; H. R. Feltz (June–July 1965), who returned to Egypt for a re-evaluation of water-quality investigations in the New Valley Project; and G. D. Bennett (January–March 1967), who made a quantitative evaluation of the aquifer characteristics of the Nubian system in Kharga Oasis based on data available as of January 1967.

As of the planned phaseout of active USGS technical support of the New Valley Project in May 1967, approximately 80 percent of initially identified project goals had been achieved, and, to attain the balance 20 percent, a series of short-term assignments by USGS specialists over an ensuing 2-year period had been planned and authorized by US AID and the UAR government. This balance, however, was not achieved as the project was terminated in June 1967.

Among the more tangible completed work activities in the Ground Water Investigations in the Western Desert (New Valley Project) as of May 1967 were the following: (1) about 86,000 sq mi of aerial magnetometry and photography (scale 1:50,000 contact prints and 1:500,000 controlled photo-mosaics) for resources planning and development, (2) surface geologic mapping and subsurface geologic studies in Al Wāhāt al Khārijah and Wāhāt ad Dākhilah oases, (3) surface resistivity, magnetic, and gravimetric surveys, (4) completion of about 80 percent of data collection, recording, and evaluation

of geologic and hydrologic data, (5) systematic artesian pressure and discharge measurements on 210 deep and 963 shallow wells in the two oases, (6) water sampling and analyses at 208 deep and 420 shallow wells, (7) single-well aquifer tests at 77 wells, (8) full corrosion studies in 14 representative wells, (9) construction of 231 wells ranging from 80 to 1,232 m deep under the guidance of US AID drilling advisors, (10) preparation of 19 reports under USGS authorship and 6 under Egyptian authorship relating to general and specific aspects of project activity, and (11) training of some 40 EGDDO geologists, chemists, and engineers in modern techniques of ground-water investigations.

As of the end of 1970, the UAR government was negotiating with the United Nations Development Programme (Special Fund) for renewed technical assistance in a 5-year land and ground-water development project in the New Valley.

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ETHIOPIA

Since World War II and under the leadership of His Imperial Majesty Haile Selassie I, Ethiopia followed an active policy of economic development and social improvement with monetary credits and technical assistance from the U.S. and other foreign donors. As of the end of 1968, U.S. bilateral aid to Ethiopia had reached a total of more than $229 million during the antecedent 20 years. USGS participation in the U.S. technical assistance program in Ethiopia began first in early 1966 and has been virtually continuous since February 1968. The scope and objectives of USGS technical support are described in the following sections.

Water-Supply Investigations for National Range Development Project, 1966, 1968–70

As part of its National Range Development Project with the Ethiopian Ministry of Agriculture, the U.S. Agency for International Development late in 1965 requested the short-term services of a U.S. specialist to review the water-supply problems in Sidāmo (Sidamo Province) of southern Ethiopia and to identify needs for water-resources investigations and pilot development that might be undertaken to improve the pastoral economy as well as to mitigate recurrent conflicts over local water supplies among tribal peoples of the region. D. A. Phoenix, USGS hydrologeologist, was assigned to the work and during February 1966 completed ground surveys and airborne reconnaissance of some 52,000 km² in southern Sidamo Province (figs. 17, 18, and 19). In his report he identified areas favorable, semifavorable,

FIGURE 17.—Aerial view of Borana tribal village with protective thorn-bush enclosures, one for the herdsmen and the other for livestock. About 15 km east of Yabelo (Iavello), Sidāmo (Sidamo Province).

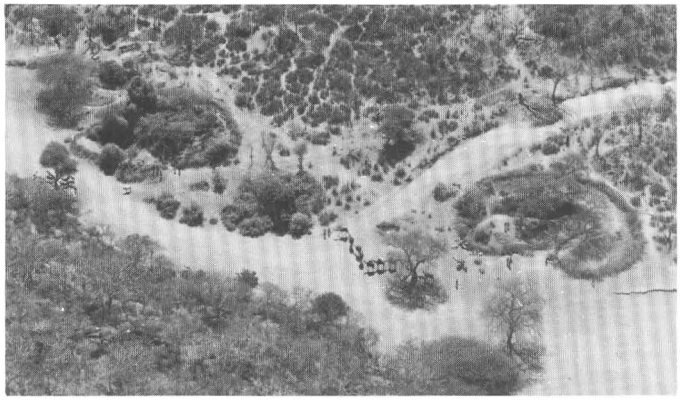

FIGURE 18.—Aerial view of two native wells at Salole, 147 km northeast of Mēgā, Sidāmo. Wells used for watering camels, cattle, and goats are surrounded by thorn-brush enclosures to exclude nocturnal predators or unwanted visitors.

FIGURE 19.—Borana herdswomen lifting water for their cattle from a spring-cum-well 2 km south of Mēgā, Sidamo. These two women form part of a four-stage human lift. An empty bucket goes down and a full one comes up.

and unfavorable for development of water supplies and distinguished areas where ground-water or surface-water development could be emphasized for livestock water supplies. He also outlined the scope, personnel, and equipment requirements for a long-term project of water-resources investigations and pilot development.

In February 1968, J. R. Jones, USGS hydrogeologist, arrived in Addis Ababa to undertake implementation of certain of Mr. Phoenix's recommendations for Sidamo Province, as well as to provide general advisory services in hydrology to the Ethiopian Water Resources Department in the Ministry of Public Works and Communications. Mr. Jones remained in Ethiopia until July 1970. During his 2½ year tenure, Mr. Jones oversaw the location of sites for drilling of wells and for construction of stock-water catchments by the Community Water Supply Division of the Water Resources Department as part of the National Range Development Project. He also worked with the Water Resources Department in establishing procedures and standards and in training Ethiopian personnel in ground-water geology and hydrology. During his stay in Ethiopia he participated in brief ground-water and water-supply studies near Yabelo, Mak'amet (Nekemtī), Gimma, Gondar, Keter, Mak'ale (Mekele), Robi, in the Alledeighy Plain, near Erer-Gota, Dirēdawā, Ayshā, Hārar, Jijigā, Chercher Awraja, Asalā, Qoshe, Tora, Ajjy and Dabrazabit. He also began an areal water-resources investigation in the Arreo area of Sidamo Province. Mr. Jones was especially effective as a member from September 1969 through June 1970 of the Asmara Water Emergency Committee, which was set up to develop long-range plans for alleviating water shortages resulting from recurring droughts in northern Ethiopia. After home leave, Mr. Jones was reassigned to Dacca as chief of party of the East Pakistan Ground Water Survey and was replaced by H. E. Gill, who arrived in Addis Ababa in December 1970.

SURFACE-WATER INVESTIGATIONS PROGRAM OF THE WATER RESOURCES DEPARTMENT, 1968

In response to a request of the Imperial Ethiopian Government to US AID/Addis Ababa, Walter Hofmann, USGS hydrologist, was assigned from April to June 1968 to review the status of the surface-water investigations program of the Ethiopian Water Resources Department in the Ministry of Public Works and Communications, to evaluate the adequacy of the stream-gaging network and the operational activities of the Department, to assess the training requirements of the Department in collecting and evaluating streamflow data and in using and maintaining hydrologic instruments and equipment, and to recommend a long-range program of technical support and training of Ethiopian personnel in surface-water investigations.

According to Mr. Hofmann's report of May 1968 the Water Resources Department was then operating 50 stream-gaging stations in the Blue Nile River

Basin and some 47 other stations in the Awash, Wābi Shabalē, Takaze, Bāro, Omo, and Central Lakes Basins. He pointed out also the importance of adequate streamflow data in the design, construction, operation, and management of hydroelectric power, irrigation, flood-control, and public water-supply projects. He emphasized the need for consolidating stream-gaging activities and sediment- and water-quality data collection in the Water Resources Department. He also recommended an intensive training program with USGS support over a 2-year period that would cover all aspects of streamflow data collection, including network design; gaging-station design, installation, and operation; discharge measurements, both direct and indirect; office computations and procedures; and hydrologic-study techniques.

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GHANA

When Ghana emerged in West Africa as an independent republic in March 1957, it embarked on an active program of social and economic development. Most important in this program was the Volta River Project, a $300 million dam at Akosombo impounding the Volta where it crosses the Akwapim-Togo Range about 105 km east of Accra. The dam, which was constructed during the early 1960's and became operational in 1964, has the potential to generate 1 million kilowatts of hydropower, of which 60 percent will be used for the beneficiation of aluminum ore (bauxite) and the rest for general electrification and industrial purposes.

The need to resettle a large rural population in the area that would be inundated by the creation of Lake Volta gave impetus to the investigation and development of ground water for rural and small municipal supply, particularly in the Volta River basin of central Ghana. Accordingly, the Volta River Authority in late 1963 requested US AID/Accra to provide the services of a U.S. specialist to evaluate the status of ground-water exploration and development in Ghana and to recommend measures for strengthening the program. H. E. Gill, USGS hydrogeologist, was assigned to the work and during February–May 1964 completed a countrywide ground-water reconnaissance in company with representatives of the Ghana Division of Water Supplies and the Geological Survey of Ghana. His report of April 1964 contains recommendations relating to organizational and personnel requirements, collection of basic hydrologic data, and areal ground-water investigations in the Coastal Plain and Voltain geohydrologic provinces. Also a formal report, which gives a general résumé of the availability and use of ground water and describes the occurrence of ground water in the five major geohydrologic provinces of Ghana, was published as a USGS Water-Supply Paper 1757–K in 1969.

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KENYA

Centrally situated in the equatorial region of East Africa and favored home of the lion, elephant, and zebra, as well as the big game safari, Kenya is a land of great geographic diversity that extends from high well-watered volcanic plateaus on the west to low semidesert steppes on the east. Kenya became a self-governing republic on December 12, 1963, within the British Commonwealth of Nations. Since independence, the U.S. has provided economic aid and technical assistance to Kenya, emphasizing agricultural and rural development and education and training for institutional management. The USGS has participated in the US AID program since mid–1967, chiefly in water-resources evaluations and pilot development in coastal and eastern Kenya.

Water-Supply Investigations of the Range Lands in the Coast Province, 1967

In mid–1967 the Government of Kenya requested US AID/Nairobi to provide the services of a U.S. specialist to evaluate its water problems and to recommend a long-term program of water-resources investigations and pilot development directed toward improving the economy of selected rangelands in the Coast Province. D. W. Brown, USGS hydrogeologist, was assigned to the work and between July and October 1967 completed a hydrogeologic reconnaissance of 60,000 km^2 in this region. His report of October 1967 described the general hydrology of the province and identified the water problems. He proposed a 4-year investigation of the available water resources in the province necessary for planning their rational development and utilization. The

recommended surface-water phase was to be directed toward the location of suitable "pan" or small reservoir sites on ephemeral streams and the evaluation of the permanence of the water inflow to these reservoirs. The ground-water phase was to be directed toward the evaluation of (1) the extent and geologic characteristics of the ground-water reservoirs, (2) the occurrence, movement, and recharge of ground water, (3) the potential yields of boreholes tapping the ground-water reservoirs, and (4) the chemical quality of the water. These recommendations were subsequently put into effect in a regionally oriented project in eastern Kenya, as described in the following section.

Range Water Development Project in the North-Eastern Province, 1968–70

A re-orientation of policy in early 1968 placed new emphasis on regional development in US AID's East African program. As a consequence of this re-orientation, it was decided to re-direct and incorporate Mr. Brown's proposals for Kenya's Coast Province toward a regional range-water development project that would start in eastern Kenya but that, if politically feasible, could ultimately be coordinated with similar work in contiguous areas of Ethiopia and Somalia. Accordingly, H. E. Thomas and J. R. Jones, USGS hydrologists, and F. D. Abercrombie, US AID range management expert, joined forces in April–May 1968 to review the requirements and to identify the scope and objectives of a regionally oriented project. As proposed in their report, the Range Water Development Project was designed (1) to be a cooperative undertaking between US AID and the Ministry of Agriculture in the Government of Kenya (GOK), and (2) to promote livestock production and proper management of the range in a region of perennial water deficiency in East Africa. Messrs. Thomas, Jones, and Abercrombie also recommended a 4-year project to be staffed by a U.S. team comprising a senior hydrologist, a hydrogeologist, a range planner, and an agricultural engineer, all under the leadership of the senior hydrologist.

As subsequently implemented, the project area covers about 125,000 km² comprising the North-Eastern Province of Kenya and including the Mandera, Wajir, and Garissa Districts. It is largely a semiarid plain whose vegetal cover is chiefly thorn scrub and grass. Because of low rainfall and the absence of water sources for large-scale irrigation, the area is best suited for production of livestock and game animals. The North-Eastern Province of Kenya is part of a larger region, about 350,000 km², that includes adjoining and economically associated areas in Somalia and Ethiopia. The overall long-term GOK objective is to expand the dry-season grazing area of 26,000 km² by about 25 percent and at a rate dependent on the economic exploitation of the water resources of the area. The specific goals of the project are (1) to provide the GOK with information on the water resources in the North-Eastern Province necessary to permit the development of these resources in support of expansion of utilization of the rangelands, and (2) to assess the livestock and game-carrying capacity of the range and formulate plans for the utilization of the water resources for optimum development of the range.

The project was formally begun in December 1968 with the arrival in Nairobi of M. J. Mundorff, USGS hydrologist, as project chief. W. V. Swarzenski, USGS hydrogeologist, arrived in February 1969 to work with Mr. Mundorff. F. H. Mass, range planning expert, and R. C. Kornegay, agricultural engineer from the U.S. Forest Service, arrived in April 1969 to complete the project team. The work activities of the U.S. team have included: (1) appraisal of the general hydrology and ground-water resources of the entire North-Eastern Province, (2) site selection and supervision of drilling of exploratory and production wells, (3) ecologic survey of the province and appraisal of the livestock and game carrying capacity of the range, (4) overall appraisal of the surface-water resources of the province, (5) formulation of plans for developument of surface water and ground water for optimum use of the range, (6) delineation of range management grazing units and evaluation of their carrying capacities and water requirements, (7) selection of sites and supervision of construction of surface-water storage catchments, and (8) exploration for ground-water supplies, including evaluation of quantities available and the design of supply wells. A feasibility report on development plans for surface-water storage reservoirs, well construction, and range management in the Mado Gashi-Kalalut area (about 7,200 km²) of the North-Eastern Province was completed in 1970, and other studies are in progress in areas farther north. The USGS team also will prepare a separate general report on the regional geohydrology of the North-Eastern Province.

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LIBYA

Libya, centrally located in North Africa, first emerged as an independent state on December 24, 1951. Soon after establishment of independence, the Government of Libya (GOL) embarked on an expanded program of agriculture and industrial development with the technical assistance of foreign donors. As Libya is largely desert, with only 6 percent of its 1.6 million km^2 classified as agricultural land and with virtually no permanent streams, the newly founded GOL placed great emphasis on the exploration and exploitation of ground-water resources as an essential requisite for the development program.

Ground-Water Geology Project, 1952–64

The GOL in January 1952 signed an agreement with the U.S. Technical Cooperation Administration, a forerunner of US AID, to provide long-term technical assistance in ground-water exploration and pilot development. The USGS was requested by US TCA to furnish the expert technical support services. Formal USGS support of the "Ground-Water Geology Project," as it was known for most of its history, was begun in April 1952 and was continued virtually without interruption until June 1964.

Although during its 12-year history the project underwent several modifications in scope, direction, and content as a result of the changing needs of the GOL, the general project objectives remained essentially the same. These were as follows: (1) to investigate the ground-water resources of Libya, (2) to report on the results of investigations, (3) to assemble, file, and interpret available hydrologic data and reports on ground water in Libya, (4) to assist in the promulgation of legislation necessary for the orderly development, management, and conservation of Libya's water resources, (5) to advise and assist in the building of an agency within the GOL responsible for directing and administering the beneficial development and use of the nation's ground-water resources, (6) to provide on-the-job technical training to Libyan counterparts in the methods and techniques of ground-water investigations, (7) and to advise the GOL, US AID, other international agencies, private individuals, and corporations on matters relating to ground-water availability, development, and management in Libya.

During the life of the Ground-Water Geology Project, the number of USGS hydrogeologists assigned to technical support at any one time ranged from one to four men. Libyan counterpart staff in the same period ranged from 10 to 20 individuals of technician or sub-professional level. For operational and administrative purposes the project ultimately was divided into three subprojects corresponding to the former provinces of Tripolitania, Cyrenaica, and Fezzan in the Libyan federation with the Nazarat (Department) of Agriculture in each province as the chief counterpart agency. In 1960, ground-water investigations were distinguished and separated from the production drilling activities of the nazarats and were designed as a responsibility of the central (federal) government. Thus, in the later stages of USGS support, there existed, in effect, four subprojects. The USGS technical support covered a wide range of activities grouped in the categories of (1) exploratory and pilot production well drilling, (2) areal ground-water investigations, (3) laboratory and on-the-job training of Libyan counterparts, and (4) general advisory and consultative services to GOL officials on all aspects of ground-water investigation, development, and management.

Formal USGS support of the Ground-Water Geology Project was begun with the short-term (April–October 1952) assignment to Libya of R. C. Baker, who assembled ground-water data on the Al Jifārah (Gefara-coastal plain) of Wilāyat Tarābulus (Tripolitania) and submitted a brief report on his findings. G. B. Maxey, (November 1952–July 1954), who succeeded Mr. Baker, began a regular program of ground-water investigations in the Al Jifārah (fig. 20) and elsewhere in the Wilāyat Tarābulus (Tripo-

FIGURE 20.—Libyan technicians measuring water level in ancient well, still in use for hydrologic observations, as part of Ground Water Geology Project, 1952–64. Ruins of theater built by Romans at Leptis Magna in coastal Al Jifārah form backdrop.

litania) subproject, including the collection, recording, and organizing of hydrologic data, and the selection and procurement of equipment for exploratory drilling. H. A. Whitcomb (June 1954–June 1956) continued the work of Mr. Maxey, guiding the exploratory drilling program in the Gefara and in the Jabal Nafūsah of Wilayat Tarābulus. During the latter part of his stay in Libya, Mr. Whitcomb started the Wilāyat Fazzān (Fezzan) subproject and also undertook and completed a general areal reconnaissance of the ground-water resources of the Wilāyat Fazzān (Fezzan) region in southwestern Libya. D. J. Cederstrom (July 1955–July 1957) shortly after his arrival in Tarābulus (Tripoli) assumed responsibility for USGS technical support activities in Wilāyat Tarābulus, while Mr. Whitcomb concentrated on work in the Wilāyat Fazzan. Among other advisory and consultative duties, Mr. Cederstrom during his stay undertook and completed a comprehensive investigation of the ground-water resources of the Tarābulus area, the economic and political center of Libya. R. C. Vorhis (January 1956–September 1960) was assigned to work with Mr. Cederstrom on the Wilāyat Tarābulus subproject. Mr. Vorhis was notably successful during his 4½-year stay in training Libyan counterparts in ground-water hydrology and in systematizing the collection and tabulation of hydrologic records in the Nazarat of Agriculture. He also completed ground-water studies near Surt (Sirte), Zlitan, and elsewhere in coastal Wilāyat Tarābulus. G. C. Tibbitts, Jr., (April 1956–October 1962) on his arrival in Sabhah (Sebha) assumed responsibility from Mr. Whitcomb for USGS support of the Wilāyat Fazzān subproject. During his 6-year stay in Libya, Mr. Tibbitts centered most of his work on exploratory drilling and ground-water investigations, notably in the Wādī ash Shātī' (fig. 21) but also in the Ghāt, Sabhah-Samnu, and Hūn-Waddān areas and the Hammādat-Marzuq (Murzuk) basin, all in the Wilāyat Fazzān.

USGS support of the Wilāyat Barqah (Cyrenaica) subproject began in 1956 with the arrival of W. W. Doyel (August 1956–September 1958) in Banghāzi (Benghazi). Mr. Doyel directed his efforts chiefly toward ground-water investigations and exploratory drilling in the coastal zone south of Banghāzi and in studies of ground-water conditions near Darnah (Derna) and Tubruk (Tobruk) on the eastern Wilāyat Barqah coast. J. R. Jones (March 1958–June 1964) during his first 3-year tour and with headquarters at Banghāzi concentrated his efforts on ground-water investigations and exploratory drilling in the Wilāyat Barqah subproject, notably in the coastal plain near Banghāzi, in Al Jabal al Akhdar, and elsewhere in the Wilāyat Barqah littoral zone. In 1960 he participated in a regional ground-water reconnaissance with USGS hydrogeologists, G. C. Tibbitts, Jr. and T. G. Newport, and Libyan counterparts of the vast desert region in southern Wilāyat Barqah and western Libya, extending from the Mediterranean coast south to the central Sahara. This reconnaissance led to the discovery of extensive artesian aquifers in the Nubian Series of Al Hufrah basin (Kufra Basin). These aquifers in 1970 were under development for large-scale irrigation.

FIGURE 21.—Libyan technicians operating hand-powered drilling rig in the Wādī ash Shatī under direction of USGS hydrogeologist, G. C. Tibbitts, Jr. Driller at left turns drilling rod to rotate bit. Men pull down on drilling line, lifting bit, which drops about 45 cm on release of line. Hand winch at right raises and lowers tools.

On his return from home leave in 1962, Mr. Jones' headquarters were transferred from Banghāzi to Tarābulus so that he could assume more effectively overall direction of the USGS/USAID Ground Water Geology Project which he continued until June 1964. During the last 2 years of his stay in Libya, Mr. Jones concentrated his efforts (1) on planning for the organizational development of a Water and Soil Department in the Libyan Ministry of Agriculture and Animal Wealth, (2) on the design of a National Water Law for the GOL, and (3) on general advisory and consultative services to the GOL, US AID, international agencies, and private organizations on matters pertaining to ground-water development and management throughout Libya.

T. G. Newport (March 1959–June 1961) was assigned to the Wilāyat Barqah subproject after Mr.

Doyel's return to the United States. Active USGS support of the Wilāyat Barqah subproject ended with the completion of Mr. Newport's tour. During his tour, Mr. Newport directed his efforts principally toward training of Libyan technicians and well drillers and toward exploratory drilling and groundwater investigations in Al Marj (Barce) area of the Al Jabal al Akhdar region. Meanwhile, active USGS support of the Wilāyat Tarābulus subproject continued with the short-term (Jan. 1960) assignment of W. T. Stuart, who reviewed the significance of water-level declines determined from pumping tests in wells of the Gefara. Also William Ogilbee (November 1960–December 1962), who arrived in Tarābulus to succeed Mr. Vohris, continued the training of Libyan counterparts and undertook and completed ground-water investigations in the Qasr al Qarahbulli, Al Mayah, Surmān, and Az Zāwiyah areas of the Al Jafārah (fig. 22) and also in the Surt (Sirte) area. Completion of Mr. Tibbitts' tour (October 1962) and that of Mr. Ogilbee (December 1962) ended active USGS support of the Wilāyat Fazzān and Wilāyat Tarābulus subprojects. Mr. Jones, however, continued as the sole and senior USGS groundwater expert in Libya until the phaseout of the project in July 1964.

Among the more tangible accomplishments of the Ground Water Geology Project during its 12-year life were the following: (1) completion of field studies including collection, recording, and evaluation of hydrogeologic data in some 25 localities or areas with critical ground-water problems, chiefly in the coastal areas of Wilāyat Tarābulus and Wilāyat Barqah but also in the Wilāyat Fazzān, (2) completion of several general nationwide assessments of ground-water availability, including a comprehensive survey of the ground-water resources of the entire country, (3) establishment of a continuing observation-well program in Wilāyat Tarābulus and Wilāyat Barqah, (4) construction of 171 exploratory and pilot production wells for a cumulative depth total of 16,194 m, (5) a leading role in planning and design of a draft National Water Law, which was enacted in 1965 by the Libyan parliament subsequent to the phaseout of the project, (6) advisory and consultative services to GOL on a dozen or more specific ground-water development projects carried out by private contractors, particularly during 1960–64, (7) planning and design for a National Water and Soil Department in the Ministry of Agriculture and Animal Wealth, (8) preparation of some 35 technical and administrative reports under USGS or joint USGS-Libyan authorship relating to general and specific aspects of project activity, and (9) training of some 50 Libyans, almost all at sub-professional or technician level, in on-the-job well drilling techniques, as well as in hydrologic data collection, processing, compilation, and analysis.

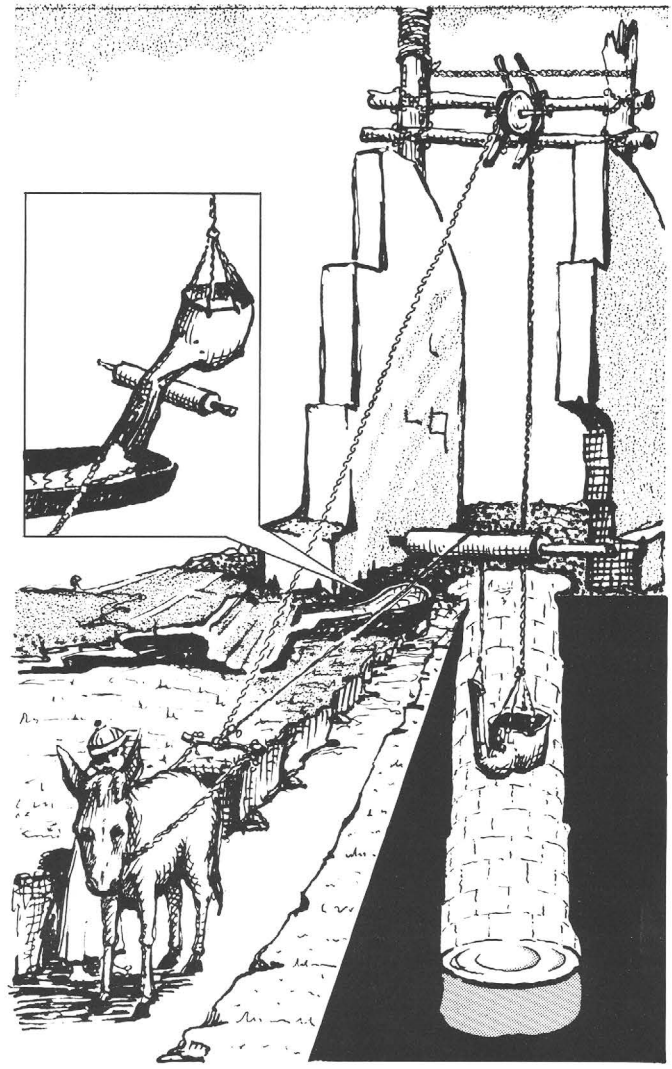

FIGURE 22.—Sketch illustrating operation of a "dalu," an age-old method of drawing water from shallow dug wells by rope cable, leather bag, and animal power. Still widely used in Al Jafārah of Libya and elsewhere in North Africa.

POST-PROJECT REVIEWS, 1967, 1969, 1970

After the phaseout of the US AID technical assistance program in Libya, the Government of Libya in mid–1967 requested the U.S. Geological Survey through the U.S. Embassy in Tarābulus to provide the short-term advisory and consultative services of J. R. Jones on a fully reimbursable basis. Mr. Jones arrived in Libya in early October 1967. During a 6-weeks sojourn he (1) reviewed for the Ministry of

Planning and Development the specifications of a proposed Inventory of the Natural Resources of Libya submitted by the Government of France, (2) reviewed for the Ministry of Agriculture and Animal Wealth the progress in water-resources investigations since the phaseout of the Ground-Water Geology Project in June 1964, (3) advised the Ministry of Planning and Development on organizational and staffing requirements of the Water and Soil Department then in the process of activation, and (4) conferred with various government officials in several ministries on then-current problems in ground-water investigations, development, and management.

At the invitation of the Government of Libya, Mr. Jones participated during April 14–18, 1969, in a Symposium on the Geology of Libya sponsored by the University of Libya in Tarābulus. In a symposium session attended by more than 300 Libyan and expatriate scientists, engineers, and administrators, Mr. Jones presented a paper on "Ground Water Provinces of Libya" which was well received by those interested in and concerned with Libya's ground-water problems. On the occasion of this visit, he again reviewed briefly current progress and problems in ground-water investigations and development with the Libyan officials.

While in transit to East Pakistan in August 1970 and at the request of the U.S. Embassy, Mr. Jones stopped in Tarābulus to discuss with Libyan officials a proposal for renewed USGS technical assistance in hydrologic training and related ground-water studies. He also reviewed for the Ministry of Agriculture and Agricultural Reform a French consortium's proposal for water, soil, and agro-economic surveys of selected areas in Libya and a Yugoslav consortium's proposal for agricultural development in the Surt area.

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MOROCCO

Most of central Morocco is occupied by highlands of the Atlas Range, which serve as the water catchment for bordering semiarid valleys and plains. Because of the spatial and temporal imbalance of its water supply, the Government of Morocco (GOM) has long recognized the need to optimize the use and management of the nation's water resources to sustain continuing economic development. To further this objective the GOM in mid–1967 requested US AID/Rabat to furnish the short-term services of a U.S. expert (1) to review the current status of hydrologic knowledge with respect to actual and proposed water-resources development in Morocco and (2) to identify needs for possible US AID technical assistance in this field. D. A. Phoenix, USGS hydrologist, assigned to the work, completed during July–September 1967 (1) a historical review of hydrologic investigations and the operations of GOM agencies responsible for them and (2) a field reconnaissance of the geohydrologic features of the major river basins and ground-water systems of the country.

Mr. Phoenix's report of October 1967 evaluated current and past hydrologic and hydrogeologic investigations by GOM technical and scientific agencies, described the geohydrologic features of the major river basins (figs. 23 and 24) and groundwater systems, and presented recommendations for a possible 4-year joint US AID/GOM program of hydrologic investigations with the Moroccan Division of Water Resources in the Ministry of Public Works as the chief counterpart agency. The report highlighted the fundamental needs of Morocco with respect to expanding industrial and municipal water requirements, limitations of ground-water supplies (fig. 25), repetitive damage by floods, augmentation of irrigation perimeters, and salinity alleviation and control.

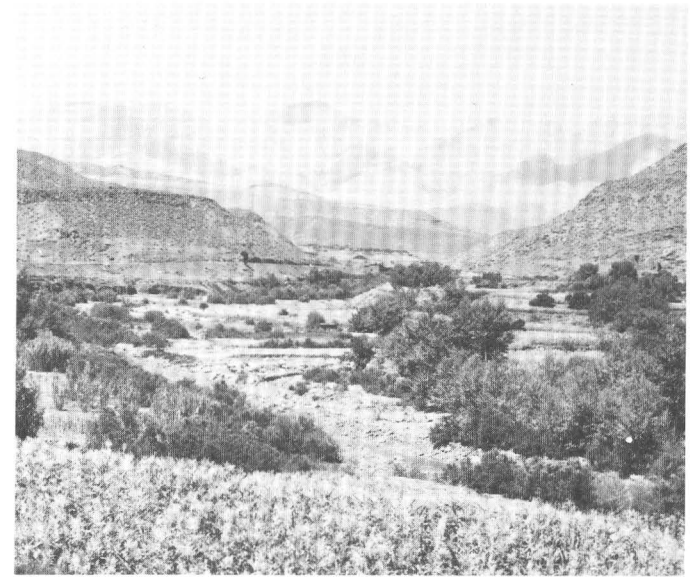

FIGURE 23.—Upper watershed of the Oued Draa. View west toward the crest of the Haut Atlas, eastern Morocco.

FIGURE 24.—Spring-fed tributaries of the Oued Sebou. Springs discharge from piedmont gravels underlying the Meknes-Fes Plain. View northeast toward the Moyen Atlas about 12 km west of Meknes.

The proposed 4-year program included recommendations for systematic evaluation of the occurrence and chemical quality of the water resources in the more important river basins; summarization of existing hydrologic data to identify water wastage, deterioration, and reserves; installation of a hydrologic laboratory with related equipment; exploration of ground-water reservoirs; and training of Moroccan professional and subprofessional personnel. The proposed program was approved by US AID/Rabat but as of 1970 had not been implemented because of limited availability of and earlier priorities for technical assistance funds in Morocco.

FIGURE 25.—Camel-driven water-wheel or "noria" used to recover ground water from shallow dug well in semiconsolidated deposits of dune sand and coquina. Such wells are used to irrigate small vegetable gardens along the Atlantic Coast between El Jadida and Safi.

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NIGERIA

Nigeria, the most populous nation in Africa, was initially organized as a federation comprising three semiautonomous regions, Eastern, Western, and Northern, that corresponded to broad religious, linguistic, and tribal groupings. On October 1, 1960, Nigeria was established as an independent nation in the British Commonwealth. Not long after in early 1961 and in response to a request from the new government, US AID/Lagos approached the USGS with respect to providing technical support for water-resources investigations in Nigeria. The USGS support program in water resources began in June 1961 with a brief review of requirements for ground-water investigations in the Northern Region (now Northwest, Northeast, and North-Central States). This review led to initiation in November 1962 of countrywide advisory services in hydrogeology to the Geological Survey of Nigeria (GSN) and somewhat later to moderately intensive ground-water investigations in the Chad and Sokoto Basins of the former Northern Region. In 1963 a general assessment was made by a USGS hydrologist of the status and requirements for water-resources investigations throughout Nigeria. Recommendations included in the report on this assessment led to initiation in 1964 of USGS support of surface-water investigations in the former Northern Region and then later in 1965 to support of surface-water investigations in the former Eastern Region. By late 1965 systematic investigations of water resources were receiving support from all major Federal and Regional natural-resource departments in Nigeria.

GROUND-WATER INVESTIGATIONS IN THE NORTHERN REGION, 1961, 1962–68

To further its policy of stabilizing nomadic populations (fig. 26) and improving the pastoral economy of the former Northern Region, the Government of Nigeria (GON) began in the late 1950's an extensive program of well and borehole construction for village and stock-water supplies, chiefly in the Chad and Sokoto Basins. Early in 1961 the GON decided to request US AID/Lagos for U.S. technical assistance to review the results of earlier ground-water development and to recommend technical support needed in long-term investigations for guidance of future development. As a result of this request, H. E. Thomas and L. C. Dutcher, USGS hydrogeologists, were assigned to Nigeria and completed during June 1961 an evaluation of past and proposed ground-

FIGURE 26.—Women of nomadic Shuwa tribe filling clay pots and calabashes at flowing artesian well near village of Ngala in Chad Basin of northeastern Nigeria. This is a 11.4 cm diameter well, which was screened between depths of 285 and 291 m and initially flowed 9.5 l/s.

water development programs in the former Northern Region. Their report of August 1961 also identified the scope, objectives, equipment, and personnel requirements and proposed USGS technical support of 4-year ground-water investigations both in the Chad Basin of northeastern Nigeria and in the Sokoto Basin of northwestern Nigeria with the Geological Survey of Nigeria (GSN) as principal counterpart agency. In addition they pointed out the need for a senior USGS ground-water advisor with country-wide responsibilities and attached to the GSN headquarters at Kaduna.

D. A. Phoenix, USGS hydrogeologist, arrived in Kaduna in November 1962 to serve as senior USGS advisor on the program, designated by US AID/Lagos as "Water Supply Investigations," and continued in this capacity until his return to the U.S.A. in November 1966. During his stay in Nigeria he served as principal USGS advisor to the Director, US AID/Lagos and to the Director, GSN and the Chief, Water-Supply Section in planning, organizing, and conducting GSN's program of ground-water exploration, appraisal, and investigation, chiefly in the former Northern Region but also elsewhere in Nigeria. From time to time he served as advisor to the Nigerian delegation of the international Chad Basin Commission on problems related to water-resources development in the Lake Chad region. He also gave general programming direction and logistic support to USGS personnel assigned to the Chad and Sokoto Basin projects and the water-quality laboratory in Kaduna. While in Nigeria and in addition to his advisory and consultative duties, Mr. Phoenix completed reconnaissances of ground water near Ahmadu Bello University, Hunkuyi, and Manchok in Zaria Province; at the Ikoradu Farm Institute in the Western State (Western Region); at Lafia in Benue-Plateau State (Benue Province); and in the Anambra Basin in the former Eastern and Northern Regions. He also conducted a lecture series on problems in ground-water geology and hydrology, to geology and engineering students at the university centers in Ibadan and Zaria. Before his departure from Nigeria, Mr. Phoenix began preparation of a general description of the water resources in Nigeria, which was later completed on his return to the U.S.A.

Chad Basin Project.—USGS support of a two-phased ground-water investigation in an area of about 65,000 km^2 of the Chad Basin in Bornu and Dikwa Emirates, began in January 1963 with the arrival in Maiduguri of R. E. Miller, USGS hydrologist, to serve as project chief. R. H. Johnston, USGS hydrogeologist, arrived in March 1963 to work with Mr. Miller. Also three Nigerian hydrogeologists and several technicians of the GSN assisted in project activities and were trained by Messrs. Miller and Johnston and their successors during the life of the project. Owing to effective planning and timing of GSN counterpart and logistic support, Messrs. Miller and Johnston were notably successful in achieving practically all objectives of the first phase of the project during their 2-year stay in Nigeria. Mr. Johnston returned to the U.S.A. in April 1965 and Mr. Miller in May 1965. F. E. Clarke, USGS corrosion specialist, visited the project briefly in March 1965 to evaluate corrosion problems in well casings and screens. His report of July 1965 describes in some detail requirements for long-term corrosion studies and measures needed for corrosion control under conditions prevailing in the Chad Basin.

The principal objectives during the project's first phase were (1) to evaluate the characteristics of the geohydrologic system including the occurrence, movement, recharge, and discharge of ground water, with particular emphasis on the behavior of the Middle Zone artesian aquifer in the Pliocene-Pleistocene Chad Formation and (2) to determine the quantity of artesian water available and the flow life of the artesian system with respect to actual and potential rates of extraction from some 250 active flowing boreholes (drilled wells) as of 1965. First-phase project activities included: (1) construction by Balakhany (Chad) Ltd. and under USGS guidance of 50 exploratory and observation boreholes (fig. 27) from about 150 to 400 m deep and scattered through the project area, (2) installation of automatic pressure recorders on six artesian observation boreholes, (3) monthly measurements on a network of water-table wells and artesian boreholes throughout the project area, (4) completion of a depth-to-water map of the shallow ground water and potentiometric maps of the Middle Zone artesian aquifer, (5) completion of comprehensive flow (aquifer) tests on the Middle Zone aquifer at four sites, (6) measurements on several streams in the area to evaluate infiltration rates at different rates of discharge, (7) inventory in 1965 of extraction and water use (fig. 28) from the Middle Zone aquifer, (8) initiation of water-quality studies of the ground water including problems of well-casing corrosion in boreholes, (9) special studies related to development of a ground-water supply for the city of Maiduguri, and (10) training of 10 Nigerian professional and technician counterparts. Two USGS open-file reports and USGS Water-Supply Paper 1757–I that

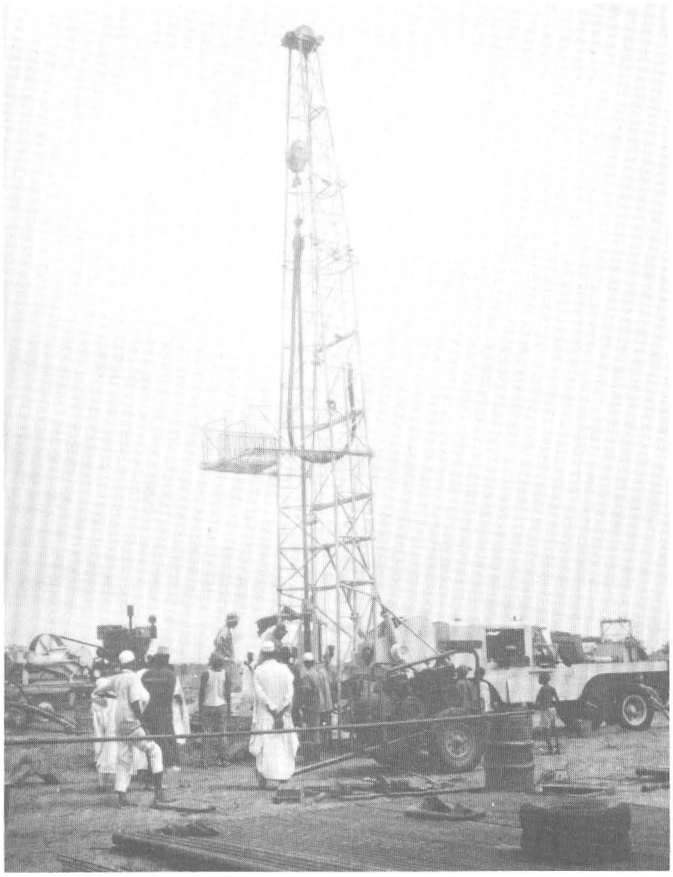

FIGURE 27.—Rotary rig (Failing-1500 model) used for drilling small-diameter (11.4 to 17.8 cm) wells to depths down to 457 m in Chad Basin Project, northeastern Nigeria.

describe the technical results of these activities have been published.

The most tangible benefits of first-phase activities were: (1) identification of optimum spacing and individual rates of withdrawal from boreholes tapping the Middle Zone aquifer in a 65,000 km^2 area, (2) recommendations as to optimum water use based on chemical quality and available quantities, (3) alleviation of water shortages for the city of Maiduguri and Bornu Ranch, (4) improvements in techniques of artesian well construction and development in the basin, (5) training of Nigerian counterparts.

After a break of several months, during which routine hydrologic observations were continued by GSN technicians, a second phase of study was begun in the Chad Basin Project in January 1966 with the arrival of G. C. Tibbitts, Jr., USGS hydrogeologist, in Maiduguri (fig. 29). Mr. Tibbitts served as project chief until the termination of USGS support and his return to the U.S.A. in August 1968. From September 1967 until August 1968, Mr. Tibbitts was

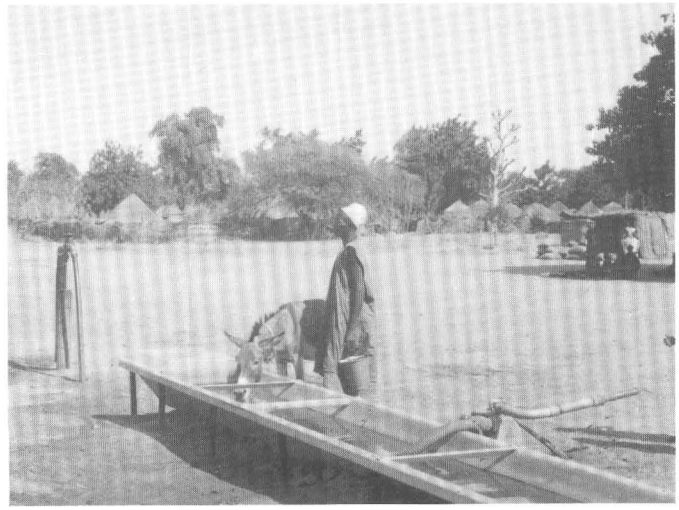

FIGURE 28.—Metal cattle trough supplied by flowing artesian well at village of Ngala, Chad Basin, northeastern Nigeria. Trough contains float-operated valve, which prevents wastage and conserves artesian pressure.

FIGURE 29.—Cereals and peanuts, a dietary staple, on sale at the Maiduguri market.

ably assisted by S. W. Carmalt, geologist of the Peace Corps Volunteers. For the most part, project objectives during Mr. Tibbitts' stay were continuations or extensions of first-phase activities. Field studies of the geohydrologic system concentrated on the behavior of the Upper Zone (shallow) aquifer, intensified water-quality data collection for geochemical studies of the Middle Zone aquifer, additional test drilling and exploration of the Middle Zone along the highways between Maiduguri and Beni Sheik and between Damakuli and Mongonu, and continuation and intensification of geohydrologic data collection. Mr. Tibbitts also assisted and

advised the GON on problems related to the development of ground-water supplies for the city of Maiduguri and the Teacher Training College at Bauchi.

Sokoto Basin Project.—USGS support of a two-phased ground-water exploration project began in March 1963 with the arrival in Sokoto of William Ogilbee, USGS hydrogeologist, to serve as project chief. Mr. Ogilbee worked on the project until July 1965 when he returned to the U.S.A. H. R. Anderson, USGS hydrogeologist, arrived in Sokoto in June 1964 to work with Mr. Ogilbee and continued on in Nigeria until the termination of USGS support of the field activities in October 1966. Three Nigerian hydrogeologists of the GSN were trained by Messrs. Ogilbee and Anderson during the project life. The chief objective of the project was to define the hydrogeologic framework of the Sokoto Basin, a 65,000 km^2 region in northwestern Nigeria, with respect to the areal distribution of confined (pressure) aquifers, the hydraulic characteristics of the aquifers, the potential yields from flowing boreholes, the areas of artesian flow, and the chemical quality of the ground water. The Geological Survey of Nigeria (GSN) was the chief counterpart agency throughout the project life, but the Regional Ministry of Works (MOW) and the Sokoto Native Authority also participated in the project in its second phase.

The first phase of the project, begun in March 1963 and completed in March 1965, was directed toward ground-water exploration of the Eocene Gwandu Formation, which crops out in the western part of the Sokoto Basin. The principal goal was to define areas where flowing water might be obtained from the confined (pressure) aquifer in the basal Gwandu, the purpose being to satisfy needs for livestock and village water supply, principally in the arid region west of the Sokoto (River). During this study the source of the water, the direction of ground-water flow, the areal extent, and the physical, chemical, and hydraulic characteristics of the Gwandu confined aquifer (fig. 30) were evaluated from the results of 23 exploratory boreholes put down at 9 sites by Balakhany (Overseas) Ltd. These boreholes, ranging from 55 to 601 m deep, have proved that the confined aquifer in the basal Gwandu extends under about 14,840 km^2 of the western Sokoto Basin and generally yields water of good chemical quality. Free flow, with artesian heads ranging from a few centimetres to 25.3 m above land surface, was found at five sites, and subartesian conditions that would require pumping for water extraction were found in the remainder. Also, artesian flows sufficient for livestock and village water supplies can be obtained from boreholes tapping the basal Gwandu aquifer in five subareas totaling about 2,600 km^2.

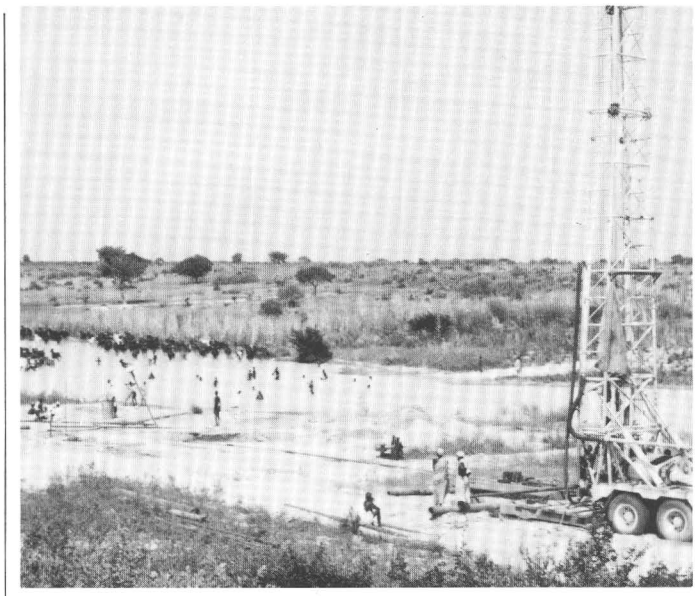

FIGURE 30.—Boreholes GSN 3056 and 3066, put down to depths of 264.8 and 266.7 m, respectively, at Kurdula for tests of the artesian aquifer in the Eocene Gwandu Formation of the Sokoto Basin. Tower of rotary drilling rig is at right.

After completion of exploratory drilling in the Gwandu Formation in March 1965, some 30 boreholes were put down in Cretaceous formations in the eastern half of the Sokoto Basin. These boreholes also were drilled by Balakhany (Overseas) Ltd. but under contract to the MOW and the Sokoto Native Authority to provide water for village use and road construction. Although the boreholes were drilled primarily for local water needs, they also provided valuable data for regional evaluations of the physical, chemical, and hydraulic characteristics of aquifers in the Cretaceous Gundumi Formation and Rima Group. In July 1966 test drilling was resumed through agreement between the GSN and US AID to explore the downdip extensions of the Cretaceous aquifers underlying the western part of the Sokoto Basin. Drilling operations on this phase continued until May 1967. Altogether five deep boreholes were drilled to depths ranging from 275 to 488 m. The results showed, in fact, that flowing water could be obtained from boreholes tapping Cretaceous aquifers but only in low-lying tracts, such as in the Sokoto (River) flood plain (fig. 31). Although USGS support of the project was terminated a few months ahead of schedule, virtually all planned project objectives were achieved. The technical results of the

FIGURE 31.—Sokoto (River) near Birnin Kebbi. View upstream along flood plain (fadama). Terrain is underlain by Upper Cretaceous and lower Tertiary sedimentary rocks.

work are described in a USGS open-file report and USGS Water-Supply Paper 1757–L.

Water-quality project.—As part of USGS support of US AID's Water-Supply Investigations program in northern Nigeria, R. T. Kiser, USGS chemist, was assigned from June 1965 to August 1968 to advise on water-quality studies with headquarters at Kaduna. The general purpose of Mr. Kiser's assignment was to improve knowledge of the chemical characteristics of the water resources of Nigeria, particularly in the Northern Region. The objectives of his assignment included (1) strengthening the water-chemistry activities in the GSN Laboratory at Kaduna, (2) establishing laboratory and field procedures for water-quality studies in support of ground-water investigations, (3) investigating the chemistry of ground waters in the Chad and Sokoto Basins with emphasis on their corrosive effects on metallic components of wells, screens, pumps, and distribution pipes, and (4) training of Nigerian personnel in the methods and techniques used in water-quality studies.

Specific accomplishments resulting from Mr. Kiser's assignment included (1) nearly 400 complete chemical analyses of surface-water and ground-water samples from the Chad, West Chad, and Sokoto Basins, the Kerri Kerri area, the Kaduna-Zaria area, and Lake Chad itself, all in the former Northern Region, (2) improvements in updating analytical procedures and equipment in the water-quality section of the GSN Laboratory at Kaduna, (3) training of two Nigerian chemists and several laboratory technicians of the GSN in water-quality analysis, (4) joint field studies with Mr. Tibbitts of water quality in the Chad Basin, (5) four GSN and USGS open-file reports on water quality in northern Nigeria.

ASSESSMENT OF NEEDS FOR WATER-RESOURCES INVESTIGATIONS IN NIGERIA, 1963

The Federal Ministry of Economic Development had recognized for some years the fragmented condition of water-resources investigations among the federal and regional governments of Nigeria and the need to obtain a comprehensive inventory of the nation's water resources for planning and development objectives. In late 1962, the ministry requested US AID/Lagos to provide the short-term services of a U.S. expert for an assessment of the status of existing water-resources investigations and an evaluation of ways of sharpening their focus toward national needs. W. H. Robinson, USGS hydrologist, was assigned to the work and during January–April 1963 completed a detailed appraisal of these activities throughout the federation. His reports of April–May 1963 recommended an intensive 2-year National Water Survey to be undertaken under the guidance of a 10-man interdisciplinary team of U.S. hydrologists, hydrogeologists, and hydrochemists working directly with both federal and regional water-resources agencies and coordinated by a U.S. project leader. The entire staff would have been administratively attached to the Federal Ministry of Economic Development.

Although Mr. Robinson's recommendations were not fully implemented, parts of the proposal that pertained to surface-water investigations in the former Northern and Eastern Regions subsequently resulted in the assignments of USGS hydrologists, Colson, Sieber, and Lucero, as described in the following sections.

SURFACE-WATER INVESTIGATIONS IN THE NORTHERN REGION, 1964–68

The nationwide assessment of needs for water-resources investigations in Nigeria by Mr. Robinson led US AID/Lagos to request in early 1964 the services of two USGS hydrologists for technical support of surface-water investigations, as a phase of US AID's Land and Water Resources Appraisal program in the former Northern Region. In fulfillment of this request, B. E. Colson arrived in Nigeria in July 1964 to assist in developing long-term surface-water investigations, with emphasis on the availability of water for major irrigation development of streams of the Komadugu Yobe River system contributory to Lake Chad (fig. 32). With headquarters

FIGURE 32.—Native in boat made of reeds passing staff gage at Wulgo on El Beid River near Lake Chad.

at Kano, Mr. Colson first worked with the Irrigation Division of the Regional Ministry of Agriculture in upgrading surface-water observations. A subsequent reorganization transferred the project to the Regional Ministry of Natural Resources and Community Development, later to the Regional Ministry of Works and Water Resources, and then to the Kano State Ministry of Works and Survey. During Mr. Colson's stay, 25 Nigerian professionals, technicians, and field observers were trained to operate automatic stream-gaging equipment, to compute daily records, to make discharge measurements, and to collect depth-integrated sediment samples. Mr. Colson also directed the collection during 1964–68 of records at 28 sites that included river stage, discharge, chemical quality, and sediment data. Satisfactory rating curves were defined at 15 sites and 55 station-years of mean daily discharges were computed. More than 500 water samples were collected and were analyzed in the Kano Soils and Water Laboratory of the Ministry of Agriculture for chemical quality and sediment content. Information was made available also for a feasibility study for major irrigation development carried out by a U.S. Bureau of Reclamation (USBR) team under US AID auspices. The data furnished the USBR team included flood hydrographs, instantaneous peak discharge, and chemical and sediment data, as well as the daily, monthly, and annual mean discharge of the major streams of the Komadugu Yobe River system. Mr. Colson succeeded in accomplishing most project objectives. He returned to the United States in November 1968. A general description of the hydrology together with hydrologic data for the Komadugu Yobe River system were released in January 1969 in a USGS open-file report.

A second USGS hydrologist, C. R. Sieber, was assigned to Nigeria in September 1964 with headquarters at Kaduna. Mr. Sieber's primary mission was to assist in the establishment of a regional hydrologic office at the headquarters of the Irrigation Division, Ministry of Agriculture, where all hydrologic records for northern Nigeria could be processed, filed, and evaluated primarily with respect to irrigation-feasibility appraisals. The office would have brought together all records on precipitation, surface runoff, and storage for design of irrigation layouts and for flood routing through reservoirs. Although Mr. Sieber was successful in training several Nigerian technicians in basic stream-gaging methods, the primary mission was not accomplished. Mr. Sieber returned to the USGS domestic program in October 1966 and was not replaced.

SURFACE-WATER INVESTIGATIONS IN THE EASTERN REGION, 1964–67

Another outgrowth of Mr. Robinson's 1963 review of needs for water-resources investigations in Nigeria was a request from US AID/Lagos in later 1964 for the services of a USGS hydrologist to assist in developing long-term surface-water investigations as a phase of US AID's Land and Water Resources Appraisal program in the former Eastern Region. In accord with this request, E. D. Lucero, USGS hydrologist, was assigned to the work, arriving at Enugu headquarters in November 1965. The objectives of Mr. Lucero's mission were to organize a Surface-Water Hydrology Department in the Regional Ministry of Works; to staff and train Nigerian personnel to carry on the functions of the department; to collect streamflow records, sample water for chemical quality and sediment analysis, and collect precipitation and some evaporation data; to establish and operate hydrologic stations on streams of the former Eastern Region; and to collect, compile, compute, and evaluate antecedent as well as new data.

During Mr. Lucero's 22-months' stay in Nigeria, 30 professionals, technicians, and field observers were trained to operate automatic stream-gaging equipment, to compute daily records, to make discharge measurements and to collect depth-integrated water-quality and sediment samples. Mr. Lucero also directed the construction of two stream-gaging stations equipped with continuous water-stage recorders and the installation of staff gages at 15 sites.

Five automatic and 40 nonrecording rain gages also were installed in the Cross River Basin. At the Uzo-Uwani Irrigation Project, periodic discharge measurements were made during the 1966–67 irrigation season to determine amounts of water diverted, canal carrying capacities, canal seepage losses, and water waste from irrigation.

Throughout his stay, the Nigerian counterpart support of Mr. Lucero's mission was excellent. In August 1967, Mr. Lucero was reassigned to the USGS domestic program.

Review of Hydrologic Program in Nigeria, 1961–68

To review progress on USGS supported water-resources investigations and with the concurrence of US AID/Lagos and the Government of Nigeria, H. E. Thomas, USGS hydrologist, visited Nigeria briefly in April–May 1966. In his report of May 1966, he presented a brief summary of the hydrologic cycle and the rôle of the hydrologist in water-resources development and management in Nigeria. He also outlined the history of USGS support of hydrologic investigations in Nigeria beginning in 1961 and presented recommendations for continuation of the support beyond 1966. Reiterating Mr. Robinson's 1963 recommendation, he also strongly advocated the establishment of a central agency for water-resources information in Nigeria.

The considerable accomplishments of the USGS staff in Nigeria during 1961–68 were partly the result of the well-timed planning documents and proposals stemming from visits to Nigeria by senior USGS scientists. In no small measure, however, the positive benefits from various hydrologic investigations were directly the result of the close alliance between well-qualified American, British, and Nigerian engineers, geologists, and hydrologists attached to the various government and private institutions throughout the country.

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RHODESIA

In response to a request in early 1959 from the Government of Southern Rhodesia (now Rhodesia) to US ICA/Salisbury, P. E. Dennis, USGS hydrogeologist, was assigned from May to October 1959 to make a preliminary investigation of the ground-

water resources of the entire country with particular reference to irrigation potentials in the alluvial deposits of the Sabi River Valley, in the Kalahari sands of the Gwaai region, and the artesian belt of the Sebungwe region. His 1960 report outlined a program of ground-water investigations, including test drilling and pilot development to be carried out under the guidance of a five-man staff of geologists and engineers in the Rhodesian Division of Irrigation and Lands with emphasis on ground-water extraction from alluvial deposits of the river valleys and from the Kalahari sands of the Gwaai region. This work has since been undertaken and completed.

The technical findings of Mr. Dennis' work were subsequently published in USGS Professional Paper 424–D, where he described the occurrence and availability of ground water and the hydraulics of the alluvial aquifer in the Sabi River Valley and in USGS Water-Supply Paper 1757–D, where he presented a reconnaissance-level description of ground-water conditions throughout the country.

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SENEGAL

The Third Assemblée Générale du Comité Inter-Africain d'Etudes Hidrauliques (CIEH) was held in Dakar, Senegal, January 5–9, 1965. In late 1964, US AID requested the USGS to provide the services of a French-speaking American hydrologist to attend the assembly meetings as U.S. observer and to prepare a report evaluating the proceedings. L. C. Dutcher, USGS hydrologist, was assigned to the mission. His report of February 1965 summarized the assembly proceedings, outlined the general structure of the agencies and organizations now making hydrologic studies for the CIEH and the several independent African states, discussed the general status of hydrology and hydrologic studies in that part of West Africa largely influenced by French technology, and raised several points for consideration by US AID concerning possible changes of emphasis in types of hydrologic studies then (1965) in progress in West Africa.

SUDAN

Sudan, the largest nation in Africa, has long been concerned with the need for appraisal, development, and management of its water resources as an essential basis for economic progress. In late 1954 the U.S. Technical Cooperation Administration was requested by the Geological Survey of Sudan (GSS) to provide the services of an experienced U.S. hydrogeologist to evaluate and to recommend areas favorable for pre-development ground-water investigation. H. A. Waite, USGS hydrogeologist, was assigned to the work, arriving in Al Khurtūm (Khartoum) in late February 1955. During the following 3 months and accompanied by representatives of the GSS, he completed 10,670 km of air travel and ground travel and ground-water reconnaissance including Mudīrīyat Kurdufān (Kordofan) and Darfur Provinces of central and western Sudan, near Jūbā in Al Mudīrīyah al Istiwāsïyah (Equatoria Province) of southern Sudan, and the Red Sea coast (fig. 33) near Sawākin (Suakin) and Būr Sūdān (Port Sudan) in Mudīrīat Kassata (Kassala Province). His report of May 1955 described the general hydrogeologic setting of Sudan and recommended a 2-year ground-water investigation of the semiarid agricultural and pastoral region in western Mudīnat Kurdufān and eastern Darfur Provinces. His recommendations included compilation and analysis of past hydrogeologic records, initiation of a system of observation wells, and areal hydrogeologic studies oriented toward ground-water development with the GSS as the principal counterpart agency. He further recommended that a USGS hydrogeologist be assigned to work with the GSS to guide the investigation and to train Sudanese personnel working on the project.

With the consent of the British and Egyptian Governments, Sudan achieved independence as a republic on January 1, 1956. In late 1960, the GSS

FIGURE 33.—Reconnaissance field party inspecting shallow dug well tapping underflow in a wadi draining from the Red Sea Hills in northeastern Sudan.

approached US AID/Khartoum with a request to begin a technical assistance project in hydrogeology based on Mr. Waite's recommendations. Responding to this request, the USGS assigned H. G. Rodis to the mission. Mr. Rodis arrived in Al Khurtūm in May 1961 and remained in Sudan until May 1963. Work completed during Mr. Rodis' stay included: (1) establishment at GSS headquarters in Al Khurtūm of a countrywide file of hydrogeologic data covering lithologic and electric well logs, water-quality analyses, ground-water levels, aquifer tests, and geophysical traverses, (2) organizing a Ground Water Section in the GSS and training a 15-man Sudanese professional and technician staff dedicated to ground-water investigations in Sudan, and (3) designing and directing of ground-water investigations in the Gash River delta (fig. 34) near Kassala, in the Juba region, and in Darfur Province, all of which were carried out by Sudanese hydrogeologists of the GSS. Mr. Rodis with the assistance of GSS colleagues also undertook and completed moderately intensive ground-water studies in Mudīrīyah Kurdufān (fig. 35). The studies included a province-wide inventory in 1962 of ground-water use and pumpage; construction of potentiometric maps of five discrete ground-water bodies in the Nubian and Umm Ruwaba Series; evaluation of the occurrence, movement, recharge, discharge, and chemical quality of water in these bodies; and a general design for further exploration and future development. The technical results of these studies were published in GSS Bulletins 12 and 14 and in USGS Professional Paper 475–B and Water-Supply Paper 1757–J.

Since Mr. Rodis' work the Government of Sudan has actively pursued ground-water exploration and development in Mudīrīyah Kurdufān, financed first with development loans from US AID and since June 1967 by other donors, including the UN/UNDP, the World Bank, and the Governments of Sweden and the USSR.

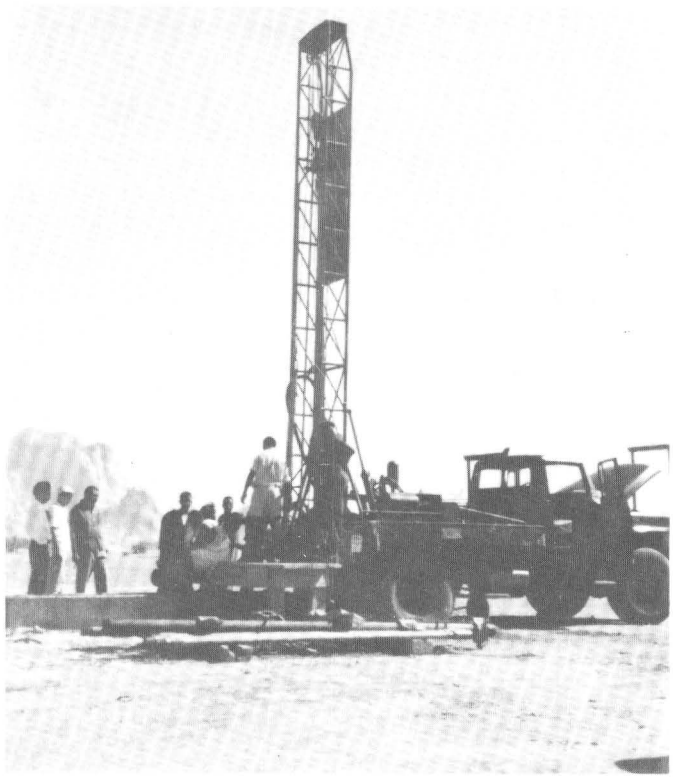

FIGURE 34.—H. G. Rodis, USGS hydrogeologist, and Sudanese hydrogeologists of Geological Survey of Sudan observing drilling operations at shallow test well put down in the subaerial delta of the Nahr al Qāsh (Gash River) near Kassalā. The alluvium is here about 23 m thick above bedrock and contains a basal water-bearing zone in sand and gravel about 7 m thick. Jabal Kassalā, a typical African inselberg in monolithic granite gneiss, forms the background on the left.

FIGURE 35.—Typical tebeldi tree in the "qoz" sand country between An Nahūd and Khuwayy (Khuwei) in central Mudirifat Kurdufān. This tree like many others in the region has been hollowed out to form a living tank for long-term storage of drinking water. Such storage is drawn upon in time of drought. Storage is replenished by lifting by hand line and bucket collected surface water which accumulates around the tree during rainy seasons.

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TUNISIA

Tunisia, on the Mediterranean coast of Africa, includes wooded hills and fertile plains in the north, a central steppe and coastal plain dedicated to grazing and olive groves, and a southern desert on the fringes of the Sahara.

The independence of the modern Republic of Tunisia was recognized on March 20, 1956, with the signing of a protocol that ended the former French protectorate. Since then and with the technical assistance of foreign donors, the Government of Tunisia (GOT) has pursued an active program of water-resources investigations and development, with the object of extending irrigated agriculture and improving public water supplies. In late 1958 at the request of the GOT to US ICA/Tunis, R. C. Vorhis, USGS hydrogeologist, was detailed from the Libyan Ground Water Geology Project to make a brief reconnaissance of ground-water conditions on the island of Jazīrat Jarbah (Djerba) and the adjacent Zarzis peninsula in southern Tunisia for evaluation of the potential of brackish-water aquifers to sustain the water requirements for a desalination plant. His report of January 1959 describes the hydrogeology of the area and chemical quality of the ground water and recommends that supply wells for the plant be located in the vicinity of Zarzis.

Hydrologic Training and Mapping Project, 1959–65

A request to US ICA/Tunis in mid–1959 from the Government of Tunisia (GOT) for long-term technical assistance in hydrogeology led to an agreement for a hydrologic training and mapping project that provided for (1) review of hydrologic and hydrogeologic data in the offices of the drilling section of the Tunisian Sous-Direction de l'Hydraulique et l'Equipment Rural (HER), Secretariat of Agriculture, (2) study of the geology and ground-water hydrology of a 13,600-km^2 region in central Tunisia (Sahel de Sousse), (3) instruction and training of Tunisian technicians of the HER, and (4) exploration and pilot development of ground water in the Sahel de Sousse region. H. E. Thomas, USGS hydrogeologist, arrived in Tunis in December 1959 to begin the project, designated "Mission Thomas" by GOT, and continued as project chief in Tunisia until his return to the USA in January 1962. In June 1960, L. C. Dutcher, USGS hydrogeologist, arrived to assist Mr. Thomas. Mr. Dutcher served in Tunisia until his return to the USGS domestic program in September 1963.

Work accomplishments of Mission Thomas included (1) drilling of four controlled test wells, 250 to 285 m deep, in the Tabulbah (Teboulbah) area under the direction of a US AID drilling advisor, (2) a special study of the depleted ground-water reservoir in the Tabulbah area, (3) field collection and office compilation of water-quality analyses, water-level measurements, well logs and altitudes for more than 500 wells in the Sahel de Sousse region, (4) advisory services to HER's drilling section on test drilling, well-construction problems, and well-site selection, (5) teaching and lecturing for a UNESCO-sponsored training school in hydrogeology held in 1961 in Tūnis under GOT auspices, (6) training of six HER Tunisian hydrologic technicians; and (7) preparation of a feasibility report for a 3-year, $1.9 million US AID development grant project to the GOT for drilling and equipping 50 production wells by American techniques and training Tunisian drillers and crews. The Fifty-Well Project, as it was designated, was designed also to provide water for intensive irrigation of 1,375 ha of new land and for future occasional irrigation during a 5-year maturation period of 4,000 ha of almond and olive trees.

Although the training phase of Mission Thomas fell somewhat short of original expectations, the mission achieved substantially all other originally planned objectives and in addition several other unprogramed but worthy goals. Technical products of the mission included four USGS Water-Supply Papers on the Tabulbah area and the Sāhil Sūsah (Sahel de Sousse) region, seven duplicated reports in French and English released by the Tunisian HER, and one journal article on the Tabulbah area.

Toward the end of Mr. Dutcher's tour in Tunisia, GOT had requested and US AID/Tunis had agreed that USGS support be continued and that Mr. Dutcher's replacement (1) would provide technical surveillance for US AID/Tunis of the Fifty-Well Project, later carried out by the Ralph M. Parsons Co., as contractor, and (2) would extend the Sāhil Sūsah regional ground-water studies to the Sāhil Safāqis

(Sahel de Sfax) region to the south. Because of administrative delay, however, it was not possible for V. C. Fishel, USGS ground-water engineer, to report for duty in Tūnis until January 1964. As a result of this delay and a decision to recast the original provisions of the Fifty-Well Project before implementation, it was decided to eliminate the Sāhil Safāqis study from Mr. Fishel's responsibilities. Mr. Fishel directed the recast of the project, which was begun in November 1964. He continued in Tunisia until July 1965, at which time he was reassigned to the USGS domestic program, and USGS technical assistance on the project was terminated.

During Mr. Fishel's tenure several successful production wells were completed in the Fifty-Well Project in the Bilād Sīsab (Bled Sisseb) area near Al Qayrawān (Kairouan) to supplement the water supply of a dam and reservoir on the Wādī Nabhānah (Oued Nebana), later completed in 1968. Two of these wells, with depths of 115 and 166 m, yielded 69 and 112 l/s, respectively. Two other wells, each drilled to depths of about 100 m in the alluvial fill of the Medjerda Valley in the Oued Meliz area, yielded about 125 l/s each. The project, however, continued beyond Mr. Fishel's stay in Tunisia, reaching full completion in 1966. In addition to the construction and equipping of 50 production wells and the training of several Tunisian drilling crews, the project also provided domestic water supply for about 60,000 people and the irrigation requirements for about 1,370 ha of land.

Since 1966 and based on the results of Mission Thomas and the experience of the Fifty-Well Project, the GOT has initiated and completed a 400-production well project with the Ralph M. Parsons Co., as contractor and financed by US AID development loans.

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ZAMBIA

Zambia (formerly Northern Rhodesia) in south-central Africa was the first of former British colonies to become a republic directly upon attaining independence, achieved on October 24, 1964. Since then and with technical assistance from expatriate advisors, the Government of Zambia (GOZ) has actively striven to maintain and improve scientific and technical institutions established under the British regime.

In early 1968, US AID requested the USGS to provide the services of an experienced hydrologist to serve for a 2-year term as a technical advisor in the Hydrological Branch, Department of Water Affairs, Ministry of Rural Development of the GOZ. L. E. Bidwell, USGS surface-water hydrologist, who was

assigned to the work, arrived in Lusaka in November 1968 and continued in Zambia until his return to the U.S.A. in December 1970.

The general goals of Mr. Bidwell's assignment in Zambia were (1) to review the overall operations of the Hydrological Branch and (2) to plan and implement endorsed changes leading to improvements in the collection, analysis, and availability of hydrologic data, particularly on surface water. Specific goals were aimed at recruitment of personnel, developing the national stream-gaging network, modifications in the traditional organization structure, automatic data processing, training of personnel, standardization of hydrologic techniques, and evaluation of and improvements in hydrologic equipment.

Specific accomplishments of Mr. Bidwell's 2-year assignment included technical guidance (1) for completion of Hydrologic Year Books for water years 1961–66, (2) for purchase and construction of new hydrologic field equipment, (3) for design of new field and office hydrologic data forms, for a new technical filing system, (4) for training three Zambian and several expatriate hydrologists in fieldwork and office work, (5) for two operational computer programs in hydrology, and (6) for compilation of written instructions for Hydrology Branch guidance in the collection of basic field data and the office analysis and computation of streamflow records. In addition, Mr. Bidwell gave lectures in hydrology to technically oriented students in secondary schools and in the Zambian Natural Resources Development College.

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ASIA AND OCEANIA

A preponderance of USGS activity since 1950 in the water-resources sector of the U.S. bilateral program has been dedicated to the needs of the old kingdoms and new republics of western, southern, and eastern Asia. This activity reflects in considerable measure the great emphasis placed by the Near East and South Asia, East Asia, and Vietnam Bureaus of US AID and its predecessors on water-resources development, particularly for irrigation and intensification of agricultural production to meet the rapidly expanding food requirements of these regions. Thus, since 1950, 112 USGS water scientists and engineers have completed assignments in 17 Asian countries (fig. 36). The bulk of this activity, however, has been concentrated in Afghanistan, Pakistan, India, and Nepal, all in the southern Asia region (table 2).

During and since World War II, the USGS also provided consultation and technical direction to many water-resources investigations in the Pacific Islands (Oceania), chiefly in the UN Trust Territories of the Pacific Islands and in U.S. island possessions. Notable among these were water-resources investigations on Okinawa in the Ryukyu Islands; Guam and Saipan in the Mariana Group; Iwo Jima in the Volcano Islands; Guadalcanal in Melanesia; Angaur, Truk, Ponape, and other islands of the Caroline Group; islands in the Samoa Group; in the Marshall Islands, and elsewhere in the Pacific. These investigations were undertaken as part of U.S. military operations during and after World War II and more recently as extensions of the USGS domestic program; consequently, they are not described in this report.

AFGHANISTAN

Afghanistan, landlocked between China, India, Pakistan, Iran, and the Soviet Union (U.S.S.R.), has occupied for centuries a position of strategic importance as the cultural and trading crossroads of central Asia. Since World War II and under the leadership of its present (1970) king, Mohammad Zahir Shah, Afghanistan has followed an active program of modernization, education, and economic development, with the assistance of foreign donors. One of the more important of these developments during the late 1940's and early 1950's was the construction by an American engineering contractor of an extensive system of dams, reservoirs, and canals in the Daryē-ye Helmand valley (Helmand River Valley) of southwestern Afghanistan to control and regulate streamflow for irrigation, drainage, hydropower, and flood protection.

Helmand Surface-Water Investigations Project, 1952–64

American engineers of the Morrison-Knudsen-Afghanistan Company (MKA) and its affiliates began surface-water investigations in the Daryē-ye Helmand basin in 1946 in connection with feasibility studies for the design and construction of engineering works on the river system. When these works were nearing completion it was recognized that there would still be continuing need for streamflow data for operation and management decisions. With this need in view, the U.S. Technical Cooperation Administration (TCA) early in 1952 requested the USGS to provide long-term technical assistance to the Afghan Helmand Valley Authority (HVA) in

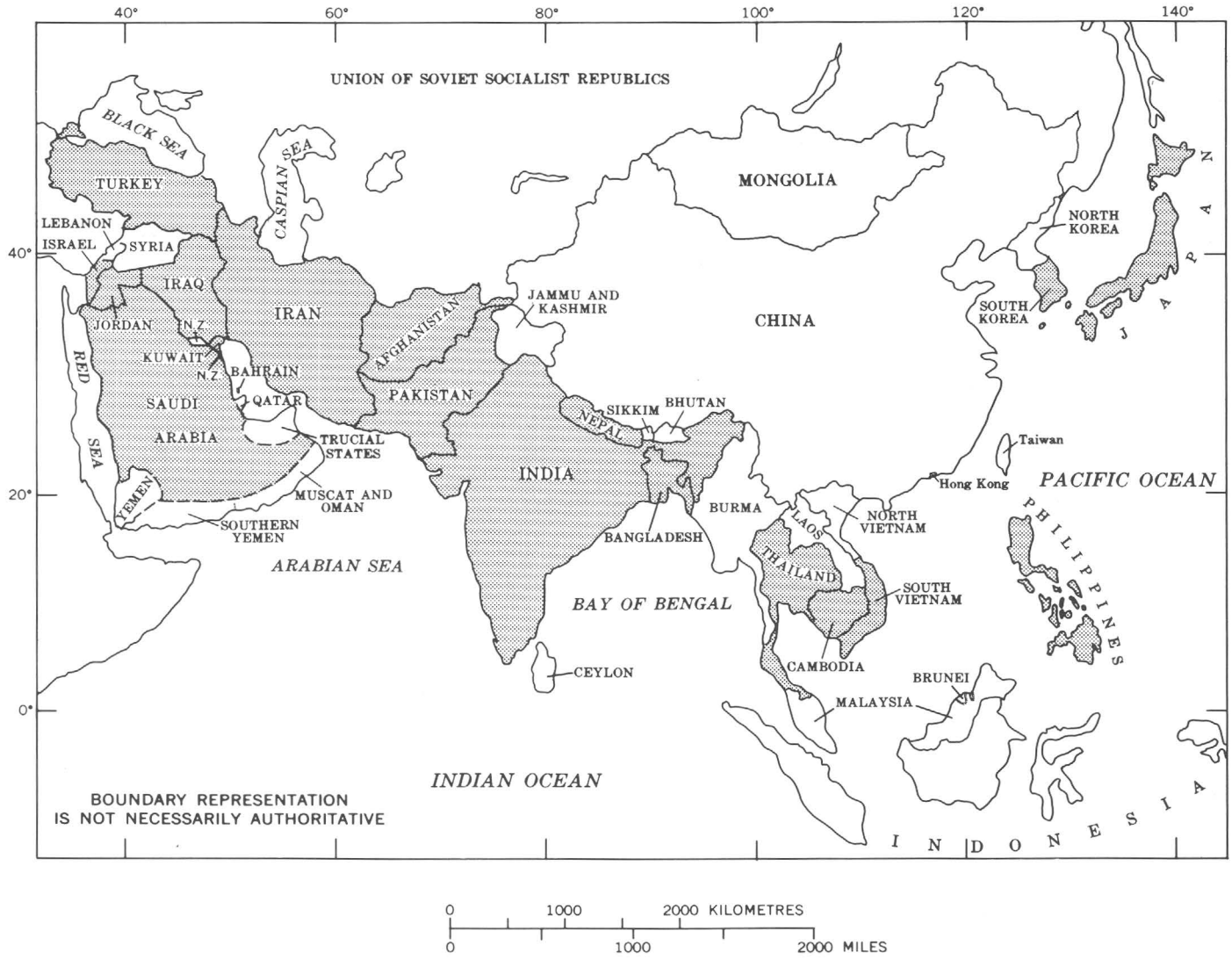

FIGURE 36.—Index map of Asia showing those countries in which the U.S. Geological Survey has been active in water-resources projects of the U.S. bilateral program, 1940–70.

(1) the collection, compilation, and evaluation of hydrologic data needed for development, operation, and management of irrigation, drainage, land-use, flood-control, and hydropower projects in the Daryā-ye Helmand basin, and (2) the training within the HVA of a competent Afghan hydrologic staff to carry out these activities, L. J. Snell, USGS hydrologist, was assigned to the work, arriving in Lashkar Gāh (formerly Bost) in June 1952. I. A. Heckmiller arrived in June 1954 to assist Mr. Snell. When Mr. Snell completed his tour of duty in Afghanistan in January 1956, Mr. Heckmiller continued as project leader until September 1959. R. H. Brigham arrived in November 1959 as Mr. Heckmiller's replacement and served in Afghanistan until June 1964. During the last few months of Mr. Brigham's tour, the Helmand Surface-Water Investigations (HSWI) Project was amplified, recast, and reoriented in a new project, which is described in the following section.

The more tangible accomplishments of the HSWI project during its 12-year life included: (1) continued operation and physical improvements of 11 stream-gaging stations established by MKA and construction of five new gaging stations, (2) compilation and publication of all streamflow, reservoir storage, and climatologic records for the Daryā-ye Helmand system and adjacent river basins through September 1960, (3) preparation and release of monthly hydrologic summaries during 1952–64 on weather conditions, temperatures, precipitation, evaporation, wind velocities, daily inflows, contents, evaporation, and outflows from Band-e Kajakaī (Ka-

jakai) and Band-e Arghandāb (Argandhab Reservoirs), (4) establishment of an operational Hydrology Section in the HVA, and (5) training of 15 Afghan hydrologic technicians in field methods of measuring river discharge, sediment data collection, snow-course surveys, office computation and compilation of basic data, and planning project activities.

Surface-Water Research Project, 1964–69

Based on recommendations by G. C. Taylor, Jr., USGS hydrologist, during a visit to Kābul in November 1961 and subsequently implemented by Mr. Brigham, the Royal Government of Afghanistan (RGA) in March 1963 created an independent agency, the Water and Soil Survey Authority (WSSA). The WSSA was charged with responsibility for all water resources and soils investigations in Afghanistan, including those in the Daryā-ye Helmand Basin. The WSSA spent much of its first year of life in organizing its administration and in coordinating technical-assistance activities of foreign donors, notably the U.S.A., the U.S.S.R., the Federal Republic of Germany, and United Nations agencies. In late 1963 the WSSA requested US AID/Kābul for expanded technical assistance from the USGS to cover surface-water investigations in all the river basins of central and western Afghanistan. In response to this proposal, the scope, objectives, and areal coverage of the former HSWI project were redefined in a new project, designated "Surface Water Research" (SWR) by US AID/Kābul.

A. O. Westfall, USGS hydrologist, arrived in March 1964 at Kābul to assume leadership of the new project. V. J. Latkovich arrived in July 1964 in Lashkar Gāh to continue supervision of activities covered by the former HSWI project and to assist Mr. Westfall in the technical organization and fieldwork of the new WSSA. An administrative reorganization in 1965 shifted the WSSA under the wing of the Ministry of Agriculture and Irrigation as the Water and Soil Survey Department (WSSD). In late 1966 a planned expansion of the stream-gaging network begun by WSSD resulted in the assignments of two USGS engineering technicians to the project. Vincent Piro arrived in March 1967 and Dallas Childers, Jr., in April 1967, both on 2-year tours. George Porterfield (March–May 1967) and D. C. Perkins and J. K. Culbertson (August–December 1968), all USGS sedimentologists, were also assigned during the project life to make special sediment studies of siltation problems in Band-e Kajakaī on the Daryā-e Helmand. During a planned phaseout of the project, Mr. Latkovich returned to the USGS domestic program in September 1968, Mr. Westfall in December 1968, and Messrs. Childers and Piro in June and July 1969, respectively.

Work accomplishments of the Surface-Water Research Project during its 5-year life included: (1) continuation of the work began in the HSWI project during 1952–64, (2) development of nationwide stream-gaging standards and procedures for the guidance of WSSD, (3) preparation in 1966 of a comprehensive nation-wide plan for surface-water investigations under the direction of WSSD, (4) preparation of three formal training manuals on stream gaging and sediment-data collection for use in Afghanistan, (5) field and classroom education and training in surface-water hydrology for engineering students at Kabul University, (6) responsibility for operation and reworking records for 10 stream-gaging stations that had been established by the United Nations Special Fund in 1961–63 on the Hari Rud system and for 4 stations built by the U.S.S.R. in northeastern Afghanistan, (7) planning, design, and construction of 63 new stream-gaging stations (fig. 37) and refurbishing 16 stations, all with ancillary equipment, (8) building 59 new cableways (45 to 232 m long), (9) establishing and equipping a laboratory for analyses of sediment samples, (10) planning and executing a comprehensive hydrographic and sedimentation study of Daryē-e Kajakai, (11) training 20 Afghan technicians of WSSD and 6 Peace Corps Volunteers in the basics of stream gaging and sediment-data collection (fig. 38),

FIGURE 37.—A. O. Westfall, USGS hydrologist, at a new stream-gaging and weather observation station on Kābul River near head of Tang-e Ghārū (Tangi Garu Gorge). View downstream. This is one of 63 new stream-gaging and weather stations constructed in Afghanistan as part of the Surface Water Research Project, 1964–69.

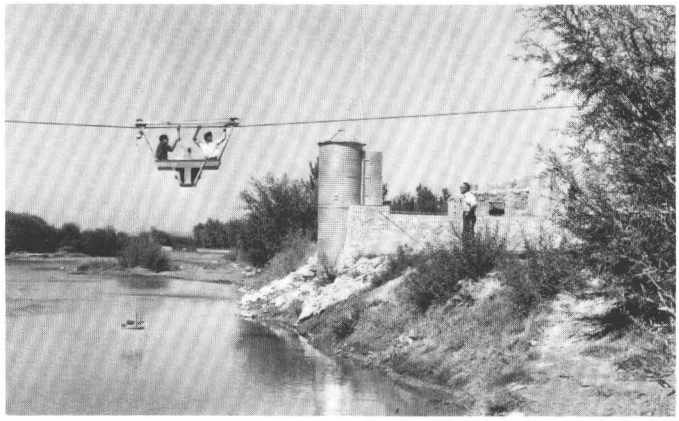

FIGURE 38.—A. O. Westfall, USGS hydrologist, instructing Afghan hydrometrists in stream-gaging methods by cableway at model gaging station on Kābul River near head of Tang-e Ghārū. View upstream.

and (12) consultation with US AID and RGA officials on water problems and policy in Afghanistan, including matters pertaining to international rivers.

In spite of considerable effort, the HSWI and SWR projects fell short of full achievement in training and institutional development goals. With respect to goals in stream-gaging station construction and hydrologic-data collection, however, both the HSWI and the SWR projects achieved nearly full success. As of 1970 the RGA had a firm physical and technical base on which to build a long-term program of surface-water investigations, essential to the orderly development and management of the nation's water resources.

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CAMBODIA

Cambodia gained full independence from France in March 1953. During the following 10 years Cambodia received $393 million in U.S. military assistance and economic aid aimed at repairing the physical damage suffered during World War II and subsequent fighting, bolstering the economic infrastructure of the country, and helping to maintain its internal security. As part of U.S. bilateral assistance during this period, the USGS provided technical advisors on three separate occasions, all directed toward improving the appraisal and development of the water resources.

GROUND-WATER INVESTIGATIONS, 1958, 1963

A prolonged drought in 1955 and resultant famine had aroused considerable interest among officials of the Cambodian Ministries of Agriculture, Public Works, and Public Health in the possibilities of utilizing ground water for supplemental irrigation as well as for urban, rural, and stock-water supply. In early 1958 the Government of Cambodia requested US ICA/Phnum Pénh to provide the services of a U.S. hydrogeologist to advise on then-current ground-water problems and to recommend a long-term program of ground-water investigations and development appropriate to Cambodia's requirements. R. V. Cushman of the USGS was assigned to the mission. During March–May 1958 and in company with Cambodian engineers he completed 3,000 kms of road reconnaissance, chiefly in Kâmpóng (Kompong Cham), Batdâmbâng (Battambang) and Kâmpôt (Kampot Provinces); collected hydrologic data on 110 representative wells and springs; and examined geologic sections of the principal aquifers. His report of June 1958 described the general geologic framework of Cambodia, the water-bearing characteristics of the major rock types, and the ground-water conditions in selected areas. He concluded (1) that ground-water conditions are not generally favorable to the occurrence of regional aquifers of sufficient productivity to sustain large-

capacity irrigation wells, except locally but (2) that conditions are favorable in most places for drilling small-yield wells for village, domestic and stock-water supply. He also pointed out the need for extensive test drilling and pilot ground-water development under competent technical direction, coupled with long-term ground-water investigations, whose scope he outlined in detail.

As a consequence of Mr. Cushman's work, US ICA/Phnum Pénh concluded (1) that exploratory drilling for irrigation water supplies promised little economic benefit and therefore (2) that ground-water exploration and development should be directed toward drought protection of village and domestic water supplies and improved rural health and sanitation. Accordingly, in mid–1960 the US ICA mission began a rural water-supply development project under the sponsorship of the Cambodian Ministry of Public Health and with the guidance of two direct-hire well-drilling advisors and a sanitary engineer attached to US ICA/Phnum Pénh. During the next 3 years 1,065 holes were drilled, mostly by the light, mobile, and inexpensive hydrojet method, and, of the total, 760 holes were considered successful and were completed as production wells for village, domestic, and stock water supply. The holes ranged in depth from 2 to 209.4 m and averaged 23.2 m. The yields obtained from individual supply wells ranged from 1.1 to 2,967 l/min (litres per minute). Holes yielding less than 1 l/min were generally abandoned.

In early 1963, US AID requested the USGS to provide long-term technical assistance in hydrogeology (1) to evaluate the results of the 1960–63 ground-water exploration program, (2) to recommend the needs and direction for further exploration, and (3) to initiate training of Cambodian engineers and geologists in ground-water geology and hydrology. W. C. Rasmussen, USGS hydrogeologist, assigned to the work, arrived in Phnum Pénh in early November 1963 and immediately began an evaluation of the 1960–63 ground-water exploration data and undertook ground-water reconnaissance in areas that had previously been explored. However, the Cambodian government decided to terminate U.S. technical assistance, US AID/Phnom Penh was dissolved, and Mr. Rasmussen was reassigned to South Vietnam in January 1964. Based on observations made during his 2-months tour, antecedent geologic reports and maps completed under the French regime, and the exploratory hydrologic data available from the US AID records, it was subsequently possible for Mr. Rasmussen to prepare a reconnaissance-level report on the ground-water resources of Cambodia. In this report he described in detail the hydrogeologic framework and the occurrence of ground water in the environs of Phnum Pénh and the 19 provinces of Cambodia. He concluded that the rivers and lakes of Cambodia will continue to be the most important and major source of water for large-scale requirements, but that ground water in adequate quantity and quality is widely available for the small-scale needs of village, domestic, and stock water supply in most of the country. He further concluded that ground-water exploration and development for small-scale use were urgently needed in those areas not fully covered by the 1960–63 exploration project.

Surface-Water Investigations, 1959

Recognizing the dearth of streamflow data in Cambodia and the essential need for such data in irrigation project planning, the Irrigation Service of the Cambodian Ministry of Agriculture in late 1958 requested US ICA/Phnom Penh to provide the short-term services of a surface-water hydrologist (1) to evaluate needs for and organize a stream-gaging program for the Irrigation Service, (2) to begin training of technical personnel of the Service in surface-water hydrology, and (3) to select sites and identify equipment needs for stream-gaging stations. L. J. Snell, USGS hydrologist, then on long-term assignment with US ICA in the Philippines, was detailed to the work for 60 days. During January and then March 1959 he completed a hydrologic field reconnaissance of central Cambodia; conducted a field training course in stream gaging for 10 Cambodian technicians of the Irrigation Service on the Prêk Tnaôt (Prek Thnot) at Kâmpóng Spoe about 50 km west of Phnum Pénh; and selected sites for 12 stream-gaging stations, mostly on streams tributary to the Tonle Sap (Grand Lac) or the main stem of the Mekong River, for irrigation project planning purposes of the Irrigation Service. Mr. Snell's report of July 1959 described the general hydrology of Cambodia. It also presented detailed recommendations for training of hydrologic technicians; for a governmental hydrologic organization; and for streamflow, sediment discharge, and evaporation data collection.

Many of Mr. Snell's recommendations were later included and implemented during 1959–62 as part of the comprehensive hydrologic survey of the Lower Mekong River Basin by the Harza Engineering Co. under contract to US AID.

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INDIA

India, homeland of the ancient Hindu philosophic and cultural tradition on the South Asian subcontinent, emerged on the world scene as a modern constitutional republic on January 26, 1950. Since independence, India's principal national goals have been to achieve self sufficiency in production of food and fiber for its burgeoning population (540 million in 1970) and to build a strong and viable industrial base for a higher living standard. In its efforts to strengthen its agricultural production, India has placed great emphasis on water-resources development for extension and intensification of irrigation as well as for industrial growth—all with massive economic aid and technical assistance from foreign donors, including some $8.6 billion of U.S. bilateral loans and grants between 1951 and 1969. As part of this assistance and through the auspices of US AID and predecessors, the USGS has provided technical advisors in support of water-resources investigations in India, first in 1950, continuously between January 1951 and July 1957, and intermittently since then. The scope, objectives, and achievements of these activities are described in following sections.

National Ground-Water Investigations, 1950, 1951–57

The Government of India (GOI) has long recognized ground water as an important part of the nation's available water supply and the need to appraise, develop, and manage the resource on a rational basis for full socio-economic benefits. Large-scale ground-water development gained impetus beginning in 1934 through the initiative of Sir William Stampe, a British civil engineer in GOI service. Stampe organized a labor-intensive scheme to construct networks of tubewells using hand-powered drilling equipment (figs. 39 and 40). For lifting water, the wells were equipped with simple inexpensive pumps, mostly of centrifugal type, that could be readily assembled and easily maintained in India. During the following 15 years, some 2,000 wells, each averaging about 75 m deep and yielding 28 to 42 l/s (litres per second), were put down in the alluvial plains of the Ganges and its tributaries to provide drought protection and irrigation supplemental to canal supplies from the rivers. The success of these wells aroused national interest in the potential of tubewell irrigation elsewhere in India. As a consequence, the Geological Survey of India (GSI) found itself under increasing pressure during the late 1940's to provide basic hydrogeologic appraisals and surveys of ground-water potentials for tubewell irrigation as well as for municipal and industrial water supply throughout the country.

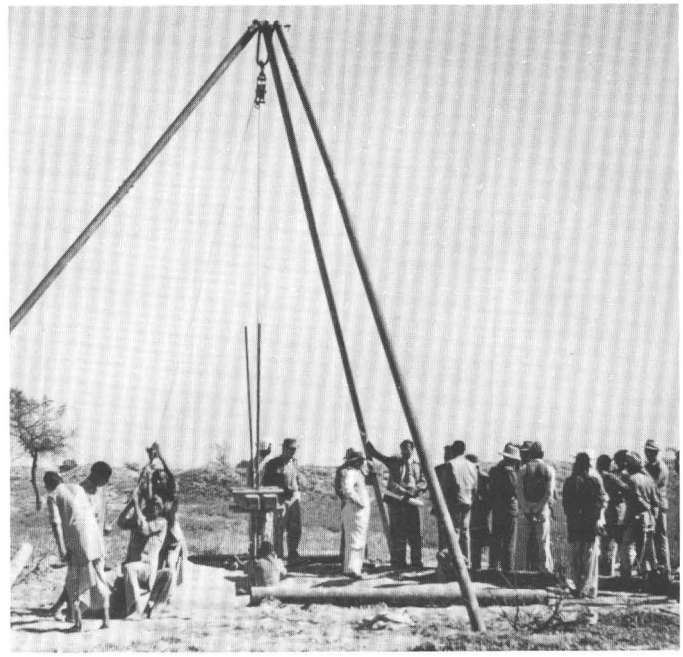

FIGURE 39.—Drilling of irrigation well by tripod and manually operated drill stem and bailer in the Ganges Plain of Uttar Pradesh.

FIGURE 40.—Indian drillers constructing 15.2-cm drilled well using bamboo tripod and hand-powered bailer in Hoshiārpur area, Punjab (Haryana).

After completion of an assignment in Thailand, G. C. Taylor, Jr., USGS hydrogeologist, was requested by the GSI through the U.S. Embassy in

New Delhi to visit selected areas in India and to design a long-term program of technical assistance to the GSI in ground-water geology and hydrology. On this mission Mr. Taylor spent 6 weeks during June–July 1950 at the GSI headquarters in Calcutta, in the Neyveli and Coimbatore areas of Madras (now State of Tamil Nudu) in the Purna Valley of Madhya Pradesh, in the Kandla (Kandla Pòrt) development on the Gulf of Kutch in western India, and in the Meerut area of Uttar Pradesh. With the formal establishment of a US TCA bilateral aid program in India in late 1950, Mr. Taylor returned to Calcutta in January 1951 to begin the technical assistance proposed in mid–1950. He continued in this work until August 1955, when he was reassigned to the USGS domestic program. During his stay in India, he concentrated his efforts in field and office training of GSI hydrogeologists, first in the GSI's Engineering Geology and Ground Water Division and later also in the Ground Water Exploration Section. He supervised and participated with GSI colleagues in reconnaissance ground-water investigations involving three- to four-man parties over 4- to 6-month periods in several parts of India, notably in the Kandla (Port Development) of eastern Kutch (now Gujarat), in the Purna Valley of Madhya Pradesh, in the Páli region of Rājasthān (fig. 41), and in the Malabar Coast region of Kerala (formerly Travancore-Cochin)—all as part of the regular program of the Engineering Geology and Ground Water Division. Fieldwork included hydrogeologic mapping, well inventories, observation-well measurements, pumpage inventories, some aquifer tests, evaluation of exploratory drilling by cooperating agencies, and ground-water quality sampling and mapping. Office work included collation and interpretation of field data through preparation and publication of reports.

In early 1952, Mr. Taylor participated with engineering personnel of US TCA/New Delhi in formulating plans to construct some 2,200 production tubewells by modern drilling techniques in the Ganges Plains. This project, the first of several modern tubewell construction projects in the Ganges Plains, was later formalized in Indo-American Operational Agreement no. 6. As part of this project, F. A. Swenson, USGS hydrogeologist, was assigned as an expert member of a US TCA-GOI inspection team which visited and evaluated drilling sites in 22 areas of Bihar, Uttar Pradesh, East Punjab (now Haryana) and the former Patiala and East Punjab States

FIGURE 41.—Indian hydrogeologist of the Geological Survey of India measuring water level in dug well near Bhawi in Rājasthān. Well is equipped with Persian water wheel driven by bullocks and taps ground water in Precambrian Aravalli slate.

Union (PEPSU) during April–May 1952. These wells were constructed during the mid–1950's by American, German, and British drilling contractors under terms of a US TCA development grant to the GOI.

An All-India Ground Water Exploration Project was conceived and proposed in August 1952 by Mr. Taylor and Dr. J. B. Auden, then Superintending Geologist of the Engineering Geology and Ground Water Division of the GSI. This project provided for the drilling of 350 exploratory wells to evaluate ground-water potentials of 15 "soft-rock" regions, scattered through India, for tubewell irrigation. The proposal was formally endorsed by US TCA/New Delhi and the GOI in mid–1953 through Indo-American Operational Agreement no. 12. Under this agreement the project was to be undertaken jointly by a newly established Exploratory Tubewells Organization (ETO) in the Ministry of Food and Agriculture and the GSI. The ETO was assigned responsibility for all phases of the operations of 15 heavy-duty drilling rigs and the construction and casing of wells, and the GSI the responsibility for selecting areas for exploration, collection, analysis, interpretation, and reporting on geologic and hydrologic data obtained from drilling operations. To serve the needs of this project a new Ground Water Exploration Section was established in the GSI, and, during the following 18 months, GSI teams, with the guidance of Mr. Taylor and later A. A. Garrett, completed site selections and evaluations for nearly all proposed exploratory wells. Mr. Taylor also participated in the fieldwork with GSI site selection teams—notably in Kutch (Gujarat); Saurasthra; the Narmadā, Purna and Tapti Valleys of central India; Assam; Madras (State of Tamil Nudu); and Travancore-Cochin (Kerala).

Meanwhile, in late 1952 the GSI had requested US TCA/New Delhi for additional technical assistance from the USGS in quantitative methods in ground-water hydrology, with emphasis on applications of techniques and principles of interpretation. A. A. Garrett, USGS ground-water engineer assigned to the work, arrived in India in April 1953. His headquarters were established in New Delhi so that he could serve as a general advisor to US TCA/New Delhi in production tubewell drilling in the Ganges Plains under Operational Agreement no. 6 as well as advisor to the GSI on ground-water investigations in central and northern India. During the first part of his tour in India, Mr. Garrett advised US TCA on problems of production well construction and design in the Ganges Plains; advised and participated with GSI teams in special demonstration studies related to water-logging problems, electrical logging of new tubewells, and hydrogeochemical problems of critical areas; and participated with GSI teams in the selection of sites for exploratory wells—notably in PEPSU, East Punjab, Bihar, and West Bengal.

Active test drilling in the All-India Ground Water Exploration Project began in January 1955 in the Narmada Valley of Madhya Pradesh where five drilling rigs under ETO supervision were placed in operation. By May 1956 when this, the first or "shakedown" phase of the project had been completed, 44 test wells had been put down to depths ranging from 24 to 323 m, with an aggregate total of 6,344 m. In this phase of the project, Messrs. Garrett and Taylor participated actively in field instruction of GSI hydrogeologists in formational and water-quality sampling, in lithologic and electrical logging of test wells, and in recording and interpreting results. At the same time the ETO received guidance from American drillers and engineers provided by the Ralph M. Parsons Co. under contract to the GOI. In the latter part of his tour, Mr. Garrett continued to serve in an advisory capacity to the GSI in the All-India Ground-Water Exploration Project and in special studies in northern India until his return to the USGS domestic program in November 1956.

Shortly before Mr. Taylor's departure for the U.S.A., P. H. Jones, USGS hydrogeologist, arrived in Calcutta in July 1955 as his replacement. During his 2-year stay in India, Mr. Jones directed the bulk of his efforts to training of the staff of the GSI's Ground Water Exploration Section and to the objectives of the All-India Ground Water Exploration Project in reviewing field records, analyzing data, and assisting in the solution of hydrogeological problems, both in the field and in the office. Particular attention was given to techniques of drilling and testing wells and interpretation of electrical logs—notably in exploration operations in Rājasthān, Saurasthra (fig. 42), and Madras (State of Tamil Nudu). Mr. Jones also advised and participated in areal ground-water studies of GSI's Engineering Geology and Ground Water Division in the Azamgarh-Ballia area of Uttar Pradesh, in the Calcutta urban area (fig. 43), and in a special study on ground-water control for mining in the Neyveli Lignite Project in Madras. USGS long-term technical assistance to the Geological Survey of India ended in July 1957 with the return of Mr. Jones to the USGS domestic program.

The All-India Ground Water Exploration Project continued until 1959, when all 350 wells were com-

FIGURE 42.—Artesian well drilled by the Government of Saurasthra for the village water supply of Sushiya. Well taps confined sand aquifer in Pliocene deposits at a depth of about 137 m.

FIGURE 43.—Indian hydrogeologists of the Geological Survey of India installing automatic water-stage recorder on observation well in West Bengal.

pleted under joint GSI-ETO direction. At that time the GSI's Ground Water Exploration Section was disbanded, and personnel were reassigned in a newly constituted Ground Water Wing. As of project termination some 1,425,000 km² of sedimentary rock terrain, ranging in age from Jurassic to Holocene, had been explored in 15 different regions of India. Of this total, 681,000 km² was proved favorable for construction of tubewells yielding individually 28 l/s or more.

The specific accomplishments of USGS technical assistance in ground-water science during 1951–57 included (1) on-the-job, group, and individual training of 60 GSI professionals, chiefly hydrogeologists and chemists, in the principles and techniques of ground-water investigations, (2) completion of joint field studies with GSI colleagues in various aspects of hydrogeology in 45 localities or areas throughout India, (3) administrative guidance to the GSI in structuring its regular nationwide ground-water investigations program as well as the special needs of the All-India Ground Water Exploration Project, (4) advisory and consultative services to the Government of India and US TCA/New Delhi in the design and execution of production drilling programs for tubewell irrigation (Operational Agreement no. 6) as well as for general ground-water exploration (Operational Agreement no. 12), and (5) preparation of 25 technical reports, either individually or jointly, with GSI colleagues on ground-water problems in India as well as numerous administrative reports and memoranda on various aspects of the technical assistance program.

During the 1960's the GSI grew steadily in technical capacity to meet requirements for increasingly sophisticated hydrogeologic knowledge in India's industry and agriculture—notably in areal ground-water investigations and in problems such as ground-water control and disposal in open-cast lignite mining, seepage from surface reservoirs into underground mines, water-logging and salinity control, reservoir leakage, effects of large-scale tubewell irrigation on ground-water regimens, and salt-water intrusion in coastal aquifers. The GSI in 1970 had a Ground Water Wing with a staff of more than 100 active professional hydrogeologists and chemists engaged in ground-water investigations throughout India and administratively directed from five regional (circle) offices.

RECONNAISSANCE OF FLOOD CONTROL PROBLEMS IN NORTH BIHAR, 1955

For many decades, the Government of India (GOI) has been concerned with controlling the devastation to agricultural lands of Bihar and Bengal caused by massive monsoon flooding and sediment deposition from the eastern tributaries of the Ganges River. As a result of particularly disastrous floods during the 1954 monsoon, India's Central Water and Power Commission (CWPC) in late 1954

requested US TCA/New Delhi to provide the services of U.S. experts to evaluate the problem and to propose possible solutions. L. B. Leopold and Thomas Maddock, Jr., USGS hydrologists, were assigned to the work and completed during March-April 1955 an areal and ground reconnaissance of the sub-Himalayan reaches of the Gandak River, Bāgmati Nadī, Kamla Nadī and Kosi Rivers. Their administrative report of April 1955 described the flow and sedimentation regimens of these rivers and the causes and effects of their natural behavior. They also evaluated the probable effects of controlling the natural hydrologic regimen of the Kosi River by a then-proposed high (183 m plus) dam at Barakhshetra or by a low barrage at Hanumanagarh with paired flood-control embankments (levees) extending downstream from the barrage. They concluded that the entire flooding and sedimentation problem of North Bihar could not be solved completely within existing economic and social constraints. They pointed out, however, that amelioration of the problem on the Kosi River was possible through construction of the Hanumanagarh Barrage and downstream embankments. Construction of the barrage and embankments begun in 1957 has since been completed; in addition, 45 km of irrigation canals serving about 708 thousand acres was completed as of 1970.

Water Resources Investigations Program for the Upper Gangetic Plain, 1966

The vast alluvial plains of the Ganges and its tributaries, containing some 64 million acres of fertile lands and underlain by the most productive aquifer system in India, have long been the cultural and agricultural heartland of more than one-fifth (110 million) of India's population. Beginning in 1934 the Government of India (GOI) and State governments, notably Uttar Pradesh and Bihar, undertook construction of a series of tubewell projects to supplement traditional irrigation from canals. The early success of publicly owned tubewells also stimulated a notable expansion of private investment in tubewell construction during the late 1950's and early 1960's. As of the end of 1966 there were some 9,325 publicly owned tubewells in these two states, with an average individual yield of 34 l/s and in addition 39,700 privately owned tubewells yielding an average 11 l/s.

Increasing concern in the GOI and among State governments as to the physical limits of water-resources development and the lack of coordinated use and management of tubewell and canal irrigation systems in the Ganges Plains led the GOI in early 1966 to request US AID/New Delhi for the services of a U.S. expert team to evaluate the status of hydrologic knowledge and water-resources development and to recommend a long-term program of investigations for guidance of on-going water-resources development and management.

P. H. Jones, ground-water hydrologist, and Walter Hofmann, surface-water hydrologist, of the USGS, were assigned and completed the mission during September–November 1966. Their report of May 1967 reviewed in considerable depth the physical, cultural, geological, and hydrological features of the Upper Ganges Basin; the 1966 status of canal and tubewell irrigation; the existing and potential effects of water use on the natural hydrologic regimen; and current water-data collection programs. They proposed a comprehensive 6-year water-resources investigations program covering all aspects of the temporal and spatial distribution of water both on the surface and underground that would be followed by continuing hydrologic observations over a longer term; the establishment of a new semi-autonomous Water Resources Investigation Agency for the Upper Gangetic Plain composed of 378 Indian scientists and engineers detailed from other GOI technical agencies; and 6 U.S. technical advisors on long-term assignments. Although the Jones-Hoffmann report and recommendations were well received in the GOI and by State governments concerned, later efforts to develop coordination among the GOI and State agencies that would have been required to implement the project have proved unsuccessful; hence, the project was not yet implemented in 1970.

Comprehensive Study of the Water Resources of the Narmadā River Basin, 1968

The Jones-Hofmann report of May 1967 on the Upper Gangetic Plain aroused great interest in the GOI and focused attention on the growing need in India for a comprehensive approach to the investigation of co-extensive river and ground-water basins and for the conjunctive management of water-resources developments in such basins. At the same time, GOI administrators foresaw difficulties arising from implementation of a basin-oriented investigation owing to the international character of the Ganges River. (Most of the tributaries of the Ganges rise in Nepal or in the Tibetian region of China and most of the mouths of the Ganges lie in East Pakistan.) As a result of these potential difficulties, the GOI decided to direct priorities to those basins lying entirely within Indian territory for comprehensive study. As regional development of the Narmadā

River Basin in central India was also then (1967–68) in the forefront of active GOI review, this basin was selected for planning a pilot or model comprehensive study. Hopefully, the results of this study would provide guidelines for comparable studies in other river basins of India.

In mid–1968 the Ministry of Food, Agriculture, Community Development and Cooperation (MFA) requested US AID/New Delhi to provide the short-term services of a U.S. expert team to determine how a comprehensive water-resources investigation of the Narmadā River Basin (fig. 44) might best be organized and conducted. G. E. Ferguson and Allen Sinnott, USGS hydrologists, were assigned to the mission and during November–December 1968 completed fieldwork and prepared the draft of an organizational plan for a comprehensive study of the water resources of the basin. This undertaking was greatly assisted by the active interest and participation in the mission by numerous representatives of the GOI as well as of the States of Gujarat and Madhya Pradesh (fig. 45). The Ferguson-Sinnott report of January 1969, which presented the scope and objectives of a proposed plan in great detail, included also a brief description of the physical, geological, and climatological features and existing water-resources development in the basin; a review of then-current (1968) water-resources investigations by the eight or more separate GOI and State governmental agencies operating in the basin; and an analysis of the elements of a comprehensive hydrologic study. They also presented detailed recommendations for organization of a coordinated water-resources study in the basin and measures for strengthening the study program. These recommendations were well received in the GOI and in the governments of Gujarat and Madhya Pradesh, and, although under continuing study by the agencies concerned, they were not yet implemented in 1970, chiefly because of uncertainties as to the context of administrative relations between the Central and State governmental agencies that would be involved.

FIGURE 44.—Narmadā River, looking downstream from railway bridge at Jamtara near Jubbulpore (Jabalpur) on November 21, 1968. Low-water discharge is measured by current meter from a boat in the quiet channel along the right bank. Flood waters inundate the alluvial deposits on the left.

FIGURE 45.—G. E. Ferguson and Allen Sinnott, USGS hydrologists, confering with Indian engineers on development plans for the Narmadā River Basin, 1968.

REVIEW OF PROPOSED GROUND-WATER ASSESSMENT STUDIES IN MADHYA PRADESH, GUJARAT, MAHĀRĀSHTRA, AND MYSORE, 1970

Through the initiative of the MFA a new Central Ground Water Board (CGWB) was constituted in October 1970 under the chairmanship of the Joint Secretary of the MFA. This board is to be guided by a three-man technical directorate deputed from other GOI agencies, including the Geological Survey of India (GSI), the Central Water and Power Commission (CWPC), and the Indian Meteorological Department (IMD). The CGWB also absorbed the entire staff of the former Exploratory Tubewells Organization (ETO), and in addition, technical personnel from the GSI, CWPC, and IMD will be deputed to the CGWB to build up the staff. Structurally, the CGWB is constituted as a quasi-governmental corporation. Where appropriate, the CGWB will also endeavor to build up satellite ground-water boards at state level, including those already operational, as for example in Rajasthan. The CGWB is to be basically oriented toward ground-water appraisal, exploration, and development but will also undertake surface-water hydrological and meteorological studies related to ground water.

In anticipation of the establishment of the CGWB and to provide technical support of ground-water development and management boards at state level, the former ETO in 1969 requested USADI/New Delhi to develop a provisional plan for ground-water evaluations and institutional development at state level. As a result of field studies by the water-resources staff of US AID/New Delhi during early 1970 this plan was formalized in US AID's Soil and Water Management Sub-Project 368.6, which provided for four specific areal evaluations in four states of central and southern India. At the request of US AID/Washington, C. L. R. Holt, USGS hydrogeologist, in company with a US AID water-resources engineer, W. D. Romig, visited India during October–November 1970 to formulate a scope of work for the project. As described in his report of January 1971, Mr. Holt visited all proposed study areas to assess geologic, hydrologic, ground-water development, and institutional problems. He reviewed project objectives, plans of action, personnel and equipment needs, and training proposals; proposed a scope of technical studies for each area study; and identified technical experience requirements for proposed U.S. personnel. He also proposed type-area ground-water studies in the Upper Narmadā River Basin in Madhya Pradesh, the Lower Narmadā River Basin in Gujarat, a Deccan Trap area in Mahārāshtra, and a crystalline rock area in Mysore.

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IRAN

Iran, modern descendant of ancient Persia, commemorated its 2,500th anniversary of established monarchy in 1971. Since World War II and under the leadership of his Imperial Majesty Mohammed Reza Pahlavi, the Shahanshah, Iran has pursued an active policy of social reform and economic development. As Iran is mostly semiarid and largely dependent on irrigated agriculture for its domestic food requirements, the Government of Iran (GOI) has given high priority to water-resources development, which has been financed by revenues from domestic oil production, with supplementary economic aid and technical assistance from the U.S. and other international donors.

During the two decades prior to 1970 the USGS provided technical assistance to the GOI, first in ground-water and later surface-water investigations, as part of U.S. bilateral aid to the national water-resources development program. The first appraisal by a USGS scientist of the water-resources problems of Iran was that of T. E. Eakin, who completed a hydrologic field reconnaissance between November 1951 and January 1952, reviewed the status of water-resources development, and recommended a program of long-term technical assistance, both in ground-water and surface-water investigations.

Ground-Water Investigations, 1952, 1960–63

Based on Mr. Eakin's recommendations, J. W. Lang, USGS hydrogeologist, was assigned to Iran between April and October 1952 to advise and consult with the GOI and US TCA/Teheran on problems of ground-water exploration and development for irrigation, village, and public water supply in critical areas throughout the country. During his 6-month stay in Iran, Mr. Lang logged 16,000 km of field travel in inspecting sites for proposed dams and in investigating ground-water problems at 25 localities —notably near Ahwaz, Abadan, Isfahan, Meshed, Shiraz, and Tabriz as well as at several points along the southern coast of the Caspian Sea. His observations and conclusions were described in a series of administrative memoranda and short technical reports issued during his stay in Iran.

Mr. Lang's work aroused great interest in GOI and focused attention on the large development potential of ground water for irrigation and other beneficial use. It was not until 1959, however, that systematic and continuing ground-water investigations were begun with establishment of a Ground Water Division in the Hydrographic Service of the Independent Irrigation Bongah (Corp.). A. F. Pendleton, Jr., USGS hydrologist, regularly assigned to surface-water investigations in Iran under US AID auspices, assumed responsibility in 1960 for advising the new Ground Water Division and in organizing and programing its activities. During the last 3 years (1960–63) of his stay, Mr. Pendleton provided basic hydrologic training through seminars and field demonstrations to a newly assigned Iranian staff of 90 geologists, 5 engineers, and 30 technicians. Beginning in 1961 a UN FAO hydrogeologist also was assigned as technical advisor to the Ground Water Division and for the next 2 years worked closely with Mr. Pendleton. Activities begun by Mr. Pendleton included basic ground-water inventories of wells and their water levels and of ghanats (infiltration galleries) and their flow in the Ghazvin, Varamin, and Karaj-Shariar Plains of the central Iranian Plateau.

After Mr. Pendleton's return to the United States in August 1963, these investigations were continued and extended by the Ground Water Division under the guidance of UN FAO advisors. In 1965 the Ground Water Division was transferred to the Hydrology Department of a newly organized Ministry of Power and Water. The present (1970) staff of the division includes about 100 geologists, engineers, and hydrologists assisted by a large group of technicians working on some 15 areal-type ground-water investigations throughout the country.

Surface-Water Investigations, 1953–63

In March 1953 and based on Mr. Eakin's recommendations as well as those of Mr. Lang, a project agreement was signed between the Iranian Ministry

of Agriculture, the Iranian Seven-Year Plan Organization, and US TCA/Teheran for U.S. technical assistance in strengthening and expanding the activities of the Hydrographic Service in the Iranian Irrigation Bongah. Known as "River Basin Surveys" the project provided for countrywide assistance in collection, collation, and publication of basic data on streamflow, precipitation, evaporation, chemical quality, and sediment transport. The USGS was requested by US TCA to provide surface-water hydrologists for long-term technical support and Karl Jetter arrived in Teheran in November 1953 to begin the project. Mr. Jetter returned to the United States in August 1956 and was replaced by J. A. Baumgartner in July 1956. Mr. Baumgartner died suddenly in February 1959, and was succeeded in May 1959 by A. F. Pendleton, Jr., who continued in Iran until termination of the project in August 1963. A UN FAO surface-water hydrologist was also assigned as advisor to the Hydrographic Service during 1953–59 and worked closely with USGS hydrologists in achieving common goals. Beginning in 1960, the scope of the River Basin Surveys project was expanded to provide for USGS assistance in a new program of ground-water investigations and collection of data on wells, springs, and ghanats.

Some of the more specific accomplishments of the project during the 10-year term of USGS technical support included: (1) expansion of a nationwide network of stream-gaging stations from a base of 130 in 1953 to 260 stations in 1963 fully equipped with modern hydrologic instrumentation, (2) organizing administrative and technical operations at Teheran headquarters and in nine district offices of the Hydrographic Service, (3) training and instruction of the Iranian staff of 200 hydrologists and technicians in the Hydrographic Service in techniques of field measurements, sampling, office compilation, and publication of hydrologic data through seminars and individual on-the-job methods, (4) establishing and equipping 100 precipitation and evaporation stations, later transferred to the Iranian Meteorological Service, (5) equipping, staffing, and training of personnel in sediment laboratories established in 1959 at Ahwaz, Kermanshah, Isfahan, and in the central soils and water laboratory at Teheran, (6) assisting in the compilation and publication of six bilingual (Farsi-English) Hydrographic Yearbooks, and (7) organizing in 1960 a Ground Water Section and training during the next 3 years of a new staff of 135 professionals and technicians in the basics of ground-water data collection and compilation. The high level of success achieved in USGS technical assistance efforts in Iran during 1953–63 was due in no small measure to the sustained interest, support, and participation of Iranian counterpart personnel in all aspects of the River Basin Surveys project.

Since 1963 the program of the Hydrographic Service has continued to flourish. The establishment in 1963 of a new Ministry of Water and Power led to the transfer of the Hydrographic Service from the Irrigation Bongah to the Hydrology Department of the new ministry. The program in 1970 included stream gaging at 465 stations, precipitation and evaporation observations (in cooperation with the Iranian Meteorological Department) at 620 stations, snow-survey courses in 41 river basins, and water and soils laboratories in 11 field offices—all under the direction of a professional, technical, and administrative support staff of 160 individuals assisted by 300 local observers.

Appraisal of Water Resources Development in the Bandar Abbas Coastal Region, 1968

A visit by U.S. Secretary of the Interior, Stewart L. Udall, to Iran in February 1967 and subsequent discussions between U.S. and Iranian government officials in Washington, D.C., during the Water for Peace Conference in May 1967 led to an agreement for U.S.-Iranian cooperation in the field of water resources. Identified areas of particular interest included weather modification, desalination, means of inhibiting the saline contamination of fresh water through its contact with naturally occurring salt diapirs and evaporite formations in south-central Iran, and the water-development potential in the Central Iranian Plateau along the northern slopes of the Zagros Mountains.

As part of this agreement, the Iranian Ministry of Power and Water in March 1968 requested the U.S. Department of State to provide the services of a U.S. expert team for an evaluation of the future water requirements and the development potential of water resources in the coastal region near Bandar Abbas, a major Iranian port city on the Strait of Hormuz between the Persian Gulf and the Gulf of Oman. To undertake this mission a team was constituted in the U.S. Department of the Interior under the auspices of the State Department's Water for Peace program. The team comprised M. E. Mattson, Office of Saline Water; J. D. Ellingboe, Bureau of Reclamation; and A. F. Pendleton, Jr., USGS hydrologist. The team arrived in Iran in late April 1968 and during the following month completed a field reconnaissance of the Bandar Abbas coastal

region in company with technical representatives of the Iranian Ministry of Water and Power. They studied pertinent climatic, hydrologic, geologic, economic, and demographic features of the region; existing and projected water requirements; water-supply systems; possible sources of future water supply; the Minab River water-supply system; desalting economics; and weather modification. Their administrative report of May 1969 concluded: (1) that the widespread presence of natural salt diapirs and evaporite formations in the region imposes severe constraints to the future development of potable water supplies, and that detailed geohydrologic studies and hydrologic data were needed to point out possibilities for interception, diversion, and isolation of naturally occurring fresh water before its contact with and contamination by salt formations, (2) that no potential for weather modification exists because of unfavorable meteorological conditions in the region, (3) that modest additional development of fresh water from the Minab River and from wells in the Issen and Takht Valleys for the Bandar Abbas municipal supply was possible during the next 20 years, and (4) that additional development of conventional water sources for the Bandar Abbas supply would be cheaper than desalting under current economic conditions.

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IRAQ

Iraq, historically known as Mesopotamia, occupies most of the broad plains of the Tigris and Euphrates Rivers, one of the great centers of early human cultural development and irrigated agriculture. The U.S. provided bilateral technical assistance to Iraq in the 1950's and the USGS participated briefly in the water-resources sector of this program during 1958–59. There has been no U.S. bilateral program in Iraq since 1959.

At the request of US ICA/Baghdad, Edward Bradley, USGS hydrogeologist, was assigned to Iraq in March 1959 to serve as a ground-water advisor to the Iraqi Development Board, which was somewhat later absorbed in the Iraqi Ministry of Social Affairs. The primary purpose of Mr. Bradley's mission was to develop and guide a long-term program of ground-water investigations in the Government of Iraq. During the early months of his tour, Mr. Bradley, with Iraqi colleagues, had developed the framework of such an investigational program, based largely on recommendations of an earlier ground-water reconnaissance of Iraq carried out by the Ralph M. Parsons Co. Mr. Bradley's proposal included areal ground-water investigations and quantitative studies in the Shari Lake, Amara-Mandali, and Jezira areas.

In July 1958, however, Iraq terminated the extensive U.S. bilateral technical-assistance program. Mr. Bradley continued for several months longer in an informal advisory capacity to the new government until his transfer to the US ICA/Jordan program in May 1959.

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ISRAEL

The State of Israel was created in 1948 as a Jewish homeland in ancient Palestine after more than 50 years of efforts by Zionist leaders. Israel, with the help of the international Jewish community and of grants and loans from the U.S. and other foreign donors, has developed a tightly knit society and a highly viable economy in a difficult natural environment. The United States provided Israel more than $1.2 billion in bilateral economic aid between 1948 and 1969.

In early 1962, Water Planning for Israel, Ltd. (TAHAL) requested US AID/Tel Aviv, as part of

the U.S. bilateral program to provide the services of a specialist in limestone geohydrology to evaluate the potential of the Cenomanian-Turonian aquifer of central Israel with respect to further development as well as for underground storage. Robert Schneider, USGS hydrogeologist, was assigned to the work between April and June 1962. During his stay and in concert with Israeli colleagues, Mr. Schneider studied available data on the geologic environment of the Upper Cretaceous Cenomanian-Turonian limestone aquifer, the development of permeability, the flow regime of the aquifer, the storage characteristics and sources of pumped water, the use of the aquifer for underground storage, and temperature distribution in the aquifer system. Based on his studies, Mr. Schneider recommended additional test drilling to define the boundaries of the aquifer, statistical evaluations of aquifer porosity, pumping tests, three-dimensional scale models for study of ground-water flow in parts of the aquifer system, and an electrical analog model of the entire system. The technical findings of Mr. Schneider were described in USGS Water-Supply Paper 1608–F.

Between 1962 and 1970, five USGS specialists in various aspects of hydrology visited Israel for short-term advisory assignments under technical-assistance programs of United Nations agencies. The scope and nature of these activities are described elsewhere in this report under "Multilateral Activities."

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JAPAN

Japan, foremost modern industrial power in the Far East, occupies a 3,200-km arc of 4 principal and 3,300 smaller islands off the coast of East Asia. Although the U.S. has never provided formal technical assistance to Japan, the USGS furnished technical consultation on water-supply problems for installations of U.S. Forces in Japan on several occasions since World War II, including a general review of ground-water problems in Japan for the U.S. Forces. Most of this work has not been recorded in available form. Where documentation exists, however, for the work of USGS hydrologists in Japan, it is described in the following paragraphs.

During January–March 1951, M. L. Brashears, USGS hydrogeologist, was assigned to evaluate ground-water problems for the General Headquarters, Supreme Commander for the Allied Powers, and to make general recommendations with respect to institutional needs for ground-water investigations in Japan. Mr. Brashears' report of May 1951 pointed out the high level of ground-water use for irrigation, industrial processing, public-water supply, and domestic use; the deleterious effects of over pumping in the Osaka, Nagoya, and Tokyo areas, resulting in reduced artesian flow, increased pumping lifts, salt-water encroachment and land subsidence; possibilities for artificial recharge of aquifers to check these problems and to recover wasted surface water; and the need for upgrading ground-water technology, surveillance, and management. He also outlined a broad program of investigations to achieve these objectives.

At the request of the U.S. Air Force, J. T. Callahan, USGS hydrogeologist, was assigned in October 1964 to make a brief evaluation of ground-water development problems at Misawa Air Base in Aomori Prefecture near the north end of Honshu Island. Mr. Callahan pointed out that the base lies in an artesian basin underlain by alluvial deposits of water-bearing sand and gravel separated by layers of clay and silt and that successful water wells have been drilled to depths of 200 to 400 m to the north, south, and west of the base. He concluded that construction of one or more production wells was feasible in the base area, but, because of the high vertical and lateral variability of the alluvial aquifers, "slim holes" should be put down at all proposed production well sites to determine the position and lithology of water-bearing zones for proper emplacement of casings and screens of production wells.

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JORDAN

Jordan, centrally located among the Arab nations, sustained a steady economic growth for the 15 years prior to 1970. An important base for this growth has been U.S. economic aid, which aggregated more than $€40 million during 1955–70. Moreover, this aid has emphasized water-resources development, notably

construction of storage and diversion dams, canals, and shallow (less than 100 m deep) wells for irrigation in the Jordan Valley and drilling of deep wells for irrigation in other more arid parts of the country. As an adjunct to this work and as part of U.S. bilateral aid to the Government of Jordan, the USGS provided technical advisors on several occasions during the 12 years prior to 1970, all of whom have directed efforts toward assisting the investigation, development, and management of Jordan's water resources.

Perhaps the first appraisal of the water resources of Jordan by a USGS scientist was that of V. E. McKelvey, who was assigned under the auspices of US ICA during October–November 1958 to evaluate the country's mineral resources with particular emphasis on the development potential of phosphate deposits. In his open-file report of 1959, he also included a description of the hydrologic regimen of the Jordan Valley–Dead Sea Basin and prepared quantitative estimates of Jordan's perennial annual water supply, surface runoff, water use, potential usable supply from replenishable sources and nonrenewable ground-water storage.

Ground-Water Investigations, 1959–60, 1962, 1966

After termination of U.S. bilateral technical assistance in Iraq, Edward Bradley, USGS hydrogeologist, was assigned from May 1959 to June 1960 to US ICA/Amman as technical advisor in ground-water geology to the Jordan Development Board's (DNB) Water Resources Department, which was absorbed in 1960 in a new Central Water Authority (CWA). During his stay in Jordan, Mr. Bradley (1) trained several geologists and engineers of the JDB in the basic methods of ground-water field studies, (2) completed in collaboration with the United Nations Food and Agriculture Organization (FAO) and Jordanian hydrogeologists, a countrywide inventory of recently constructed wells and an administrative report summarizing hydrogeologic data in Jordan, and (3) made 22 special site studies for test drilling and ground-water development, chiefly near Amman and in the West Bank area of Jordan.

In early 1962 the Government of Jordan requested US AID/Amman to provide the short-term services of a hydrogeologist to advise the Ground Water Division of the CWA on requirements for continuing ground-water investigations, use of ground-water data, coordination of technical activities with related functions of other government agencies, and training of Jordanian technical personnel—chiefly directed toward improved management and legal control of ground-water development in the Jordan River Valley. C. R. Murray, USGS hydrogeologist, was assigned to this mission from March to August 1962. For the guidance of the CWA and other agencies, his administrative report of October 1962 presented recommendations for general studies needed in the Jordan Valley and elsewhere in the country in areal and subsurface geology, ground-water recharge and discharge, water-level observations, water-table contours, water-quality analyses, test drilling, aquifer tests, ground-water law, and technical training of Jordanians. He also initiated ground-water studies near Jericho and South Shuneh, both in the Jordan Valley, that were subsequently carried to completion during 1962–64 by Jordanian hydrogeologists and ground-water engineers of the CWA.

In the early 1960's a threat to continuance of irrigation from wells had resulted from overpumping, water-level declines, and water-quality deterioration near Jericho in the West Bank area. To evaluate the problem and recommend solutions the Central Water Authority in late 1965 requested US AID/Amman to provide the short-term services of a USGS specialist. E. S. Davidson, USGS hydrogeologist, was assigned to the mission between January and March 1966. In his unpublished report of March 1966, he described the hydrogeology of the aquifer system near Jericho and the interrelations of saline- and fresh-water zones. He also presented detailed recommendations for increasing the fresh-water supply, stabilizing fresh-water levels, and arresting saline-water intrusion by pumping from new wells west of the Main Rift fault and by recharging the principal dolomitic limestone aquifer in the Cretaceous Belqa Group through ponds, existing wells or temporary dikes across the Wadi Qilt. Although the CWA had begun action to carry out Mr. Davidson's recommendations, this work was suspended in June 1967.

Surface-Water Investigations, 1962

Beginning in October 1961, Jordan undertook the building of a new National Hydrologic Service under the direction of the Hydrology Division of the Central Water Authority (CWA) with technical assistance provided by the FAO and a British consultant firm. Problems encountered during this buildup led the CWA in early 1962 to request US AID/Amman for the short-term services of a USGS surface-water hydrologist to review the program of the National Hydrologic Service and to recommend measures for improvement of operations and the hydrologic network. F. F. LeFever was assigned to this mission during March–May 1962. His administrative report

of September 1962 presented a general description of the surface-water hydrology (fig. 46) of Jordan; the work accomplished; and detailed evaluations of and recommendations for improvement of National Hydrologic Service's field procedures in stream gaging, office practices, hydrologic basic-data networks, reports, organization, personnel training, equipment, instrumentation, and gaging-station structures. Since Mr. LeFever's mission the National Hydrologic Service has attained a high level of viability.

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KOREA

The Republic of Korea (South Korea) occupies the southern part of a mountainous peninsula projecting 960 km southeast from Manchuria and the mainland of East Asia. Since 1953 the Republic of Korea (ROK) has been a major recipient of U.S. bilateral military and economic aid, including a large input of technical assistance. Between 1946 and 1968, U.S. economic aid alone to South Korea amounted to $4.7 billion. The USGS participated in the water-resources sector of the U.S. bilateral technical assistance program in South Korea first in 1963, again in 1964 and 1965, and continuously between February 1966 and February 1971. The scope, objectives, and accomplishments of these activities are described in following sections.

Ground-Water Reconnaissance, 1963, 1964

A severe drought in 1962 resulting in a loss of 20 percent of South Korea's cereal crop focused atten-

FIGURE 46.—Yarmouk River, the principal tributary of the Jordan River. View looking upstream from the Maqarin stream-gaging station.

tion on the need for proper appraisal and development of the nation's ground-water resources with a view to their use for supplemental irrigation and for drought amelioration. In late 1962, US AID/Seoul requested the USGS to provide a two-man team to make a preliminary survey of the ground-water potential of South Korea and to make recommendations for a program of ground-water exploration and development.

R. J. Dingman and W. W. Doyel, USGS hydrogeologists, were assigned to the mission and during January–March 1963 completed 3,200 km of ground and aerial reconnaissance. Their report of April 1963 outlined the general hydrogeologic features of South Korea, the extent of use of ground water in the country, and the status of ground-water investigations. The report also provided two alternative plans for nationwide ground-water investigations and training—the first (Plan I) of an intensive nature and 5 years duration and the second (Plan II) of a reconnaissance nature and 4 years duration. The alternative plans would have called for assignment of 8 to 12 U.S. scientific, engineering, and drilling personnel, a large Korean counterpart staff for technical support and on-the-job training, and substantial inputs of scientific and drilling equipment and ancillary supplies. The recommendations of the report were not implemented at the time owing to uncertainty as to which agency of the Korean government would serve as the counterpart.

In mid–1964, US AID/Seoul requested the USGS to provide the short-term services of a senior hydrogeologist to re-evaluate the proposals of Messrs. Dingman and Doyel with US AID/Korea and ROK officials, so as to reach a firm decision on which plan would be implemented and which Korean agency would serve as the counterpart. J. T. Callahan, USGS hydrogeologist, was assigned to this mission during September–October 1964. His report of October 1964 recommended that the intensive plan (Plan I) of the Dingman-Doyel mission be adopted and that the Geological Survey of Korea be designated the counterpart agency. During the months following Mr. Callahan's visit to South Korea, however, a change in US AID/Seoul policy reduced the priority of the nationwide ground-water investigation in favor of water-resources investigations directed toward integrated river basin development.

In 1968, UN FAO with UNDP financial support began a project for exploration of selected areas in South Korea to determine the ground-water potential for irrigation. This project, which included several recommendations of the Dingman-Doyel report, was still active as of the end of 1970.

Han River Basin Survey, 1965, 1966–71

The Han River Basin lies in the northern part of South Korea and a small part of it extends into North Korea. The basin, with an area of 26,200 km^2, covers slightly more than one-fourth the area of South Korea and is the largest river basin in the country. Development of the Han River for hydropower production began in the 1940's with the construction of the Chongpyong and Hwachon Dams on the North Han. Chunchon, Uiam, and Koesan Dams were completed later, and two more power dams are currently (1970) under construction. Following early development of hydropower, official recognition came in early 1965 of the need for a carefully devised multipurpose plan based on a comprehensive study to insure optimum development of the water resources of the basin. This led to a request from US AID/Washington to the U.S. Department of the Interior to provide the services of a three-man team for 60 days to undertake a preliminary survey for determination of the scope of a comprehensive study and of needs for manpower, time, and funds. The preliminary survey was completed during April–June 1965 by M. E. Von Seggern and W. F. Mac Millan, both of the U.S. Bureau of Reclamation (BuRec) and J. T. Callahan of the USGS. The team's report recommended a 5-year study by a 10-man U.S. team who would work with and train a counterpart group of 75 Korean personnel—all to be known as the Han River Basin Joint Survey Team. The subjects recommended for the comprehensive study included: hydrology, land resources, field surveys, geology and materials, drainage, flood control, navigation, engineering plans and estimates, economics, power, pollution control, recreation and wildlife, and ground water.

After some modification of the project proposal by US AID/Washington, the project was formally implemented in February 1966 with a project manager, two assistants, and nine divisions—each headed by an American specialist with a Korean counterpart and staff. The nine divisions included: administration, ground water, hydrology, power, planning and estimating, flood control and navigation, economics, land resources, and field engineering. Mr. Callahan of the USGS returned to Seoul in February 1966 to head the Ground Water Division of the Joint Survey Team and continued in Korea until February 1971. Mr. Von Seggern of BuRec returned to serve as Project Manager. Other American Division chiefs were

also BuRec specialists. The Korean Water Resources Development Corp. was established in the Ministry of Construction to serve as the principal counterpart agency in the ROK government.

The final draft report of January 1971 on the Han River Basin Survey included a general summary volume and 18 appendixes covering the 5-year study. The report concluded (1) that firm surface-water supplies during low flow on the Han River system are barely adequate for present needs, and future demands will require surface storage reservoirs to regulate the supply, (2) that construction of six storage reservoirs in the upper watershed and a barrage on the lower tidal reach of the Han are needed to provide firm water supplies, to control floods, and to optimize development of the Han River Basin, (3) that ground water is widely available for development in the alluvial valleys and in the rocks of the basin, as much as 25 percent of total projected water needs by the year 2001, (4) that flood-damage protection through provision of storage for flood runoff in proposed reservoirs is feasible and desirable, (5) that hydropower generation is feasible at three proposed storage reservoirs but that the amount of generable hydropower is small compared with the total power needs of South Korea, (6) that inland waterway navigation potential is submarginal, (7) that at least 38,800 ha of upland in Han River Basin could benefit from irrigation and for which it would be feasible to provide irrigation supplies, (8) that reclamation of tidelands for agriculture is infeasible, and (9) that the recommended plan for river-basin development will meet projected future water requirements until about the year 2012, provided this development is integrated with existing hydraulic works.

Mr. Callahan's report of January 1971 on the hydrogeology of the Han River Basin, which constituted the Ground Water Appendix of the Han River Basin Survey report, described the hydrogeologic framework of the basin, results of exploratory drilling, current ground-water use in 1970, future potential development, well-construction problems, ground-water development costs and benefits vis-a-vis surface-water development, interrelations of the ground-water regimen with streamflow, and the ground-water yield of the Han River Basin.

Among the more lasting accomplishments of the ground-water phase of the Han River Basin Survey were the training and equipping of a 15-man Korean professional and technical staff of ground-water specialists in the Water Resources Development Corp. At the end of the 5-year term of the project, this staff had reached a high level of competence and can serve in the future as a technical and scientific nucleus for direction of continuing ground-water investigations in the basin as well as elsewhere in Korea.

Much of the success of the exploration phase of the hydrogeologic study resulted from Mr. Callahan's collateral participation as advisor in the drilling program of the U.S. Army Corps of Engineers, Far East District, which began in 1966 and continued through the project history. During these 5 years more than 30 wells were drilled in the Han River Basin, and more than 100 wells were drilled at U.S. and Korean installations in other areas of South Korea.

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KUWAIT

Kuwait, occupying 15,700 km² of hot, sandy and almost featureless desert near the head of the Persian Gulf, enjoys the highest per capita income (about $3,200 annually) in the Middle East, owing to its revenues from petroleum production. Since the discovery of oil in 1938 and subsequent exploitation of its vast reserves, Kuwait has been transformed into a highly developed welfare state with a free economy. The arid environment, lack of arable land, and dearth of fresh water, however, has prevented significant development of an agricultural base for the country, so that most food, except fish from the gulf, must be imported. Moreover, the provision of potable water, adequate to sustain the basic requirements of a growing population and an industrial base, has been a continuing problem with the Kuwait government for the past two decades.

Although the U.S. has contributed no bilateral economic aid, the USGS has provided short-term technical assistance in the water-resources sector to the Kuwait government on a reimbursable basis twice during the past 25 years. On the first occasion, S. L. Schoff, USGS hydrogeologist, was assigned to Kuwait for about a month in October–November 1947 to review available hydrogeologic data in Kuwait and to evaluate it in hopes of identifying potential sources of potable ground water. Mr. Schoff concluded that possibilities for finding fresh ground water in substantial quantity were generally very poor in Kuwait, but recommended test drilling in unexplored areas to check out even remote possibilities.

In the latter part of 1965, the Government of Kuwait requested the U.S. Embassy to provide the services of a U.S. government expert on a reimbursable basis to (1) assess Kuwait's water resources, including current desalting operations, the Raudhatain fresh ground-water basin, and a proposed Shatt-al-Arab water import project, (2) evaluate the operational plans of engineering consultants for the ground-water development of the Raudhatain basin and other areas in Kuwait, and (3) advise on proposed installations of desalting plants at Shuaiba and Shuwaikh. H. E. Thomas, USGS hydrologist, undertook and completed this work in November–December 1965. His administrative report of December 1965 identified the water resources of Kuwait in four categories, sea water, imported surface water, fresh ground water, and brackish ground water. The report also detailed means of integrating the development of the resources and their use for greatest benefit to Kuwait's economy. He pointed out (1) that desalination of water from the Persian Gulf would contribute as much as 147,000 cubic metres per day to Kuwait's fresh water supply by 1970; (2) that fresh water imported by pipeline from the Shatt-al-Arab in Iraq, which conceivably could amount to as much as 450,000 m³/d, would have to be stored, at least in part, underground for lack of suitable surface reservoirs, (3) that Shatt-al-Arab fresh water could be injected underground in the Raudhatain, Umm Al-Aish, and possibly Al Quashaniya and Mutla basins, as native fresh ground water is withdrawn and before aquifers are contaminated by subjacent brackish or saline ground water, and (4) that reliable quantitative estimates were needed of the reserves of brackish water (less than 5,000 mg/l (milligrams per liter) of dissolved solids) in the Dammam Limestone aquifer. Mr. Thomas also recommended establishment of a National Resources Research Institute under the sponsorship of the Government of Kuwait to be staffed by international experts conversant in the scientific and technical disciplines related to water-resources development and management in the arid region of the Arab World.

Following Mr. Thomas' recommendations the Government of Kuwait negotiated and signed an agreement in June 1968 with the United Nations Development Programme (Special Fund) to establish a

jointly-sponsored Water Resources Centre. The agreement provided for a director of the Center and five experts in the fields of desalination, chemical engineering, hydraulic engineering, hydrochemistry, and hydrogeology. In addition to water-oriented technical studies, the Center would conduct training courses in the operation, maintenance, and management of desalination and powerplants. The Center also would provide facilities for 100 trainee students with initial construction costs estimated at $2 million.

NEPAL

Nepal, once called the "Hermit Kingdom of the Himalaya," lies landlocked between India and the Tibetan region of China. Because of its geographic isolation in the rugged vastness of the highest mountain range in the world, Nepal has only recently joined the world stream of social reform and economic development that has characterized the mid–20th century. The modern era in Nepal began in 1951, when it opened its doors to outside influence. First, under the leadership of the late King Tribhuvan, and subsequently His Majesty King Mahendra, Nepal has made steady progress with the assistance of international donors. Among these, the U.S. has provided about $137 million in bilateral economic aid and technical assistance to Nepal between 1951 and 1969.

As part of the country's planning for flood control, hydropower, irrigation, and public water-supply developments the Government of Nepal (GON) has recognized since the late 1950's the important and essential need for basic data and appraisals of its available water resources. To acquire this knowledge the GON in 1960 requested US AID/Kathmandu to provide the short-term services of a U.S. expert team (1) to evaluate needs for a comprehensive and continuing hydrologic survey and (2) to recommend a program for establishing a nationwide stream-gaging network and other hydrologic stations for systematic collection of water data and for developing a Nepalese agency to collect, compile, and publish hydrologic data and reports.

F. M. Veatch (May–August 1961) and Harry Hulsing (June–October 1961), USGS hydrologists, were assigned to this work and during their 5-month stay, completed systematic ground and aerial reconnaissance of all the river basins of the country. Their report of October 1961 outlines the topographic, geographic, climatic, and hydrologic features of Nepal and the needs for water data and a basic-data collection program. In addition, it recommends establishment of a Nepalese agency for multipurpose water-resources investigations; stream-gaging, ground-water, quality of water, and meteorological studies; U.S. technical assistance; and supporting equipment and supplies.

SURFACE-WATER INVESTIGATIONS, 1962–68

Implementation of the nationwide Hydrologic Investigations project proposed in the Veatch-Hulsing report began in May 1962 with the arrival in Kathmandu of D. E. Havelka, USGS surface-water hydrologist, who continued in Nepal until May 1964. During his tour, Mr. Havelka emphasized construction of stream-gaging stations (fig. 47), organization of a new Nepalese Department of Hydrology and Meteorology, and training of Nepalese engineers and technicians in basic field methods of stream gaging (figs. 48 and 49). He was succeeded in June 1964 by W. F. Curtis, USGS surface-water hydrologist, who remained in Nepal until November 1964. Mr. Curtis initiated sediment-data collection at key gaging stations, established a sediment-analysis laboratory, and trained Nepalese counterparts in techniques and procedures of office computation and compilation of streamflow data. Mr. Curtis was followed in December 1964 by W. W. Evett, USGS surface-water hydrologist, who expanded the stream-gaging network and continued the activities of his predecessors until the termination of USGS long-term support of the project in September 1968.

As of project termination, the Nepalese Department of Hydrology and Meteorology was an active, viable organization with a staff of 35 hydrologists and technicians, of whom 18 had received training from USGS water-resources offices in the United States during the life of the project; 57 regular gaging stations and 38 partial-record stations (fig. 50)

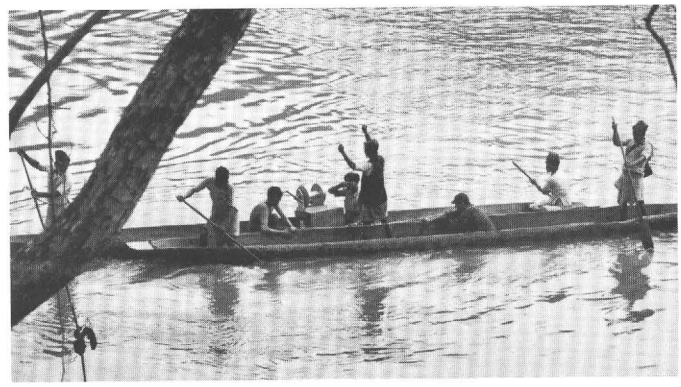

FIGURE 47.—Nepalese technicians stringing cable from two dug-out canoes for gaging station on the Karnāli River at Chisāpani.

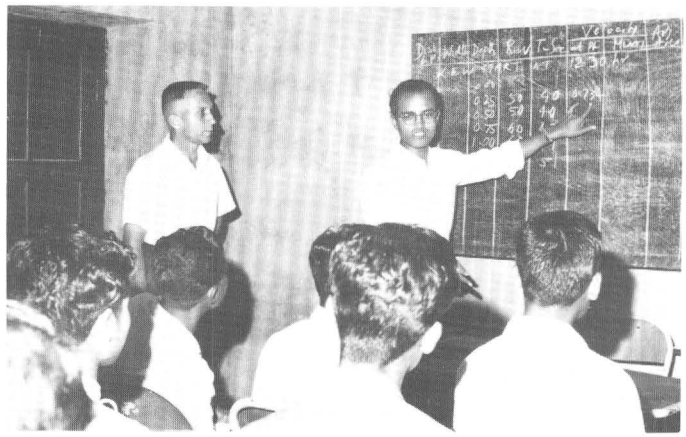

FIGURE 48.—D. E. Havelka, USGS hydrologist, assisting Nepali engineer during training session for Nepali hydrologic technicians in Kathmandu.

FIGURE 49.—D. E. Havelka, USGS hydrologist, measuring discharge of Sapt Kosi River from a dugout canoe with a Nepali family as interested observers.

FIGURE 50.—Nepali technicians installing staff gage at Chadorge Khola at Chadorge. This stream rises in the snow fields on the south side of Mt. Everest.

were constructed, fully equipped, and operational; and stream-discharge records spanning 6 years (1962–68) had been computed, compiled, and published for 46 stations. Mr. Evett described the scope and nature of these activities as well as other aspects of the hydrology of Nepal in his January 1969 open-file report, "Hydrology and Water Resources Development in Nepal."

GROUND-WATER INVESTIGATIONS, 1968, 1969–70

Recognizing the potential importance of ground water for irrigation and other use in the Terai belt along the southern border of the country, the GON in early 1968 requested US AID/Kathmandu to provide the services of a U.S. team to assess the existing knowledge of the ground-water resources of the Western Tarai and the needs for an investigative program to evaluate fully the ground-water potential and the development of a ground-water investigative agency in the GON. H. M. Babcock and W. V. Swarzenski, USGS ground-water hydrologists, were assigned to the work during April–June, 1968. They concluded that wells with sufficient yields (25 to 50 l/s) for irrigation could be developed throughout much of the western Tarai and that food production could be increased by raising two or three crops per year instead of one. Their report of June 1968 described the general geographic, geologic, and hydrologic features of the Western Tarai and existing and potential ground-water development. The report outlined the functions, operations, and organization of a proposed ground-water investigative branch in the Nepalese Department of Hydrology and Meteorology and a proposed 4-year program of training in ground-water methodology and of ground-water investigation and development—including hydrogeologic mapping, test drilling, water sampling, basic data collection, and report preparation.

The Ground Water Survey of the Western Tarai, as US AID/Kathmandu designated the project, was initiated in March 1969 with the arrival of G. C. Tibbitts, Jr., USGS hydrogeologist, as chief of party. William Ogilbee, also a USGS hydrogeologist, arrived in September 1969 to work with Mr. Tibbitts. In 1970 they were being assisted by a US AID well-drilling advisor and three Peace Corps Volunteer geologists on 1-year assignments. Test drilling during the first 18 months of the project, through a contract with an Indian drilling company, has indicated the presence of an artesian zone in the Lumbini area along the piedmont border of the Ganges Plains in the Western Tarai. Artesian aquifers occur in sand and gravel stringers intercalated with silt and clay

at depths ranging from 46 to 246 m below land surface. Test wells thus far completed indicate individual artesian flows of as much as 60 l/s with 12 m of artesian head above land surface. Also, two U.S.-made combination rotary-percussion drilling rigs arrived in Nepal in December 1970 and these will make possible additional departmental test drilling during 1971,

Other activities completed prior to December 1970 included an inventory of more than 1,000 dug wells and deep tube wells in the Western Tarai; construction of a supply yard, warehouse, and equipment-maintenance base at Bhairawa; organization of a staff of 45 Nepalese geologists, engineers, and support personnel in a new Ground Water Section in the Department of Hydrology and Meteorology; training of five Nepalese participants in the U.S. and West Pakistan; and establishment of a facility and equipping a laboratory for quality of water analyses.

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NEAR EAST WATER RESOURCES STUDY

After the Arab-Israeli war of June 1967, hopes in the U.S. Congress that the continuing crisis in the Near East might be resolved by peaceful means led to the passage in December 1967 of U.S. Senate Resolution No. 155 introduced by Senator Baker of Tennessee. This resolution, recognizing water scarcity as a continuing source of tension between Israel and its Arab neighbors, recommended that possibilities for nuclear desalting of sea water be explored to provide benefits both to the Arab states and to Israel. Subsequent to the passage of this resolution, it became evident that a regional appraisal of the conventional water resources of the Near East was not then available but that such an appraisal was needed for planning future U.S. water-resources development assistance in the region. Consequently, US AID requested the Department of the Interior to undertake a 6-month desk study of the water resources of the Near East region based on reports and data available in the U.S.A.

The Department designated the Bureau of Reclamation (BuRec) and the USGS to carry out the study. A 10-man interdisciplinary team composed of a planning engineer, an irrigation and drainage engineer, an agriculturist, economists, hydrogeologists, hydrologists, and soils and land-use specialists was organized under the leadership of Dominic Pastir of BuRec. H. E. Thomas, USGS hydrologist, assisted by G. C. Taylor, Jr., W. W. Evett, and Dallas Childers, Jr., also USGS hydrologists, provided inputs to the study relating to the water-resources inventory, hydrogeology, physiographic and climatic features, water law, and social and economic constraints affecting water-resources development and use.

The study began in May 1969 and a report was completed in draft form in September 1970. The study covered eight countries—Egypt (UAR), Lebanon, Israel, Syria, Jordan, Iraq, Kuwait, and Saudi Arabia north of lat 20° N. The principal objectives of the regional study were: (1) an appraisal of the conventional water resources, including an inventory of the surface-water and ground-water resources; (2) the description and analysis of the status of water development as of 1970 and use and plans for the near future (through 1985); and (3) the identification and analysis of opportunities and alternatives for further water development and land-use improvement in the near future.

The study report concluded: (1) that proposed national programs for water-resources development should be completed as scheduled, because additional studies probably would not improve planned projects sufficiently to justify delay in implementation; (2) that efforts to optimize utilization of land and water resources already developed should take precedence over development of additional water resources and reclamation of new lands.

PAKISTAN

Pakistan entered on the world stage as an independent republic on August 14, 1947, when Great Britain, decided on partition of British India and establishment of two independent successor states,

Pakistan and India, both affiliated in the British Commonwealth. Pakistan was set up to include contiguous Muslim-majority areas; thus, there came into being a geographically divided country with two wings, East and West, separated by the 2,400 km breadth of the new Republic of India with its Hindu majority.

Agriculture and processing of agricultural products have traditionally constituted the principal base of the economy in both wings of Pakistan. Water excesses or deficits, however, have long impeded efforts to improve agriculture and consequently national goals of self-sufficiency in food and fiber production for a large and growing population and of production of marketable surpluses for foreign exchange. Since gaining independence, however, Pakistan has given increasing attention to evaluation, development, and management of its water resources, with technical assistance and economic aid from foreign donors. U.S. bilateral aid to Pakistan during 1950–69 aggregated more than $3.7 billion. As part of this aid and through the aegis of US AID and its predecessor agencies, the USGS has provided continuous technical support to water-resources investigations in West Pakistan since late 1953 and in East Pakistan beginning in March 1967. The scope, objectives, activities, and achievements of this program are described in following sections.

West Pakistan Ground-Water Survey, 1953–67

Irrigated agriculture in the vast alluvial plains of the Indus River and its tributaries has been practiced with ground water and diversions from streams for more than 2,500 years. Modern irrigation in the Indus Plains, however, dates from the mid–19th century when British engineers constructed large diversion dams (barrages) on the major rivers coupled with a ramified system of "regime" canals and distributaries. This system now (1970) has attained an aggregate length of more than 16,100 km and irrigates 9.31 million ha, the largest contiguous block of irrigated land in the world. The press of population growth (some 100 million in 1970) and attendant needs for increased food production during the early decades of the 20th century gave impetus to a rapid expansion of the canal system and of irrigated lands. Lack of provision for subsurface drainage under irrigation and leakage from canals that resulted from this expansion ultimately resulted in aggravated problems of high water table (waterlogging) and widespread soil salinization (figs. 51 and 52). By 1950 an estimated 2.02 million ha had become nonproductive because of soil salinity and more than 28,000 ha was going out of production each year.

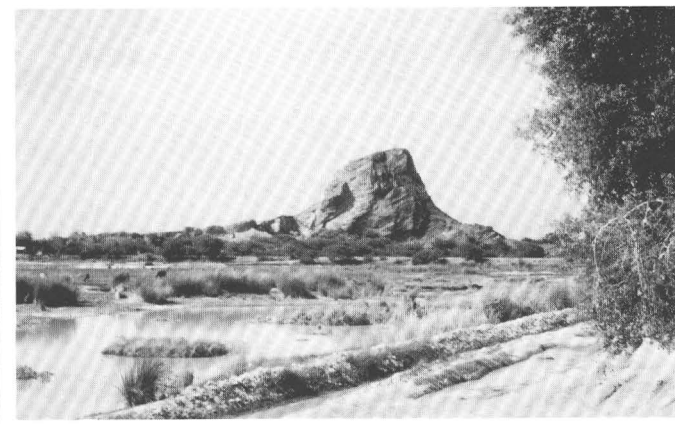

FIGURE 51.—Waterlogged land near Sāngla (Sangla Hill) in Rechna Doāb.

FIGURE 52.—Salinized land near Shekhūpura in Rechna Doāb.

To cope with these problems, the Pakistan government in 1953 reached general agreement with a predecessor of US AID for a comprehensive program of technical assistance and economic aid in soils and water-resources investigations; in engineering studies related to improvement of the irrigation system and design of necessary works; and in the construction of operating salinity-control and land-reclamation projects. As a part of this program, the USGS was requested by a predecessor of US AID to provide USGS scientists and engineers for long-term assistance in developing a scientific and technical organization within the Government of West Pakistan capable of collecting, analyzing, interpreting, and publishing data on the soils and water resources of the Indus Plains and for technical support of required field and laboratory investigations.

The USGS/USAID project, designated "West Pakistan Ground Water Survey" or "Project 035" by US AID/Lahore, had as its short-range objectives the provision of soils and water data essential for agricultural development, improved irrigation, salinity control, and land reclamation in West Pakistan. Major areal units first covered by the USGS/US AID project agreement included Thal, Chaj, Rechna, and Bāri Doābs—all in the Punjab region. Later, the Bahāwalpur, Dera Ismāīl Khān, Dera Ghāzi Khān, Bannu, Kohāt, and Hazāra Districts, as well as so-called Special Areas outside the Indus Plain, were added to the project. Data for all these areal units were to be collected, tabulated, analyzed, interpreted, and published in scientific and technical reports with appropriate tables, figures, and maps. The data required included: precipitation and evaporation; flow of rivers, canals, and drains; ground-water levels and fluctuations in levels; chemical quality of water; ground-water pumpage; surface and subsurface geologic information to permit identification and delineation of aquifers; hydraulic characteristics of aquifers; and physical and chemical characteristics of soils. The long-range objective of Project 035 was to build within the West Pakistan government an organization to train Pakistani personnel competent to carry out independently comprehensive and continuing soils and water-resources investigations required for effective management of these resources and increased agricultural production.

USGS support of the West Pakistan Ground Water Survey began in December 1953 with the arrival in Lahore of the first project advisor and continued without break until termination of the project in June 1967. During the project's 13-year life the USGS staff generally ranged from 4 to 6 men, and the total service of the 18 men assigned through June 1967, was about 62 man-years. The USGS personnel, assigned between 1953 and 1967 with their dates of assignment and areas of technical concern, are shown in the following table. In addition, the Ralph M. Parsons Co., under contract to US AID, supplied 10 drilling supervisors and experts totalling 20 man-years of service during active test drilling between 1956 and 1960.

Training and education of Pakistani personnel were always an important function of Project 035. Between 1962 and 1967 the USGS advisory group provided active technical support through field consultations, formal lectures, work shops, and seminars on general and specific topics in hydrology to personnel of the counterpart agency as well as to students of the Geology and Engineering Departments of the University of the Punjab at Lahore. The USGS also provided participant training in the United States during 1953–67, both in-service and

USGS Advisors attached to the West Pakistan Ground Water Survey, 1953–67

USGS advisors	Dates of assignment	Areas of technical concern
G. A. LaRocque	December 1953–July 1958	Project Chief, ground-water hydrology and hydraulics.
F. D. Bertelson	January 1954–November 1960	Soil scientist, soil surveys and land classification.
R. C. Baker	October 1954–September 1956	Geologist, subsurface geology and test drilling.
R. E. Miller	July 1955–July 1957	Geophysicist, borehole geophysics and geophysical studies.
C. C. Yonker	June 1955–June 1957	Hydraulic engineer, stream-gaging network design and sediment studies.
R. T. Kiser	July 1955–April 1958	Chemist, water quality analyses and laboratory procedures.
R. P. Borncamp	February 1956–December 1957	Ground-water engineer, well-drilling training.
R. L. Cushman	January 1957–January 1959	Ground-water engineer, aquifer tests and quantitative hydrology.
A. N. Sayre	November–December 1957	Ground-water hydrology, project review.
G. W. Caughran	October 1957–January 1960	Hydraulic engineer, stream-gaging and surface-water hydrology.
D. W. Greenman	December 1958–September 1962	Project Chief, regional ground-water geology and hydrology.
E. P. Patten	April 1960–April 1962	Geologist, ground-water hydrology.
W. V. Swarzenski	June 1961–October 1965	Geologist, ground-water hydrology and areal hydrogeochemistry.
G. D. Bennett	January 1962–July 1966	Ground-water hydrologist, aquifer hydraulics and analysis; analog model studies.
M. J. Mundorff	September 1962–December 1966	Project Chief, water-budget analyses; aquifer analyses; analog model studies.
J. W. Hood	September 1962–September 1964	Geologist, ground-water geology and hydrology.
H. L. Young	August 1963–December 1966	Geologist, ground-water geology and hydrology.
F. E. Clarke	March 1964; March–April 1965; October–November 1966.	Chemical engineer, well casing and screen corrosion and encrustation evaluations.
G. T. Malmberg[1]	June 1965–July 1969	Project Chief, areal ground-water hydrology and water-budget analyses.

[1] Terminated the West Pakistan Ground Water Survey and initiated the subsequent Hydrologic Monitoring and Research Project.

academic, for 30 Pakistanis of the counterpart agency, including 6 soil scientists, 3 chemists, 2 geophysicists, 1 mathematician, 7 geologists, 10 engineers and hydrologists, and 1 laboratory technician. Many of these now occupy positions of leadership in WASID and other Pakistani agencies as circle, section, and project chiefs.

The Pakistani counterpart agency during the first 6 years of the project life was the Ground Water Development Organization (GWDO) established in the West Pakistan Department of Irrigation. In April 1960, however, the GWDO was transferred to the West Pakistan Water and Power Development Authority (WAPDA) where it was reorganized and renamed the Water and Soils Investigation Division (WASID) headed by a Chief Engineer. WASID in 1967 included Geohydrology, General Hydrology, Quality of Water, Surface Water, and Soil and Land Classification Circles (Branches) and in addition a Water and Soils Laboratory and a Technical Coordination and Review Section. As of 1967 the WASID staff comprised about 260 professional and subprofessional employees, chiefly engineers, geologists, chemists, soil scientists and draftsmen, with several hundred other support personnel including drivers, drillers, clerks, secretaries, and general laborers.

Between 1953 and 1960, US AID equipped a modern soils and water-quality laboratory for WASID at Lahore under terms of Project 035. Also modern drilling rigs, air compressors, welders, vehicles, roadgraders, earth movers, and pumps as well as hydrologic, meteorologic, and geophysical equipment were supplied by US AID to sustain the operations of WASID. After 1960, equipment replacements were provided through regular WAPDA procurement channels.

During 1953–67, areal ground-water investigations totalling 13.6 million ha were completed by WASID, with the assistance of USGS advisors in Thal (3.3), Chaj (1.3), Rechna (2.8), and Bāri (3.0) Doābs, as well as in Bahāwalpur (1.8), D. I. Khān (0.9), and Bannu (0.5) Districts. Data were obtained on the extent, thickness, geologic, and hydraulic characteristics of the aquifers; the quality of the water; and the delineation of saline-water zones by means of 1,325 exploratory wells totalling 264,255 m of drilling. Complete aquifer tests were made at 184 wells. An observation-well program was established that included periodic water-level measurements on 300 wells and 40 continuous water-stage recorders. An electric analog model for hydrologic simulation and analysis of the Punjab region was equipped and placed in operation. Also a hydrologic-monitoring network was established for Salinity Control and Reclamation Project no. 1 (SCARP–1) and the Mona Reclamation Scheme and annual analyses of the water budget were begun in these areas to evaluate changes resulting from reclamation pumping. In addition, some 50 technical reports were released by WASID for public use as well as large volumes of tabulated hydrologic data and maps. Those reports in which USGS personnel participated are listed in the Pakistan references.

Between 1953 and 1960, USGS hydrologists assisted in the development of an integrated program of stream gaging, sediment sampling, and water-quality sampling on the Indus River system (fig. 53) and meteorologic data collection carried out by WASID's Surface Water Circle. This advisory assistance was continued between 1960 and 1967 by Harza International Engineering Co.

In soils surveys, some 11 million ha of soils mapping and classification was completed between 1954–60 by WASID's Soil and Land Classification Circle, with USGS advisory assistance, and in addition, special salinity-alkalinity surveys were made of 3.2 million ha. Periodic monitoring of soils reclamation in SCARP–1 was also begun in 1961 together with other special studies.

A fully equipped, staffed, and efficiently functioning Soils and Water Quality Laboratory at Lahore had been established by 1960, with the assistance of USGS advisors, and had completed by 1967 more than 74,000 analyses of water samples. The WASID

FIGURE 53.—Cultivated terraces in the Swat River Valley near Saidu with the snow-capped Himalaya in the background. The Swat is an important upstream tributary of the Indus River.

Quality of Water Circle also completed during 1962–67 special hydrochemical studies relating to the corrosion and encrustation of well casings and screens, and began in 1961 a periodic water-quality monitoring program involving 2,000 wells in SCARP–1 and 139 wells in the Mona Scheme.

The soils data and maps, water-table maps and hydrographs, exploratory well logs, hydrogeologic cross-sections, aquifer-test results, water-quality analyses and maps, technical reports, and voluminous additional data collected by WASID during the life of Project 035 form the essential base for the design and construction of Salinity Control and Reclamation Projects (SCARPs) by WAPDA with advisory assistance of U.S. consulting engineers. Ultimately, as many as 18 SCARPs in 405 to 809,000 ha blocks were envisaged in the Indus Plains. SCARP–1, covering 485,600 ha, has been in operation since 1961. Also as of June 1967, SCARP–2 (930,800 ha) and SCARP–3 (526.1 ha) were under construction; and feasibility reports had been prepared for SCARP–4 (890,300 ha) and SCARP–5 (1.09 million ha). The operational results of SCARP–1 now (1970) demonstrate that both soil-salinity and water-supply problems can be effectively alleviated by the reclamation measures that have been implemented. The quantity of water made available for irrigation by some 2,500 production tubewells put down for reclamation in SCARP–1 doubled that previously available, and overall crop production has increased markedly. The value and production of crops in SCARP–1, for example, increased more than 90 percent in 1964–65 over the 1959–60 base.

As of the end of 1966, hydrologic investigations and the collection and reporting of data were well ahead of then-current needs for the design, construction, and implementation of operating SCARPs. For this reason it was decided to terminate Project 035 in June 1967 and to recast USGS technical support in a new project oriented toward hydrologic monitoring and research.

Water-supply Investigation at Kharian Cantonment, Gujarat District, West Pakistan, 1958

At the request of the U.S. Corps of Engineers, J. B. Cooper, USGS hydrogeologist, was assigned during May–August 1958 to undertake a water-supply investigation at the Kharian Cantonment for the Armed Forces of Pakistan. This area, in the Indus Plains, is not particularly favorable for large well yields. Based on his study, however, Mr. Cooper determined that a well field to yield the required supply of 9,460 m^3/d could be located in an abandoned channel of Bhimbar River (Bhimbar Nallah) about 1 km south of Guliana. He recommended that the several wells in the field be spaced at intervals of 300 m or more and each be constructed to yield a few tens of litres per second.

White House-Department of Interior Panel on Water-Logging and Salinity in West Pakistan, 1961–63

During an official visit to the United States in July 1961, President Ayub Khan of Pakistan indicated to President Kennedy (1) his concern with waterlogging and salination which threatened the future of agriculture in the Indus Plain, and (2) Pakistan's need for a broad-based socio-economic study by a panel of American experts to formulate approaches to solution of these problems. President Kennedy, in response, asked the Secretary of the Interior, Stewart L. Udall and Jerome B. Wiesner, the President's Advisor for Science and Technology, to form a panel of such experts. Roger Revelle, then Science Advisor to the Secretary of the Interior, was designated Chairman of the Panel. He assembled a 21-man panel, which included experts in agriculture, hydrology, engineering, and the economic and social sciences. The panel included W. B. Langbein, Thomas Maddock, Jr., and H. E. Skibitzke, all senior USGS hydrologists.

The team delved deeply into all aspects of the social and economic framework of the Indus Plain as well as of its interrelations with the hydrologic regimen of the region during 1961–63. The final report on the study, titled "Land and Water Development in the Indus Plain," was published under White House auspices in January 1964. The report emphasized approaches toward lifting agriculture in the Indus Plain above the subsistence level and setting it on the road to substantial productivity. The USGS panel members, with substantial USGS "in-house" assistance, provided detailed economic analyses of the hydrologic regimen of the Indus Plain based on analog- and digital-computer studies. This work was described in Chapter 7 of the published report. Since its publication, this work has formed the basic reference for agricultural development planning in West Pakistan.

Hydrologic Monitoring and Research Project, 1967–71

Although the historical causes and effects of waterlogging and salinization in the Indus Plains had been successfully evaluated and sufficient soils and water data had been obtained for planning, construction, and implementation of SCARPs by the end of 1966, problems encountered in the construction, operation, and maintenance of SCARP–1 pointed up the need

for additional assistance. Accordingly, a new project, designated "Hydrologic Monitoring and Research" or Project 257 by US AID/Lahore, was begun in July 1967 with USGS technical support and was phased out in December 1971. The objectives of Project 257 were (1) to develop from operational monitoring and research the data, techniques, and staff essential for continuing operational guidance in existing SCARPs and the planning of future SCARPs; (2) to monitor all phases of the hydrology of the Indus Plains for determination of changes in the hydrologic regimen resulting from installation of tubewells; (3) to conduct specialized hydrologic research in the Mona Experimental Project pertinent to the planning of other SCARPs; (4) to use electric-analog models for appraisal and evaluation of hydrologic problems related to water management; (5) to train WASID technicians in computer techniques related to processing all types of hydrologic data, so as to insure prompt and efficient analysis, storage, and retrieval of these data; (6) to analyze the quantitative and qualitative effects of tubewell-development projects (SCARPs) on water levels, ground-water flow systems, canal leakage, gains and losses in streamflow, and other hydrologic factors; (7) to determine limitations of pumping from salt-water zones so as to prevent serious contamination of adjacent fresh-water zones; (8) to evaluate differences in lateral and vertical permeabilities of aquifers underlying the Indus Plains and the effects of these differences on the vertical movement of ground water; (9) to delineate fresh-water bodies overlying saline water at relatively shallow depth; and (10) to investigate problems related to the hydraulics of wells and factors and treatments effecting their yield.

USGS technical support of the Hydrologic Monitoring and Research Project was originally planned at a level of four long-term advisors for the full 4-year project life. Owing to cutbacks in U.S. foreign aid available for development grant assistance, it was necessary beginning in early 1968 to limit the long-term USGS advisory staff to one or two men and to resort to a wider use of short-term USGS consultants and specialists. By this means it was possible to achieve nearly all identified objectives by the end of the project. The USGS personnel, assigned between 1967 and 1971 with their dates of assignment and areas of technical concern, are shown in the following table.

Active hydrologic training and education of WASID personnel continued throughout the life of Project 257 as in the antecedent project. Between 1967 and 1971, seven Pakistanis of WASID received academic and in-service training in the U.S. under USGS guidance, including three analog-model specialists, one hydrologist, two geochemists and one administrator in technical management. In addition USGS specialists during this period provided individual field and laboratory training as well as group training to WASID personnel in Lahore through lectures, workshops, and seminars in technical report preparation, electric analog model analysis and interpretation, computer processing of hydrologic data, and hydrogeochemical interpretation of water-quality data.

USGS advisors attached to the Hydrologic Monitoring and Research Project, 1967–71

USGS advisors	Dates of assignment	Areas of technical concern
G. T. Malmberg[1]	June 1965–July 1969	Project Chief, areal ground-water hydrology, water-budget analyses, and general advisory assistance.
H. A. Waite	April 1968–May 1970	Project Chief, areal ground-water hydrology and general advisory assistance.
C. A. Morgan	January–April 1969; January–April 1970.	Computer specialist, digital computer programing and processing of hydrologic data and computer programing training in hydrology.
S. N. Longwill	April–July 1969; April–July 1970	Analog model specialist, electric analog model construction, analyses, and interpretation and analog model training in hydrology.
P. R. Seaber	November 1969–December 1971	Project Chief, areal hydrogeochemistry, general advisory assistance and project formulation.
W. D. E. Cardwell	November–December 1970	Reports specialist, technical reports preparation and processing, training in hydrological reports preparation.
William Back	January–February 1971	Hydrogeochemist, hydrogeochemical investigations and analyses.
R. N. Cherry	February–March 1971	Hydrogeochemist, hydrogeochemical interpretation and analyses.
A. R. Leonard	October-December 1971	Geologist: ground-water hydrology, data evaluation and analysis.
E. P. Patten	October–November 1971	Analog Model Specialist; advisory assistance on hydrologic interpretations from electric analog models.

[1] Assigned to the antecedent West Pakistan Ground Water Survey and initiated Hydrologic Monitoring and Research Project.

As in the antecedent Project 035, the Water and Soils Investigation Division (WASID) was the counterpart agency for USGS technical support throughout the life (1967–71) of Project 257. An Analog Model Laboratory and a Central Monitoring Organization were established in WASID in 1968 in addition to those circles already extant.

At the phaseout in December 1971, nearly all objectives of Project 257 were essentially achieved. The Central Monitoring Organization in 1971 was functioning actively and effectively and had undertaken on a centralized and ocordinated basis, hydrologic monitoring and research on present and planned SCARPs. Annual hydrologic monitoring and water-budget reports have been prepared since 1965 by WASID for SCARPs 1 and 2, the Mona Experimental Project, the Khairpur area, and the Lower Indus project. These reports describe the quantities and distribution of pumpage from operating tubewells, annual and long-term changes in the position of the water table and in ground-water storage, ground-water inflow and outflow from project areas, surface-water inflow and outflow through canals and drains, precipitation, consumptive use by crops, and canal leakage. WASID's Analog Model Laboratory since 1968 has constructed operating electric analog models of several SCARPs and has completed several hydrologic analyses and reports on these with USGS assistance. Several programs have been developed in WASID for digital computer processing of water-quality and water-level and other hydrologic data on WAPDA's IBM 360 Model 30 computer. The WASID Quality of Water Circle began an active water-quality evaluation program in 1967 and, with the assistance of WAPDA's IBM 360 computer and USGS advisors, has undertaken long-term salt-balance studies of the ground-water systems in proposed and operating SCARPs. Vertical and lateral permeability studies, by special neutron moisture-probe meter, have been completed by WASID in several localities, but the coverage was not yet adequate at project termination. Reconnaissances of the areal and depth distribution of fresh and saline ground-water bodies have been completed in the Punjab region, and more intensive studies are now (1970) in progress in Rechna and Chaj Doābs. Performance tests have been made semiannually or annually since the early 1960's on a network of about 10 percent of operating SCARP tubewells to measure changes in specific capacity (the ratio of well discharge to cumulative decline in pumping level) that result from corrosion and encrustation of well screens and casings. Various restorative measures have been tried, with varying degrees of success.

The WASID/WAPDA, with a present scientific and technical cadre of 260 and an additional several hundred support personnel, had as of 1971 attained a high level of sustained performance and capability. During the years 1953–71, WASID, with continuous USGS technical support, with increasing precision, collected, analyzed, and evaluated, through some 80 technical reports as well as numerous maps and graphic summaries, great volumes of basic soils and water data, including the quantity, quality, availability, variability, and cost of water. Broader questions, however, still remain to be answered: What is the economic life of the SCARPs? What is the nature of soil, water, and plant interactions in the SCARPs? What scientific and pragmatic lessons have been learned in West Pakistan that are appliacble to irrigated lands in other arid and semiarid regions? What is the future of soils and water-resources development to be in West Pakistan? Assessments of the occurrence, availability, and quality of water are of slight practical significance unless they are geared to social and economic demands on the resources within the prevailing political and legal framework. These are the coming challenges of WASID/WAPDA and West Pakistan.

East Pakistan Ground-Water Survey, 1967, 1970–71

East Pakistan, situated in the vast deltaic plain of the Ganges and Brahmaputra Rivers, has long suffered from the ravages of cyclones, torrential rains, river and sea-water flooding during southwest monsoons and from water deficits during intervening dry seasons. Owing to topography and geographic position, East Pakistan has not been able within its boundaries to seek solutions to these problems through dams and reservoirs that could store and thereby regulate river flow for flood protection and irrigation supply. Major progress has been made during the past 15 years, however, in the construction of coastal dikes to mitigate flooding from sea-water surges and of embankments to alleviate river flooding—all with technical assistance and economic aid from US AID, the International Bank for Reconstruction and Development (IBRD), the UN Food and Agriculture Organization, and other international donors. Some 1.05 million ha have thus far been protected against flooding.

Because of dry-season water deficiencies, East Pakistan beginning in the early 1950's, has sought to expand and intensify agricultural production through irrigation by low-lift pumping from peren-

nial streams. In 1970 283,300 ha largely of winter rice, was irrigated by 18,000 pumps. Since 1960 the benefits of tubewell irrigation in areas away from streams have also received increasing recognition. Of particular stimulus was a provincewide ground-water reconnaissance completed between November 1963 and March 1964 by H. V. Peterson, hydrogeologist of the International Engineering Co. In his report of June 1964, he points out the favorable development potential for irrigation of East Pakistan's ground-water reservoir. Following his recommendations, the East Pakistan Water and Power Development Authority (EPWAPDA) and Agricultural Development Corp. (ADC) have undertaken pilot ground-water developments in several areas. Between 1964 and 1970 some 1,165 tubewells of 42 to 57 l/s capacity were put down by these agencies to irrigate about 40,500 ha. Also credits have recently been extended by the IBRD group for construction and equipping 3,000 more tubewells during the next few years.

Because of growing awareness of the large potential of East Pakistan's ground-water reservoir for irrigation, industrial, public, and rural water supply as well as of the need to explore, appraise, and manage this resource on a sound scientific and technical basis, M. J. Mundorff, then USGS project chief for the West Pakistan Ground Water Survey, was assigned briefly in July 1966 to discuss with and advise provincial officials on a proposed comprehensive ground-water investigation of East Pakistan. Based on his recommendation, the Pakistan government in late 1966 decided to request from US AID/Rawalpindi a team of ground-water experts to review the then-current state of ground-water knowledge, to assess the potential of the ground water resources of East Pakistan, and in the event of a favorable assessment to prepare a plan for a long-term project of ground-water investigations and institutional development. In fulfillment of this request, J. R. Jones and H. M. Babcock, USGS ground-water hydrologists, were assigned to East Pakistan in March–May 1967 to carry out the mission. Their report of July 1967 outlined staffing, functional, operational, and organizational requirements for a proposed ground-water investigative agency in the Government of East Pakistan as well as the scope, objectives, equipment, and personnel needs for proposed USGS technical support of the new agency for a 5-year term. The report also identified five critical areas for intensive field investigation and in addition provincewide hydrologic monitoring and data collection.

The East Pakistan Ground Water Survey was not begun until August 1970 when J. R. Jones returned to Dacca to serve as USGS project chief. E. A. Sammel and N. E. McClymonds, USGS hydrogeologists, arrived in Dacca in November 1970 to work with Mr. Jones.

The USGS/USAID/GOP loan agreement provided for the services of the USGS (1) to assist in establishing and developing a new ground-water investigatory agency known as the Ground Water Circle (GWC) and headed by a technical Director within the EPWAPDA; and (2) to undertake general provincewide hydrologic monitoring and data collection as well as intensive ground-water studies of selected areas in East Pakistan, notably in the Dināj pur, Pachāgarh-Titālya, and Bārind East areas and in the Madhupur Jungle. The technical knowledge and products of the GWC were to be geared to serve the needs of all agencies concerned with ground-water development and management in East Pakistan.

Because of civil unrest, the US AID in mid–1971 terminated active technical assistance in East Pakistan, including the USGS project.

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PHILIPPINES

The archipelago of the Philippines, containing more than 7,000 islands, stretches 1,770 km along the southeastern rim of Asia. The Philippines became an independent republic on July 4, 1946, and since independence and before 1968 had received $1.8 billion in bilateral economic and military aid from the U.S.

In early 1956 an agreement was signed between US ICA/Manila and the Philippine government for a 5-year cooperative program, designated "Water Resources Planning and Development." This agreement included provision for U.S. technical assistance in both ground-water and surface-water investigations with the Bureau of Public Works (BPW), in the Philippine Department of Public Works and Communication, as the chief counterpart agency. Later in 1956, US ICA requested the USGS to provide technical support under terms of the program. Implemented in January 1957, the support continued until June 1961. The scope of this work is described in following sections.

In 1955, 1961, and 1967 the USGS also provided the consultative services of hydrogeologic experts to

evaluate water-supply problems at U.S. installations in the Philippines, all on the main island of Luzon.

Ground-Water Investigations, 1957–61

Although wells have been used extensively in the Philippines for many years, primarily for domestic and municipal water supply, it was not until the establishment in 1952 of the National Waterworks and Sewerage Authority (NWSA) by President Magsaysay that the importance of ground-water resources received national attention. The NWSA was charged in its primary mission with the provision of adequate and sanitary water supplies for the towns and villages in the islands and the ambitious goal of putting down 10,000 wells a year. In subsequent years, the NWSA proceeded vigorously with its development mission, and in 1956 the need was recognized in the Philippine government for systematic exploration and appraisal of ground-water resources, both prior to and concurrent with development. To fill the need for technical assistance in this sector as part of the "Water Resources Planning and Development" program, C. R. Murray, USGS hydrogeologist, arrived in Manila in January 1957 to serve as ground-water consultant to US ICA/Manila and advisor to a newly established Ground Water Unit in the Irrigation Division of the BPW. He also served during 1960–61 as a general water-resources advisor and consultant to US ICA/Manila and to the interagency Philippine National Water Resources Development Committee. He continued in the Philippines until his return to the USA in June 1961.

The principal goals of Mr. Murray's work included (1) organizational development of the Ground Water Unit to carry out systematic ground-water investigations; (2) selection and procurement of appropriate hydrologic instruments and drilling equipment for the Ground Water Unit; (3) training of Philippine personnel of the Ground Water Unit in the methods and techniques of ground-water investigations, including test drilling, lithologic and electrical well logging, collection and description of samples and the evaluation and publication of ground-water data; and (4) starting and guiding of ground-water investigations, first in Central Plain of Luzon, extending north from Manila Bay, and then later in Southern Luzon and in the Bicol Region (southeastern Luzon).

In the Central Plains project, started in 1957, Mr. Murray guided the activities of 15 Philippine engineers and geologists of the Ground Water Unit in hydrogeologic mapping, in hydrologic inventory of 500 wells previously put down by NWSA, in drilling 50 new exploratory wells (maximum depth 215 m), and in making 50 single-well aquifer tests for transmissivity values. The results of this work were released in a BPW publication, "Ground Water Resources of Pampanga Province," in 1959 and in a preliminary report in 1961, "Water Resources of Central Luzon." Mr. Murray assisted the Ground Water Unit in the design and beginning of a ground-water investigation of a five-province region in Southern Luzon. The fieldwork, begun in 1959 and scheduled for completion in 1962, included hydrologic inventory of NWSA wells, drilling of 100 new exploratory wells and aquifer testing, carried out under the direction of a six-man team of Philippine professionals. Special attention was given to data needed for development of village water supplies, for evaluation of potential salt-water encroachment from Manila Bay and the Passiq River, and for industrial water supplies in the environs of Manila. During early 1961, Mr. Murray assisted the Ground Water Unit in the design of a ground-water investigation for the Bicol Region, including a test-drilling contract for 20 wells. Mr. Murray was notably successful during his stay in training Philippine counterparts in field and office methodology of ground-water investigations and in the analysis and interpretation of ground-water data.

In 1963 the Ground-Water Unit was raised to the level of a Branch in a newly established Hydrology Division within the BPW. Also a U.S. ground-water advisor, R. L. Gamer provided additional technical support for the Ground Water Branch from January 1964 through May 1966 as part of a US AID/U.S. Bureau of Reclamation program with the Philippine government, designated "Water Resources Survey." Both these actions served to strengthen administrative and financial support of ground-water investigations in the Philippines during the late 1960's and to focus attention on the need for systematic appraisals of the resource for orderly development.

More recently, in July 1969, USGS short-term technical assistance in the ground-water sector was provided through UN FAO auspices to the Philippine government under the FAO/UNDP Central Luzon Ground Water Development Project. This project, however, is under the aegis of the Philippine National Irrigation Administration.

Surface-Water Investigations, 1957–61

Streamflow investigations in the Philippines were begun in 1908 by the Hydrographic Section, Irrigation Division of the BPW with the consultation and advice of the USGS. The streamflow records for

1908–22 were published by the BPW in four volumes in 1923. Unpublished records for 1923–44 were unfortunately destroyed by fire during the siege of Manila in World War II.

In late 1956, US ICA/Manila requested the USGS to provide the services of an expert in surface-water hydrology (1) to assist US ICA/Manila and the Philippine government in the design of a long-range stream-gaging program for the Philippines appropriate to national development plans; (2) to recommend a specific surface-water investigations program for Central Luzon; (3) to provide technical training (fig. 54) through field and office seminars to Philippine personnel in gaging-station site selection and in construction and field operation of stations; (4) to review needs for water-quality investigations; (5) to recommend improvements in the precipitation gage network; and (6) to inspect and comment on a new current-meter rating flume in Manila. F. M. Veatch, USGS surface-water hydrologist, was assigned and carried out this mission between February and June 1957. His report of June 1957 reviewed in detail the history, organization, financing, design, equipping, and recommendations for improvement of the stream-gaging program; the technical training program; the operation of the current-meter rating flume; the needs for a Central Luzon surface-water program; and the needs for precipitation, evaporation, and sediment stations.

FIGURE 54.—Philippine hydrologist of the Hydrographic Section, Bureau of Public Works making current-meter measurement on Angat River in Luzon.

In May 1957, L. J. Snell, USGS surface-water hydrologist, arrived in Manila on a 2-year assignment under the "Water Resources Planning and Development" program to provide technical assistance to the Hydrographic Section of the BPW in carrying out Mr. Veatch's recommendations. Mr. Snell remained in the Philippines until his return to the USGS domestic program in May 1959. During his 2-year stay, Mr. Snell assisted in the recomputation and preparation for publication of 1,291 station years of streamflow records for the years 1945–56. These were published in 1958 by the Hydrographic Section, BPW, in volumes I and II of Surface-Water Supply Bulletin No. 2 for the Philippines. He also assisted in the computation and preparation of records for 1957–59 which were published in 1962–63 as volumes I and II of Bulletin No. 3. He advised on and assisted in the preparation of a compilation report which summarized the analysis and interpretation of all streamflow data before 1958 in a 17,975-km^2 area of Central Luzon, the most highly urbanized and industrialized region in the Philippines. This report on the "Surface Water Supply of Central Luzon" was published by the BPW in 1959. The report includes data and graphs on flood and low-flow frequency, flow duration, maximum and minimum discharges, runoff per square kilometer and other data of value to water-resources planning and development agencies.

Mr. Snell also conducted several field and office seminars for BPW hydrologists and technicians in the methodology of stream-gaging and the computation and compilation of records for publication; extended the construction of stream gaging, sediment sampling, rainfall, and evaporation stations (fig. 55); and carried out with Philippine colleagues special studies in flood and low-flow frequency analysis, basin hydrology, seepage gains and losses, and tidal hydraulics in Central Luzon. Together with Mr. Murray, he assisted in design, construction, and equipping a BPW laboratory for sediment, quality-of-water, and soil analyses.

After Mr. Snell's departure from the Philippines, Mr. Murray continued as advisor to the BPW in USGS technical support of both surface-water and ground-water activities. Between February 1957 and August 1961, the stream-gaging network was expanded from a base of 100 staff gages to a 12-main

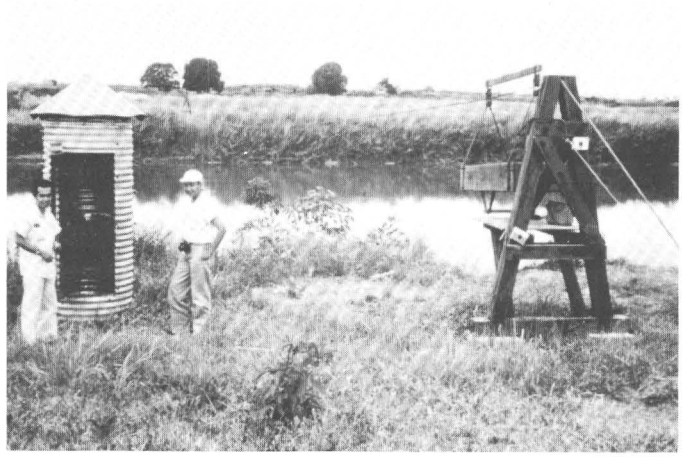

FIGURE 55.—Philippine engineers at cableway and gage house of stream-gaging station constructed with the guidance of L. J. Snell, USGS hydrologist, on the Pampanga River at Atate in Luzon.

island (except for Palawan) network of 400 stream-gaging stations, 14 evaporation stations, 191 discharge measurement cableways, 167 automatic water-stage recorders, 91 precipitation stations (of which 13 were automatic recording gages), 46 sediment sampling stations, and 6 quality-of-water stations. In 1963, the Hydrologic Section was reorganized and raised to a Surface Water Branch in a newly established Hydrology Division within the BPW. This action considerably strengthened the position of surface-water investigations in the Philippines government, both with respect to funding as well as to administrative support.

Beginning in 1963 and continuing until 1968, a U.S. surface-water advisor provided additional technical support for the Surface Water Branch as part of a US AID/U.S. Bureau of Reclamation program with the Philippine government, designated "Water Resources Survey." As of 1968 the operational stream-gaging network being maintained by the Surface Water Branch consisted of 428 stations, and suspended sediment and quality-of-water samples were collected at many of these. In addition, rainfall and evaporation data were being collected at 106 stations. Also in 1968 the technical staff of the Branch included 28 surface-water hydrologists and 30 technicians plus 334 part-time gage readers.

WATER-SUPPLY INVESTIGATIONS AT U.S. INSTALLATIONS, 1955, 1961, 1967

In response to a request to the USGS from the U.S. Department of the Navy, J. F. Poland, USGS hydrogeologist, was assigned for a 2-week period in 1955 to evaluate the hydrogeologic, hydrologic, and water-quality environment of the Cavite Peninsula and the water-supply problems of Sangley Point Naval Station on the southern coast of Manila Bay, Luzon. Mr. Poland studied in detail the hydrogeologic framework of the peninsula, the then-current (1955) conditions of salt-water contamination of supply wells and recommended followup detailed study, including test drilling under USGS guidance. These recommendations were not implemented.

Again at the request of the Navy Department, G. F. Worts, Jr., USGS hydrogeologist, visited the area in April 1967 to evaluate water records and data that had accumulated and changes in ground-water conditions that had occurred in the vicinity of the Sangley Point Naval Station since Mr. Poland's 1955 study. Mr. Worts concluded that the water-supply problems in 1967 were: (1) continued deterioration in the water quality owing to salt-water contamination of the ground-water supply, (2) poor well design, and (3) insufficient pumping capacity to meet increasing demands. He, therefore, proposed a program of remedial measures, including plugging of unused wells to prevent contamination of deep freshwater aquifers, increased pumping capacity, redesign of existing wells, and relocation of new wells to mitigate contamination. While in the Philippines, Mr. Worts also made a brief study of the water-supply problems of the San Miguel Naval Communication Station on Subic Bay, Luzon. Here he evaluated problems of insufficient supply, high iron content, well corrosion, and perforated casings, and he recommended sites, design specifications, and pumping schedules for new wells to remedy these problems.

On an earlier occasion and also at the request of the Navy Department, Mr. Worts completed during October 1961 a hydrogeologic reconnaissance of Poro Point and vicinity, also on Luzon Island, chiefly to assist in the development of a water supply for the Wallace Air Force Station. The technical results of Mr. Worts' work were published in 1964 in USGS Water-Supply Paper 1608–E in which he concluded (1) that the chief aquifer tapped by wells on Poro point is a Pleistocene coralline limestone, (2) that the fresh ground-water supply is contained in a lens ranging annually from 7.5 to 12 m thick, (3) that the annual recharge was 2.5 to 4.9 million m^3 per year, (4) that the 1961 annual withdrawal was only about 123,000 m^3, and (5) that pumping from "skimming" wells or shafts could be increased several-fold, provided pumping was maintained at a uniform rate.

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SAUDIA ARABIA

The Kingdom of Saudi Arabia, as custodian of the holy cities of Islam, Mecca and Medina, and possessor of large proven reserves of petroleum, enjoys a paramount economic and cultural position in the Arab and Moslem world. Moreover, in its efforts since World War II to break away from its traditional isolation in the vast arid region of the Arabian Peninsula between the Red Sea and the Persian Gulf, Saudi Arabia has given strong emphasis to the appraisal and development of its natural resources for strengthening the basic economic infrastructure as well as for advancing social reform. As part of this process, the USGS has provided technical assistance to the Saudi Arabian government for the past 25 years, under direct bilateral arrangements in minerals and water-resources investigations and in geologic and topographic mapping. The water-resources sector of this assistance has been a significant but quantitatively minor part of the total USGS program, which, between 1950 and 1962 emphasized areal geologic and topographic mapping and since late 1963, mineral-resources surveys and development.

G. F. Brown, USGS geologist, has played a prominent role in all major components of USGS technical assistance in Saudi Arabia during the past quarter century, 1945–70, and, indeed, is considered by many to be the man best informed on the overall geology and hydrology of the Arabian Peninsula. Mr. Brown's first work in Saudi Arabia was done between January 1945 and August 1946, as part of a technical support program of a U.S. Agricultural Mission to the Saudi Arabian Government (SAG). During his stay, Mr. Brown completed a comprehensive field investigation of the geology and groundwater resources of Al Kharj district in the Nejd region of central Saudi Arabia. In his report Mr. Brown evaluated and described in detail the geologic and geomorphic history of the district, the geohydrology of the Mesozoic and Tertiary sedimentary rock systems, and the development potentials of several aquifers for irrigation and other use.

Beginning in August 1950, the USGS, in cooperation with the Arabian American Oil Co. (ARAMCO) and under the sponsorship of the SAG Ministry of Petroleum and Mineral Resources undertook a project to map geographically and geologically the entire Arabian Peninsula. During the ensuing 13 years, fieldwork was undertaken and completed by USGS and ARAMCO geologists and two maps, one geographic and one geologic, were published between 1958 and 1964 for each of 22 quadrangles at a scale of 1:500,000. All these data were compiled in two geographic and geologic maps at a scale of 1:2,000,000 and published by the USGS in 1958 and 1963, respectively. A large part of this massive enterprise was conceived, directed, and carried to completion under Mr. Brown's leadership assisted by R. O. Jackson, USGS geologist, S. H. Kfoury, USGS cartographic technician, and others. During these years, Mr. Brown also served informally as a general water-resources advisor to the SAG Ministry of Agriculture and Water—notably, in ground-water development projects for irrigation in the Harad, Qatif, and Al Hasa oases of the Eastern Province as well as in formulating plans for water-resources development for the cities of Riyadh, Jiddah, Mecca, Medina, and elsewhere in Saudi Arabia. D. F. Dougherty, USGS surface-water hydrologist, also was assigned to Saudi Arabia from March 1952 to March 1953 to evaluate the runoff characteristics of ephemeral streams and, particularly, the potentials for surface storage and ground-water recharge near Riyadh.

Since 1963 and until recently (1970) Mr. Brown has been chiefly concerned with the leadership of a

joint USGS–SAG project to assess the mineral-resources potential of the Precambrian Shield region of central and western Saudi Arabia. During much of this interim, however, he continued in his informal capacity as a general water-resources advisor to the Ministry of Agriculture and Water. Along with other expatriate advisors, Mr. Brown assisted the SAG during the early 1960's in developing a nationwide plan for the exploration and development of ground-water resources.

Beginning in early 1965, contracts were given by the SAG to private consulting firms for ground-water surveys in six areas. These included: Area I awarded to an association of the Ralph M. Parsons Co. and Frank E. Basil, Inc. of the U.S. and covering 370,000 km² of the Great Nefud, Qassim, Wadi Sirhan, Jawf, Sakakah, and Tabouk areas of northern Saudi Arabia; Areas II and III awarded to Italconsult (Italian) covering 232,000 km² in south-central Saudi Arabia; Area IV also awarded to Italconsult covering 341,000 km² and the Qatif, Harad, and Al Hasa oases in the eastern part of the country; Area V awarded to the Societé Grenobloise des Recherches et d'Etudes Hydrauliques (Sogreah) covering 105,000 km² around Riyadh; and Area VI, also awarded to Sogreah (French), covering 200,000 km² along the Red Sea coast, except for an enclave surrounding Jiddah, Mecca, and Taif which was awarded to Italconsult. In these areas the consultants were charged with making basic appraisals of ground-water resources as well as studies of soils, agronomy, topography, hydrogeology, meteorology, geophysics, range management, and socio-economics that bear on agricultural, industrial, and municipal development. As of 1970 this work was still in progress.

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THAILAND

Since World War II, the U.S. has provided continuing monetary aid and technical assistance to Thailand which in the bilateral program aggregated some $574 million between 1946 and 1968. The USGS has participated intermittently in the water-resources sector of this program, notably in ground-water investigations in northeastern Thailand in 1954, again in 1961, and most recently in 1970.

During a brief visit to Thailand in June 1954, T. E. Eakin, USGS hydrogeologist, conferred with officials of the Thai Government and a predecessor of USAID/Bangkok concerning the need for ground-water exploration and development in northeastern Thailand to improve the rural, agricultural, and industrial economy of the region. Based on Mr. Eakin's recommendations, P. E. Lamoreaux, USGS hydrogeologist was assigned to Thailand from October to December 1954. During his 3-months' stay, Mr. Lamoreaux, in company with five Thai geologists and engineers of the Thai Departments of Mineral Resources, Irrigation, and Public Health completed (1) a reconnaissance of the geology and ground-water resources of the Khorat Plateau in northeastern Thailand and (2) an evaluation of the availability of ground-water supplies for domestic, livestock, municipal, and irrigation uses and government-sponsored industries, based on data provided by 374 exploratory wells (fig. 56) put down by the Thai Public Health Department near large population centers of the plateau during 1952–54. Mr. Lamoreaux's administrative report of January 1955 recommended (1) a comprehensive program of ground-water investigations under the leadership of

FIGURE 56.—Thai engineers and geologists recording observations during installation of hand pump on recently drilled well at Nong Tuloom school, 6 km south of Nakhon Ratchasima (Khorat). School children in background are interested observers.

the Thai Mineral Resources Department and with joint participation of the Public Works, Irrigation, and Public Health Departments; (2) expanded ground-water exploration and development in the region, with technical guidance from a US AID hydrogeologist advisor; and (3) training of key Thai personnel in ground-water geology and hydrology. The technical findings of Mr. Lamoreaux and his Thai colleagues were published in USGS Water-Supply Paper 1429, which described the general hydrogeologic framework in the Triassic and Jurassic sedimentary rocks of the Khorat Plateau and local ground-water conditions near the larger municipalities in the region.

Following Mr. Lamoreaux's work and recommendations, a joint US-Thai Ground Water Research and Development Project was begun in January 1955 with the assignment of H. F. Haworth, US AID hydrogeologist, as technical advisor to the Thai government. During the ensuing 3 years, 83 exploratory wells totaling 6,200 m in depth were put down in the Khorat Plateau under the direction of a Thai interdepartmental Ground Water Committee with the technical guidance of Mr. Haworth and US AID drilling advisors. With completion of this preliminary exploration, Daniel, Mann, Johnson, and Mendenhall, International (DMJM) under contract to US AID, were engaged to carry out more extensive ground-water exploration as well as training of Thai ground-water scientists, technicians, and drilling personnel. Between April 1958 and May 1961, the DMJM group put down, logged, and tested 411 exploratory and production wells for a total of 51,000 m in depth over an area of some 160,000 km.[2]

In May 1961, at the request of US AID/Bangkok, Mr. Lamoreaux revisited the Khorat Plateau to review the antecedent work of the DMJM contract and the Thai departments. His administrative report of June 1961 (1) described in detail the history of the first 9 years of continuous ground-water exploration, investigation, and development in the region and the institution building in the Thai departments; and (2) recommended additional investigations and production drilling in selected areas of the plateau.

During the 4 years after Mr. Lamoreaux's review the technical recommendations were carried to fulfillment under the technical guidance of Mr. Haworth with active participation of Thai colleagues. As of project termination in June 1965, 1,527 exploratory wells had been drilled in the Khorat Plateau, and, of this total, 1,242 wells were completed as production wells. The technical findings of the project were published in 1966 as Ground Water Bulletin 2 of the Thai Mineral Resources Department under the authorship of Mr. Haworth and Thai colleagues. The Ground Water Division of the Thai Department of Mineral Resources is now (1970) an active viable organization with a staff of 25 hydrogeologists, hydrochemists, technicians, and support personnel engaged in ground-water exploration and development throughout Thailand.

During July-December 1970, D. A. Phoenix, USGS hydrogeologist, while on assignment to the Mekong Committee, under US AID auspices, reviewed the status of ground-water investigations and development in Thailand. His report of December 1970 proposed renewed bilateral technical assistance to the Thai Ground Water Division and a comprehensive geohydrologic investigation of the Central Valley (Chao Phrya basin) of Thailand.

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TURKEY

Situated at the crossroads of Europe and Asia, the region now occupied by Turkey has figured in pivotal events of human history for more than 3,000 years. The modern Republic of Turkey was founded in 1923 by Musatfa Kemal Ataturk after the collapse of the 600-year old Ottoman Empire at the end of World War I. Since its founding the new republic has made steady progress in modernizing its social and economic institutions in measure with the demands of the 20th century. In support of a long tradition of friendship, the United States furnished Turkey more than $5 billion in loan and grant aid between 1947 and 1968. Because of the Government of Turkey's (GOT) priority concern with full development of its water resources for hydropower, industry, and irrigation as well as for municipal, livestock, and domestic water supply, the U.S. bilateral aid program has given strong emphasis for the past 20 years to the water-resources sector of the economy. As part of U.S. aid, the USGS has provided technical assistance to the GOT both in surface-water and ground-water investigpations, first in

1957, virtually continuously between 1958 and 1965, and intermittently since then.

Surface-Water Investigations, 1957, 1958–62

Based on an agreement signed in March 1957 between the GOT and US ICA/Ankara, K. N. Phillips, USGS surface-water hydrologist, was assigned from April to June 1957 to review the then-current program of streamflow investigations in Turkey and to formulate recommendations for strengthening these investigations in support of national water-resources planning and development. During his stay in Turkey, Mr. Phillips, in company with hydrologists and engineers of the Elektrik Isleri Etud Idaresi (EIEI) or Electrical Power Resources Survey Administration visited numerous stream-gaging stations and water-resources development projects throughout the country; observed stream-gaging instrumentation and techniques; and reviewed methods and procedures for computation, compilation, and publication of streamflow data. His report of September 1957 described the general geographic, climatic, and hydrologic features of Turkey; the history of stream gaging; the then-current EIEI stream-gaging network (244 stations); and field and office procedures and publication of records. The report also identified needs for long-term technical assistance, participant training, and hydrologic equipment support.

Responding to recommendations in Mr. Phillips' report, US ICA/Ankara requested the USGS to provide long-term technical assistance to the Hydrograhic Section of the EIEI in a project known as "Hydrological Data Study and Training." C. C. Yonker, USGS surface-water hydrologist, was assigned to the work, arriving in Ankara in December 1958 and continuing until his return to the United States in April 1961. L. J. Snell, also a USGS hydrologist, succeeded Mr. Yonker in Turkey from June 1961 until December 1962, when the long-term USGS assistance in surface-water hydrology was terminated.

The project objectives included (1) improvement and upgrading methods of collecting, processing, and publishing basic streamflow data for the comprehensive and continuing inventory of the surface-water resources of Turkey; (2) training a cadre of Turkish hydrologists in all phases of surface-water investigations; and (3) establishment of systematic sediment-data collection coupled with regular streamflow observations.

As of the end of the 4-year term (1958–62) of USGS technical assistance, a country-wide network of 290 gaging stations was firmly established, at which 1,800 discharge measurements were being made annually; 50 automatic water-stage recorders were in operation; 23 cableways had been constructed and placed in operation, including a 253-m span across the Euphrates River; and streamflow data were being regularly computed for about 150 streams. Also 9 new EIEI district offices were established throughout Turkey for streamflow data collection and gaging-station operation and maintenance. In addiiton, Messrs. Yonker and Snell assisted in upgrading the EIEI Hydrographic Yearbooks for 1958 through 1961, so that these could serve as models for succeeding years. They also fully trained a cadre of 40 Turkish hydrographers, computers, and observers in field and office methods of streamflow and sediment data collection, compilation, and publication. After completion of the project, Mr. Snell prepared a comprehensive report which was released to the GOT in October 1962. The report presented a summation of work activities and project accomplishments as well as detailed guidelines to the EIEI for future surface-water investigations and training of personnel.

Since the early 1960's, the Devlet Su Isleri (DSI), or State Hydraulic Works, has assumed the lead role in surface-water investigations in Turkey. In 1970, the DSI operated 663 stream-gaging stations, 46 lake-stage stations, 9 snow courses, 386 precipitation stations, 250 sediment stations, and 60 evaporation-temperature stations. On the other hand, EIEI operated 304 stream-gaging stations, 12 lake-stage stations, 10 snow courses, and 65 sediment stations.

Ground-Water Investigations, 1963–65, 1966, 1967

The principal governmental entity in Turkey concerned with ground-water investigations is the Ground Water Division (GWD) in the Devlet Su Isleri (DSI), or State Hydraulic Works. The GWD, which had its beginning in 1952, was organized in five sections, (1) Planning, (2) Geophysics, (3) Investigations, (4) Drilling, and (5) Production and Management. Also, representatives of the GWD were attached to each of the 10 district offices of the DSI throughout Turkey. During the first 10 years of its history, the GWD emphasized hydrogeologic investigations and exploratory drilling to define areas favorable for high-yield wells of moderate depth. Work accomplished during this period (1952–62) included (1) reconnaissance hydrogeological mapping at a scale of 1:100,000 and preparation of individual reports in the Turkish language on 153 ground-water basins totalling 315,540 km^2; (2) drilling of 1,113 exploratory wells aggregating 243,-

962 m of hole; (3) construction of 795 water-supply wells, yielding a total of 7,808 l/s for villages and military garrisons; and (4) coring for dam foundation studies and test drilling related to drainage problems.

Recognizing a need in 1962 to redirect its efforts toward more intensive studies related to ground-water development for irrigation, the DSI requested US AID/Ankara to provide the services of a general ground-water advisor to assist the GWD in the design and execution of its pilot development projects. C. R. Murray, USGS hydrogeologist, assigned to the work, arrived in Ankara in January 1963 and continued until his return to the United States in May 1965. During Mr. Murray's stay in Turkey, pilot ground-water development projects for irrigation were begun in the Konya-Alakova, Elâzig-Ulova, Kayserí, Bolu, Chabuk (Çubak) Esenboga, Merzifon-Gümüshhachköy, Malatya, and Iqdir areas in Anatolia as well as the Maritsa River (Meric) Ergene Nehri (Ergene) and Beyazköy (Beyaz Koy) areas in Turkish Thrace.

Surface resistivity surveys for ground-water exploration were first undertaken by the GWD in 1960 and seismic refraction studies, mainly at damsites, somewhat later. In mid-1963 the DSI requested US AID/Ankara to provide the short-term services of a geophysicist to evaluate the operations of the Geophysics Sections of the GWD and to recommend measures to improve these operations for the needs of ground-water exploration and development in Turkey. W. E. Davis, USGS geophysicist, was assigned to the work from October to December 1963. During this period he examined geophysical reports, field techniques, and interpretation methods of ground-water exploration projects in the Bafra and Samsun deltaic plains on the Black Sea coast and in the Sarayköy and Konya plains of Anatolia. Mr. Davis gave particular attention to surface electrical resistivity surveys for detection of fresh-water salt-water interfaces, location of fresh water-bearing sand and gravel deposits in alluvium and in limestone, and determination of positions of impervious layers. He also reviewed the GWD's seismic reflection work in the Karapinar area of the Konya plain, where surveys were in progress to determine the depth to bedrock beneath a cover of semiconsolidated lacustrine deposits. At the end of his assignment, Mr. Davis directed a 2-week seminar at Ankara for personnel of the Geophysics Section of GWD on applications of geophysical techniques to ground-water exploration in Turkey. The results of Mr. Davis' work in Turkey as well as his recommendations to the GWD for improving its field operations in surface geophysical surveys were described, both in English and in Turkish, in his report of December 1963.

Between May and August 1964, R. L. Cushman, USGS ground-water hydrologist, was assigned to demonstrate the methodology of aquifer tests and applications of quantitative techniquse in pilot GWD ground-water development projects. Mr. Cushman completed special aquifer-evaluation studies in the Konya plain in central Anatolia, in the Mediterranean coastal plain north of Iskenderun, and also in Turkish Thrace. He also directed four 2-week field seminars in applied ground-water hydraulics—each attended by different groups of 20 to 25 DSI scientists, engineers, and technicians—near Konya, Adana-Iskenderun, Lüleburgaz, and Ankara. Mr. Cushman's report of August 1964, later translated into Turkish, presented detailed recommendations to the GWD for improving field determinations and analyses of hydraulic characteristics of aquifers in applications of quantitative techniques in pilot GWD typical Turkish ground-water basins; production-well construction; and collection and interpretation

At the request of the DSI to US AID/Ankara, F. E. Clarke, USGS corrosion expert, visited Turkey briefly in March 1965 to consult with Turkish counterparts on water-well corrosion and encrustation problems in the GWD's pilot ground-water development projects for irrigation. During his stay, Mr. Clarke directed a brief seminar in Ankara attended by GWD chemists, drilling superintendents, ground-water engineers, and hydrologists on well-casing and screen corrosion and encrustation problems in Turkey. He visited several representative well installations in the vicinity of Ankara and Konya for field demonstrations of equipment used to measure on-site water quality and the corrosivity of the metal components of wells and screens. While in Turkey Mr. Clarke also consulted with municipal engineers of Istanbul on corrosion and encrustation problems in pumps, well casings, and screens, and distribution pipelines of the city water supply.

W. E. Davis, USGS geophysicist, returned to Turkey during June and July 1966 to review progress on recommendations made in 1963 with respect to the DSI's geophysical investigations in ground-water exploration for town and village water supplies and for irrigation projects. While in Turkey he reviewed (1) the field operations of seven electrical resistivity survey crews of the GWD's Geophysics Section searching for fresh-water aquifers and two seismic survey crews identifying foundation condi-

tions at the sites of proposed dams and (2) then current (1966) technical reports interpreting the results of field surveys. Mr. Davis concluded in his administrative report of July 1966 that the Geophysics Section had reached a high level of operating efficiency and technical capability.

Electrical logging of the GWD's exploratory wells was first undertaken by the Geophysics Section in 1957. Most of the early logging was done in boreholes less than 500 m deep, mainly in alluvial deposits. The usefulness of electrical loggers in identifying lithologic breaks and in preparing formational logs was soon recognized, and, by 1963, 10 loggers were in operation in DSI's ground-water projects throughout Turkey. Responding to a request from the DSI to US AID/Ankara, P. H. Jones, USGS expert in borehole geophysics and electrical log interpretation, was assigned for 1 month during May-June 1967 to review the GWD's activities in borehole geophysics and to direct a training seminar in electrical log interpretation for GWD professional personnel. Mr. Jones' administrative report of June 1967 described in detail the organization of the DSI's Ground Water Division (GWD) and its activities in borehole geophysics, the results of a field type-area study of the Develi-Yesilhisar Plain, and the content of a 2-week problems seminar in Ankara on borehole geophysics and electrical log interpretation.

The DSI's Ground Water Division in 1970 was an active and viable scientific and technical organization. With a national professional staff of some 125 hydrogeologists, engineers, geophysicists, hydrochemists, and technicians and 1,270 support personnel, the GWD had already completed reconnaissance hydrogeologic investigations and released reports in the Turkish language on 250 ground-water basins aggregating 450,000 km.^{2} The GWD had also embarked on active ground-water development projects for irrigation in 20 of the more promising of these basins that ultimately will have marked benefit to Turkey's agricultural economy. In addition, the GWD was moving ahead rapidly in its well-construction program for the potable water supplies of some 10,000 villages in Turkey that are solely dependent on ground water.

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VIETNAM

The Republic of Vietnam (South Vietnam), located on the eastern bulge of Southeast Asia, was a major recipient of U.S. economic and military aid during most of the 1960's. The USGS participated actively during 1964–70 in the U.S. program and provided technical advisors, both for water-resources appraisals and investigations in the US AID bilateral economic aid and technical assistance program as well as for water-supply problems at U.S. installations in South Vietnam. The scope of this advisory support is described in following sections.

Ground-Water Appraisals and Investigations, 1964–66, 1968–70

In late 1963 the USGS was requested by US AID/Saigon to provide the short-terms services of a USGS specialist to assist in the design of a program for development of safe and adequate water supply, chiefly from ground-water sources, for all hamlets, villages, and small municipalities in South Vietnam. The late W. C. Rasmussen, USGS hydrogeologist, completed this assignment during January-March 1964. In April 1964 Mr. Rasmussen returned to South Vietnam on a 2-year detail to US AID/Saigon as Acting Associate Chief of a newly organized Rural Water Supply Task Force (RUWSTAF) to implement the program. The RUWSTAF was originally set up as an integrated organization of 500 persons, including US AID employees, U.S. Army technicians, U.S. Navy Seabee well drillers, and Vietnamese professional, technical, and support personnel. Six months later some 16 drilling rigs were putting down village supply wells at the rate of 50 a month and surface-

water purification units were being installed at the rate of 5 a month.

In October 1964 by reason of a policy decision in US AID/Saigon the operational activities were turned over to the Vietnamese staff; the scope of the program was reduced to those hamlets, villages, and small municipalities in secure areas; the US AID employees resumed rôles as advisors to the Vietnamese government; the US military personnel were detached; and RUWSTAF became US AID's Rural Water Program. At this time, Mr. Rasmussen became chief advisor in US AID/Saigon in investigations of the occurrence, quantity, and quality of water, both surface and ground, and in training counterparts in the South Vietnamese Directorate of Water Supply, Ministry of Public Works. He served in this capacity until the end of his tour in April 1966. Mr. Rasmussen's Vietnamese counterpart staff comprised 10 professionals and technicians, whom he trained in field hydrogeology, aquifer hydraulics, lithologic sampling and logging, in test drilling, electrical and gamma-ray logging and interpretation, and technical report preparation. Mr. Rasmussen also directed and participated in numerous field surveys of water-supply problems in Quang Nam, Quang Tin, Quang Ngai, Binh Dinh, Kien Tuong, Ba Xuyen, Gia Dinh, and Phu Yen Provinces, in the Da Nang and Nha Trang areas and in the Point de Cam Ranh (Cam Ranh Peninsula). More than a dozen reports and memoranda were reared by Mr. Rasmussen and Vietnamese colleagues on these studies.

As part of the training program in the Directorate of Water Supply, Eugene Shuter, USGS expert in borehole geophysical equipment, was assigned to Vietnam for 3 weeks in August-September 1965 to direct a field and office seminar in the operation of a 915-m logger manufactured by the Neltronics Instrument Co. of Houston, Tex. Mr. Shuter also prepared a syllabus for use by Vietnamese counterparts in the fundamentals of borehole geophysical logging, as applied to water wells, which included use of the resistivity and self-potential, gamma-ray, collar locator, temperature, flowmeter and tracer injector tools of the Neltronics logger.

After completion of Mr. Rasmussen's assignment, US AID advisors, H. F. Haworth, Jesse Cooper, and R. L. Gamer, during 1966–68 provided technical assistance in hydrogeologic problems to the Vietnamese government, particularly in the area along the northern margin of the Mekong Delta and in the highlands and coastal lowlands stretching north of Saigon to the North Vietnamese border. In mid-1968, US AID/Saigon again requested the USGS to provide the services of a USGS hydrogeologist on an 18-months detail to continue the work of predecessor advisors. H. R. Anderson was assigned to this work between October 1968 and April 1970. Mr. Anderson during his stay in South Vietnam served as an advisor to the Directorate of Water Supply chiefly in problems of ground-water development for village and small municipal water supply on the Mekong Delta. His field investigations were documented in several operational memoranda and brief administrative reports. A comprehensive report was in preparation in 1970 that describes the general hydrogeology, the results from 31 exploratory wells put down to depths ranging from 90 to 291 m, and the availability of ground water for rural and municipal supply in a 15-province region of the Mekong Delta in South Vietnam and adjacent parts of Cambodia.

During Mr. Anderson's assignment, Eugene Shuter revisited South Vietnam in March 1969 and conducted a second 2-week training course in borehole geophysics for Vietnamese personnel of the Directorate of Water Supply. He also checked out the electronic of the Neltronics 3–K logger then in use by the Directorate.

Hydrologic Data Collection, 1968, 1970

At the request of US AID/Saigon, A. O. Westfall, USGS surface-water hydrologist visited South Vietnam briefly in October 1968 to review the status of hydrologic data collection in the Mekong River Delta. His report (1) described the hydrologic data collection activities of the Mekong Coordinating Committee, the South Vietnamese Navigation Service and the Hydrology Section in the Directorate of Irrigation and Rural Engineering (DIRE) of the South Vietnamese Ministry of Land Reform, Agriculture, and Fishery Devleopment and (2) recommended a technical assistance staff of 6 U.S. experts in hydrology, tidal hydraulics, sedimentology, and hydrochemistry with a Vietnamese counterpart staff in DIRE of 20 to 25 professionals and technicians; extensive commodity support in hydrologic instrumentation; and improvements in network planning, in-country training, and interagency coordination. Currently (1970) these recommendations are under consideration but have not been implemented.

In mid-1970 the Vietnam Bureau of US AID organized a five-man interagency water management team composed of experts in drainage and land reclamation, irrigation, hydropower, water-development planning, and hydrology from among the U.S. Corps of Engineers, Bureau of Reclamation, and Geological Survey. R. S. Lord of the USGS was as-

signed to the team as the expert in hydrology. During September-October 1970 the team completed a comprehensive water-management study in South Vietnam. The chief objective of the study was a professional assessment of potentials and evaluation of alternate approaches to water control upon which to base a joint program for policy decisions with the Government of South Vietnam. The team's report was countrywide in scope and pointed out measures needed in water control for drainage, flood protection, water supply, navigation, hydropower, water supply, and sea-water intrusion protection. The report stressed the need for establishment of a national hydrologic network and for strengthening collection of basic hydrologic data for water supply, flood control, hydropower, irrigation, sea-water intrusion, and other problems in water management throughout South Vietnam but particularly in the Mekong Delta. The team recommended (1) that DIRE be designated the agency responsible for the construction, operation, and maintenance of the national hydrologic network, (2) that organizational changes be made to strengthen administrative support of a Hydrology Service in DIRE, and (3) that DIRE be provided with adequate funds for staff and commodities to support the network. The team further recommended that US AID/Saigon provide a U.S. technical advisor in hydrology to support the activities of the Hydrology Service. As of the end of 1970, W. J. Schneider, USGS hydrologist, was scheduled to visit South Vietnam in May 1971 for followup assistance in implementing these proposals.

Water-Supply Investigations at U.S. Installations, 1966–68

Between early 1965 and mid-1966, U.S. military strength in South Vietnam expanded greatly. This expansion entailed the construction of facilities, including the drilling of 250 wells for water supply at 23 sites scattered throughout South Vietnam. In mid-1966 the Naval Facilities Engineering Command, Department of the Navy, requested the USGS to provide a series of advisors in hydrogeology on short-term assignments to assist the Navy's Officer in Charge of Construction (OICC) in water-supply problems in and near U.S. installations. The first of these advisors, G. D. DeBuchananne, served in South Vietnam during September-December 1966 and guided initial drilling operations for water supply at new port installations near Da Nang, Qui Nhon, and Cam Ranh Bay.

After Mr. De Buchananne's return to the U.S., H. G. Rodis and the late M. C. Van Lewen, USGS hydrogeologists, were assigned to the OICC during February-May 1967 (1) to locate sites for new wells and to predict probable depths, water levels, yields, and water quality; (2) to evaluate well-completion reports for contract compliance; (3) to advise drilling crews on construction techniques, well development, and testing; and (4) to review and evaluate reports of private consultants in water-resources feasibility studies. Mr. Van Lewen worked chiefly on water-supply problems at U.S. installations near Saigon and in the Mekong Delta. Mr. Rodis worked in north-central South Vietnam and, among other activities, advised on means of (1) preventing salt-water deterioration of the ground-water supply at Cam Ranh Bay and (2) obtaining water supplies from granite gneiss at An Khe, from basalt at Pleiku, and from coastal deposits at Phan Rang and Phu Cat.

Messrs. Rodis and Van Lewen were followed in South Vietnam by H. R. Anderson, who arrived on detail to the OICC in August 1967 and continued there until February 1968. Mr. Anderson directed much of his work to locating fresh ground-water sources for U.S. installations in the Mekong Delta where complex vertical and lateral variations in water quality complicate the exploration for and development of potable water supplies. He also studied coastal ground-water and well-development problems for OICC at U.S. installations near Phan Rang, Nha Trang, Vung Tau, and at Bien Hoa near Saigon. Mr. Anderson also continued technical support activity for OICC on an informal basis while on detail to US AID/Saigon from October 1968 through April 1970.

AUSTRALIA

Australia, the island continent, has sustained a long tradition of friendship with the U.S., marked by close cultural and economic relations. The USGS provided hydrologic specialists and consultants under bilateral arrangements with federal and state governments fo Australia on several occasions during 1960–70 and also technical consultation for U.S. installations in Australia. Some of these activities, where documentation exists, are described below.

At the request of the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO), W. B. Langbein, USGS hydrologist, was assigned as a U.S. representative to a National Symposium on Water-Resources Use and Management held at Canberra during September 9–13, 1963, and Mr. Langbein presented a paper and served as chairman of the Symposium Session on Evaporation. Later, he consulted with CSRIO officials on hydro-

logic research and basic water-data programs. He also visited typical areas in Australia for field observations of the morphology of rivers.

At the request of the Australian Water Resources Council, S. W. Lohman, USGS ground-water hydrologist, was assigned to Australia during May 1967 to deliver a series of lectures on ground-water hydraulics at a 2-week ground-water school sponsored by the council in Adelaide. Mr. Lohman also visited Canberra during his assignment to advise the Australian Bureau of Mineral Resources, Geology and Geophysics on the organizational structure of a proposed Hydrogeological Branch in the Bureau. J. G. Ferris, USGS ground-water hydrologist, was assigned to Australia to delivery a similar series of lectures at another ground water school sponsored by the council at Adelaide in May 1970.

F. E. Clarke, USGS hydrologist, visited Australia during October–November 1967 at the request of the Queensland Irrigation and Water Supply Commission for consultation and observation of well-corrosion problems in the Bundaberg District, a cane-growing area along the coast of Queensland about 320 km north of Brisbane. His report of November 1967 summarized in broad terms the water problems of Australia and also described briefly the ground-water problems in the Bundaberg area, including aquifer characteristics, artificial recharge, water quality, and well corrosion. He also directed a seminar on corrosion and encrustation processes in water wells for an interagency group sponsored by the University of Queensland at Brisbane.

On the invitation of the New South Wales Rivers and Water Supply Commission, H. C. Riggs, USGS hydrologist, visited Armidale in December 1967 for consultation and exchange of research knowledge on low-flow probability forecasting needed for pollution control and for rationing water supplies during drought cycles.

D. A. Davis, USGS hydrologist, at the request of the U.S. Naval facilities Engineering Command, on three occasions during 1966–69 visited the U.S. Naval Communications Station at Northwest Cape in Western Australia to advise on water problems. On the first occasion in May 1966 he visited the station to determine the best procedures and to make recommendations for increasing the yields of newly developed salt-water wells for cooling purposes. He visited the station again in September 1967 to assess the results of his earlier recommendations. In January 1969 he returned to design a ground-water exploration project aimed at discovering new water sources to meet the increasing demands of the installation.

Reference

Schumm, S. A., 1968, River adjustment to altered hydrologic regimen—Murrum-bridge River and paleochannels, Australia: U.S. Geol. Survey Prof. Paper 598, 65 p., 2 pls., 36 figs.

MULTILATERAL ACTIVITIES

Comparatively, the USGS participation in water-resources activities of the United Nations and regional intergovernmental agencies during 1950–70 was more extensive in terms of subject matter and geographic coverage but less intensive in terms of manpower, training, and commodity inputs than in the U.S. bilateral program. Overseas acitvities of the USGS in this category are authorized under Public Laws 85–795, 87–626, and most recently 91–175.

USGS water scientists and engineers completed 87 assignments, mostly of less than 90 days duration, in project-oriented activities of international and regional intergovernmental agencies (table 3) in 70 countries during 1950–70 (table 4). Some 29 of these assignments were undertaken for projects under the aegis of the United Nations Educational, Scientific, and Cultural Organization (UNESCO), chiefly since 1965, in support of the program of the International Hydrological Decade (IHD). Another 17 assignments were undertaken in behalf of projects of the Food and Agriculture Organization of the United Nations (FAO), 16 assignments on projects of the United Nations (UN) itself, and the

TABLE 3.—*United Nations and regional intergovernmental agencies to which USGS water resources personnel have been assigned, 1950–70*

United Nations Agencies
Economic Commission for Africa (ECA)
Economic Commission for Asia and the Far East (ECAFE)
Food and Agricultural Organization of the United Nations (FAO)
International Atomic Energy Agency (IAEA)
International Bank for Reconstruction and Development (IBRD or World Bank)
United Nations Development Programme (UNDP)
United Nations Educational, Scientific and Cultural Organization (UNESCO), including the International Hydrological Decade (IHD)
United Nations (UN)
World Meteorological Organization (WMO)
Regional Intergovernmental Agencies
Central Treaty Organization (CENTO)
North Atlantic Treaty Organization (NATO)
Organization for Economic Cooperation and Development (OECD)
Organization of American States (OAS)
Organization of African Unity (OAU)
Pan-American Health Organization (PAHO)
Pan-American Institute of Geography and History (PAIGH)

TABLE 4.—*Countries to which USGS water resources personnel have been assigned in projects of United Nations and regional intergovernmental agencies, 1950–70*

North and South America	*Europe*	*Africa*	*Asia and Oceania*
Argentina	Austria	Algeria	Aden
Brazil	France	Angola	Afghanistan
Barbados	Germany	Burundi	Cambodia
Bolivia	Hungary	Cameroon	India
Canada	Greece	Canary Is.	Iran
Chile	Iceland	Chad	Iraq
Colombia	Italy	Egypt(UAR)	Israel
Costa Rica	Norway	Kenya	Jordan
El Salvador	Poland	Libya	Korea
Ecuador	Spain	Morocco	Kuwait
Guatemala	Switzerland	Mali	Laos
Honduras		Mauritius	Lebanon
Jamaica		Mauritania	Nepal
Mexico	Australia	Niger	Pakistan
Nicaragua		Nigeria	Philippines
Panama		Sudan	Saudi Arabia
Paraguay		Tunisia	Thailand
Peru		Uganda	Turkey
Trinidad		Upper Volta	Vietnam
Venezuela			

rest scattered among some 8 international and regional intergovernmental agencies. In addition USGS water scientists and engineers have been deeply involved in numerous symposia, seminars, working groups, hydrologic-research panels, and training activities sponsored by these agencies, most particularly since 1965 in the International Hydrological Decade (IHD). All these activities are summarized in following sections.

UNITED NATIONS AGENCIES

ECONOMIC COMMISSION FOR AFRICA

The Economic Commission for Africa (ECA) established in 1958 with headquarters in Addis Ababa, Ethiopia, is the youngest of the four regional commissions of the United Nations. The chief objective of the ECA is to further economic and social development in the African member states. In the water-resources sector, ECA aims at organizing existing data on the water resources of the region and assisting member African states in the establishment or expansion of hydrologic networks. It is concerned with questions of hydrologic training and manpower and the development of national and international river basins in Africa. It also provides advisory services to governments and intergovernmental agencies in development problems of international river basins.

At the request of ECA and with the financial support of US AID, C. C. McDonald, USGS hydrologist, was assigned between April and July 1970 to a joint ECA/WMO team to selected African countries to design minimum networks required for hydrologic-data collection and to recommend training programs for technical staffs. The objective of the mission was to develop agreed-upon hydrologic-data collection and training programs in Burundi, Malawi, and Cameroon that could be implemented with ECA and WMO financial and technical assistance. The team's report pointed out (1) that there was no existing hydrologic program in Burundi; (2) that in Malawi an adequate streamflow network existed but that gaging stations were poorly sited and data incomplete or of questionable accuracy; and (3) that in Cameroon the network in the southern humid sector was adequate but deficient in the northern semiarid sector. The team recommended that ECA place strong emphasis on the education and training of nationals in hydrology, both at professional and technician levels, concurrent with development of hydrologic networks.

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST

The Economic Commission for Asia and the Far East (ECAFE), established in 1947 with headquarters at Bangkok, Thailand, is by far the most active in hydrology and water-resources planning and development among the four United Nations commissions concerned with regional social and economic development. Since its establishment, ECAFE, either singly or together with other UN agencies, has sponsored numerous conferences, working groups, seminars, training courses, and technical-assistance activities in the water-resources sector in Asian member states. ECAFE's program includes planning and development of water resources, studies and assistance to governments in development of international rivers, studies and assistance in flood-control methods, and hydrologic studies. ECAFE has published 35 volumes in its Water Resources (formerly Flood Control) Series since 1950 and since 1963 has published also a Quarterly Water Resources Journal, which describes activities in the water-resources sector in the ECAFE region as well as among other UN agencies.

USGS scientists and engineers have participated extensively in ECAFE water-resources seminars and conferences since 1957, as shown in the following table, as well as in technical-support activities, which are described below.

TECHNICAL SUPPORT FOR THE COMMITTEE FOR COORDINATION OF INVESTIGATIONS OF THE LOWER MEKONG BASIN

The United States, through its mutual security program, stimulated planning in 1956 for development of the Lower Mekong River Basin as a symbol and focal point for regional economic and social advancement. In 1957 a report by the Bureau of

USGS scientists and engineers participating in ECAFE-sponsored water resources seminars and conferences, 1957–66

USGS attendee	Role	Co-sponsor	Date	Seminar or conference place	Subject
C. R. Murray, L. J. Snell.	Advisors to Philippine delegation.	None	Dec. 4–10, 1957.	Bangkok, Thailand.	Third Regional Conference on Water Resources Development in Asia and the Far East.
W. B. Langbein	Lecturer on hydrologic data networks.	WMO	July 14–27, 1959.	----do ----------	Interregional Seminar on Hydrologic Networks and Methods.
R. E. Oltman	Lecturer on field methods in hydrometry.	WMO	Nov. 27–Dec. 11, 1961.	----do ----------	Interregional Seminar on Field Methods and Equipment Used in Hydrology and Hydrometeorology.
A. O. Westfall	Advisor to Afghanistan delegation.	WMO	Jan. 26–Feb. 23, 1966.	Kabul, Afghanistan.	Seminar on Use and Interpretation of Hydrologic Data
V. J. Latkovich	----do ----------	WMO	Apr. 19–26, 1966.	Bangkok, Thailand.	Interregional Seminar on Assessment of Magnitude and Frequency of Flood Flows.
W. W. Evett	Advisor to Nepal delegation.				
J. G. Ferris	Lecturer on quantitative methods and techniques in ground-water investigations	UNESCO UN	Oct. 16–Nov. 5, 1966.	Teheran, Iran.	Second Seminar on Methods and Techniques of Ground-Water Investigations and Development.

Flood Control and Water Resource Development of ECAFE recommended establishment of a committee of the riparian nations to investigate possibilities for developing and managing the Mekong River for water supply, irrigation, drainage, hydropower, flood control, and navigation. Based on this recommendation, Cambodia, Laos, Thailand, and the Republic of Vietnam (South Vietnam) established the Committee for the Coordination of Investigations of the Lower Mekong Basin (Mekong Committee) under the aegis of ECAFE. The United Nations (UN), United Nations Development Programme (UNDP), the IBRD (World Bank), WMO, UNESCO, FAO, US AID, 26 nations, the Ford and Asia Foundations and 4 major private industries have since provided technical and financial support to the Mekong development program. This support between 1957 and 1970 aggregated about $200 million of which the riparians provided nearly half and the United States about 15 percent. The responsibilities of the Committee include pre-investment planning (basic-data collection, overall basin planning, individual main-stem and tributary project planning, navigation improvement planning, etc.); construction; finance; and management. A report, first authorized by the Mekong Committee in 1962 and completed in preliminary form in 1970, contains the grand design for the next 30 years, a construction program whose river-associated facilities would cost nearly $8 billion.

Water management of the Lower Mekong River and its tributaries is needed to regulate storage and release of water for irrigation, to generate hydroelectric power, to reduce or control floods, and to provide navigable waterways. Irrigation, drainage, and flood control are essential throughout the Lower Mekong Basin, but more particularly in the Mekong Delta, in efforts to increase production of food and fiber and to contain the destructive flood potential of the Mekong and its tributaries.

Hydrologic data are essential for all aspects of water management in the Lower Mekong Basin, and the USGS has played an active rôle first in the design of the hydrologic network on the Mekong River system and, more recently, in evaluation of the data-collection process and products and in training in hydrometric methods and techniques.

During a brief visit to Thailand in July 1959, W. B. Langbein, USGS hydrologist, advised the Mekong Committee on the basic requirements for hydrologic-network design. After Mr. Langbein's visit the Harza Engineering Co. under contract to US AID began in 1960 the construction of 21 new stream-gaging stations and installation of hydrometric equipment on the Mekong and its tributaries as well as rehabilitation of eight existing stations. The company also began a series of Hydrologic Yearbooks, which were taken over by the Mekong Committee on termination of the Harza/US AID contract in July 1962. Of the 21 stations established, 13 were recording stations on the main-stem Mekong. About 2,900 discharge measurements were made with the guidance of O. A. Mussey, a former USGS hydrologist, then employed by Harza during the life of the contract. The Harza Co. also set up 4 sediment laboratories and began sediment sampling at 24 stations, rainfall observations at 79 stations, and evaporation measurements at 19 stations.

The first formal evaluation of the Mekong hydrologic network was made under US AID auspices in November–December 1966 by E. L. Hendricks, USGS Chief Hydrologist, and W. J. Schneider, USGS hydrologist, together with experts of the riparian countries and the Mekong Committee technical staff. The Expert Group reviewed the adequacy of the network, the existing gaging practices on the Mekong system, the methods of data processing and preparation for the Hydrologic Yearbook, the data being collected for a flood-warning system, and the needs for computer programing and analysis of the hydrologic data. Their report of December 1966 presented recommendations for improvement in all these areas.

At the request of the Mekong Committee and under the auspices of US AID, G. F. Smoot, USGS hydrologist and designer of the "moving-boat" stream-gaging method, visited Thailand and Laos in July 1967 to demonstrate the method to US AID/U.S. Bureau of Reclamation technical personnel as well as to Mekong Committee and riparian hydrologists and engineers. Two demonstrations were held—one at Bangkok on the Chao Phrya River and the other at the Pa Mong damsite on the Mekong River, about 16 km upstream from Vientiane. At the Pa Mong site, the average discharge of the Mekong from eight moving-boat measurements was found to be 4,280 m^3/s on July 17, 1967, each measurement requiring 4½ minutes. The flow computed from the rating curve, which had been defined by conventional current-meter measurements, was found to be 4,200 m^3/s. The speed and accuracy of the moving-boat technique so impressed US AID and Mekong Committee observers that a decision was made to use the technique at several other sites on the Mekong, with procurement of six sets of moving-boat equipment for use in the entire hydrologic network.

W. J. Schneider returned to Thailand and Laos in November–December 1967 to evaluate, both in the office and in the field, the followup activities on the recommendations of the December 1966 report of the Expert Group on the Mekong hydrologic network and methods of observation. During this assignment, he also presented papers on the computer processing of streamflow data and a technique for measuring flow in the Mekong at a ECAFE/Mekong Committee-sponsored seminar for riparian technical personnel on the hydrology of the Lower Mekong Basin. This seminar was held at Vientiane, Laos on November 20–25, 1967. He also directed a field demonstration of discharge and sediment measurements with the latest USGS equipment and methods at the Vietiane gaging site on the Mekong.

Messrs. Schneider and Smoot were assigned again to Thailand and Laos under US AID auspices in May–June 1969. On this occasion, Mr. Schneider evaluated for the Mekong Committee the current use of hydrologic equipment and data-collection activities of riparian countries. Mr. Smoot, with Mr. Schneider's assistance, directed an ECAFE/Mekong Committee-sponsored training course on the moving-boat method of measuring streamflow held at Vientiane, Laos, on June 1–8, 1969 (fig. 57). The course included lectures on river hydraulics and conventional stream gaging and on the theory and method of the moving-boat technique. Mr. Smoot also directed field training in the operation and maintenance of the equipment. Some 45 participants from Cambodia, Laos, Thailand and Vietnam and from the Mekong Secretariat attended the course.

The fourth in a series of annual evaluations of the hydrologic-data collection activities in the Lower Mekong Basin was made by Mr. Schneider, under US AID auspices, in May–June 1970. On this occasion he made particular note of the substantial improvements in the procurement and distribution of spare parts for hydrologic-network equipment that had taken place in the previous year. His administrative report noted that, of 67 stations in the network, 30 stations had been adequately rated by streamflow measurements during 1968 but that the rest still lacked an adequate number of measurements for definition of rating curves. Mr. Schneider also directed a training course for hydrologic data processing held June 7–14, 1970, in Bangkok, sponsored by the ECAFE/Mekong Committee, and at-

FIGURE 57.—G. F. Smoot, USGS hydrologist, instructing hydrologic personnel of the Mekong Committee in the moving-boat method of stream gaging on the Mekong River near Vietiane, Laos. Native canoe to the left.

tended by 33 participants from Cambodia, Thailand, Laos, and Vietnam and from the Mekong Secretariat. The course included lectures on the collection and processing of hydrologic and sediment data by Mr. Schneider and of precipitation, evaporation, and weather data by others. As of the end of 1970, plans had been made for a fifth annual evaluation by Mr. Schneider in May 1971 of the Mekong hydrologic network, with emphasis on the equipment and spare parts program. Moreover, a training course under USGS/WRD leadership was planned for July–August 1971 at Saigon in field techniques of sediment-data collection and laboratory analysis.

Ground-water exploration in the Khorat Plateau of Thailand and adjacent parts of Laos during the 1950's and early 1960's revealed the presence of deposits of rock salt and other evaporites as well as extensive tracts of saline ground water in the Triassic and Jurassic sedimentary rocks of the region. Several of these deposits and tracts are coextensive with lands proposed for irrigation from the Pa Mong and related reservoirs on the Mun and Chee Rivers under the Lower Mekong Basin development program. For this reason, there exists a potential hazard from a buildup in ground-water head as a result of irrigation that could result in a more active circulation and discharge of saline ground water and in saline contamination of soils and streamflow. To evaluate this problem, at the request of the Mekong Committee, D. A. Phoenix, USGS hydrogeologist, was assigned, under US AID auspices, to Thailand and Laos from July to October 1970. His administrative report of December 1970 reviewed the current status of geologic and hydrologic knowledge in the Khorat Plateau region with respect to proposed irrigation and presented recommendations for a 4-year program of technical assistance and regional geohydrologic investigations, with priority emphasis on the Chaiyaphum area of the Plateau.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

The Food and Agriculture Organization of the United Nations (FAO) was established in 1945, with headquarters at Rome. FAO's basic mission is the appraisal, development, and management of soil and water resources in the interest of raising world nutritional levels and standards of living. Since its founding, FAO has played a worldwide role in water-resources investigations and development for agriculture, including water management for forestry, inland fisheries, and animal husbandry. FAO, since 1965, has also actively participated in the International Hydrological Decade (IHD), providing the technical secretariat for two of the IHD Working Groups—namely, Hydrology of Carbonate Terranes of the Mediterranean Basin and Influence of Man on the Hydrological Cycle. FAO is also working with many International River Basin Commissions, notably the Chad Basin Commission, the Senegal River Basin Commission, and the Lower Mekong River Basin Committee.

The USGS between 1952 and 1970 provided consultants, advisors, experts, and technical support for 17 water-resources-investigations projects in 10 countries under the direction of FAO, as executing agency, with the United Nations Development Program (UNDP) as financing agency. In addition, the USGS also participated on two occasions in symposia and conferences sponsored by FAO. These activities are summarized in the following table.

INTERNATIONAL ATOMIC ENERGY AGENCY

The International Atomic Energy Agency (IAEA), a specialized agency of the United Nations family, was founded in 1957 with headquarters in Vienna. IAEA's activities are designed to promote the peaceful utilization of nuclear energy for the benefit of mankind and the use of radioisotopes in medicine, agriculture, and industry as well as in hydrology. IAEA's hydrology program includes: (1) studies of the so-called environmental isotopes, hydrogen, oxygen, and carbon, found in natural waters; (2) application of tracer techniques involving the injection and detection of isotopes in hydrologic systems; and (3) use of nuclear instrumentation in measurement of hydrologic parameters. Since 1965, IAEA has also been actively involved in the International Hydrological Decade (IHD), providing the technical secretariat for the IHD Working Group on Nuclear Techniques in Hydrology.

The USGS has participated since 1961 in the hydrology sector of IAEA's program by providing long-term technical support at Vienna headquarters and in field projects as well as by participating in symposia, training courses, and working groups sponsored by IAEA. The technical support activities are described below, and the participation in symposia, training courses, and working groups is summarized in the following table.

Technical Support for the Hydrology Program of the IAEA

Since July 1963 and continuing through the end of 1970 the USGS has provided technical support to IAEA's hydrology program through a series of long-term assignments of specialists in radiohy-

USGS scientists and engineers participating in FAO-sponsored water resources projects and symposia, 1952–71

USGS assignee	Purpose of assignment	Date	Country	Project or activity
P. E. Dennis	To assist Afghanistan government in preparation of request to FAO–UNDP for ground-water development in selected areas.	June–Aug. 1961.	Afghanistan	Ground-water development of selected areas for irrigation.
R. H. Johnston	To undertake hydrogeologic investigations related to waterlogging problems and ground-water potential for irrigation.	Oct. 1967–Oct. 1968.	India	Irrigation and drainage in Chambal Project, Rajasthan.
P. E. Dennis	To evaluate the status of ground-water investigations and development in Iraq and to design a long-term program for institution building, and ground-water exploration and development.	June 1952–July 1953.	Iraq	Nation-wide ground-water investigations and development.
G. F. Worts, Jr.	To evaluate research in artificial recharge in limestone, sandstone, basalt and coastal alluvial aquifers; tracer studies, using chloride and radio-isotopes; mathematical models; and coastal collectors.	Feb. 1964	Israel	Underground Water Storage Project and Coastal Collector Study.
William Back	To advise FAO and Israel government on geochemical processes during pumping and recharge operations, corrosion of metal pipes, solution of concrete pipes, deterioration of ground-water quality and quality changes in recharge water.	Feb.-Mar. 1964.	do	Geochemical aspects of Underground Water Storage Project.
J. F. Poland	To evaluate performance of proposed Coastal Collector system and feasibility of extracting surplus ground water without causing salt-water intrusion; to review hydrologic aspects of Nahal Shikma Watershed Pilot Project.	May 1965	do	Review Panel on Experimental Coastal Ground Water Collector Project; Hydrology Panel on Nahal Shikma Watershed Pilot Project.
S. M. Lang	To undertake geohydrologic evaluation related to the Nahal Shikma Watershed Pilot Project.	Apr.-May 1965.	do	Surface and ground-water resources of the Nahal Shikma Watershed Pilot Project.
R. E. Stallman	To participate on expert panel in review of Underground Water Storage Project.	March 1967	do	Review Panel on Underground Water Storage Project.
R. L. Cory	To present paper on primary production and diel oxygen measurement in the Patuxent Estuary.	Dec. 9–18, 1970.	Italy	Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing held at Rome.
H. E. Skibitzke	To present paper on airborne measurement of oil spillages.			
V. T. Stringfield	To undertake preliminary review of plans for FAO ground-water investigations in Pedro Plains, Queen of Spain's Valley and Moneague Basin karst areas.	Sept. 1965	Jamaica	Ground-Water Research and Surveys.
Do	To review progress on ground-water investigations in three karst areas of Jamaica.	July–Aug. 1966.	do	Do.
Do	do	Oct.–Dec. 1967.	do	Do.
D. B. Bogart	To review and evaluate water-budget and streamflow studies and geohydrologic reports on karst areas in Jamaica.	July 1967	do	Do.
R. A. Young	To direct exploratory drilling for ground-water development of selected areas for irrigation.	July 1968–Feb. 1971.	Korea	Ground-water development of selected areas for irrigation.

USGS scientists and engineers participating in FAO-sponsoreed water resources projects and symposia, 1952–71—Continued

USGS assignee	Purpose of assignment	Date	Country	Project or activity
P. T. Voegeli, Sr	To review status of hydrogeologic investigations and recommend construction procedures for production wells for irrigation in volcanic terrane.	July–Aug. 1967.	Mauritius	Ground-water survey and development for irrigation.
B. J. Bermes	To undertake electric-analog model, water-balance, and hydrogeologic studies in Sous Valley and other areas.	Sept. 1969–June 1971.	Morocco	Ground-water surveys and development for irrigation.
C. W. Carlston	To undertake comprehensive study of geohydrologic data in Rechna Doab, West Pakistan and identify causes of waterlogging.	1952–1953	Pakistan	Subsurface drainage and salinity control in the Indus Plains.
Thomas Maddock, Jr., H. E. Skibitzke, W. V. Swarzenski, G. B. Bennett.	To present lectures and discuss principles of water-resources utilization, ground-water movement, maintenance of the salt balance, in arid-region irrigation systems.	Nov. 16–28, 1964.	----do	Symposium on Waterlogging and Salinity at Lahore.
William Meyer	To assess available geohydrologic data and design analog models for two ground-water irrigation projects.	July 1969	Philippines	Ground-water development in Central Luzon Plains.

USGS scientitsts and engineers participating in IAEA-sponsored water resources symposia, training courses and working groups, 1961–70

USGS attendee	Role	Symposium, training course or working group			
		Co-sponsor	Date	Place	Subject
L. L. Thatcher, E. S. Simpson.	Consultants	----------	May 3–10, 1961.	Vienna, Austria	Symposium on Applications of Tritium in the Physical and Biological Sciences.
E. S. Simpson	Consultant	----------	May 7–15, 1961.	----do	Panel on Radioactive-Waste Disposal into Fresh Waters.
R. M. Richardson	Advisor on new uses for isotope techniques in hydrology.	----------	Nov. 6–9, 1961.	----do	Panel on Application of Isotope Techniques in Hydrology.
Do	Consultant	----------	Dec. 17–21, 1962.	----do	Panel on Isotopes in Hydrology.
C. V. Theis	----do	----------	Mar. 5–9, 1963.	Tokyo, Japan	Symposium on Application of Radioisotopes in Hydrology.
R. J. Pickering	To present paper on radioactivity in bottom sediments of streams.	----------	May 16–20, 1966.	Vienna, Austria	Symposium on Disposal of Radioactive Wastes into Seas, Oceans, and Surface Water.
G. H. Davis	To present paper on tritium content of ground waters in Vienna Basin, Austria.	IUGG/IASH.	Nov. 14–18, 1966.	----do	Symposium on Isotopes in Hydrology.
W. S. Keys	To present paper on radiation logging in ground-water hydrology.				
J. G. Ferris	Lecturer in hydrology and ground-water hydraulics.	----------	Apr. 16–May 27, 1967.	Ankara, Turkey	Inter-regional Training Course in Application of Isotope Techniques in Hydrology.
Alfred Clebsch, Jr	To present paper on subsurface waste disposal.	----------	May 27–June 5, 1967.	Vienna, Austria	Symposium on Disposal of Radioactive Wastes to the Ground.
R. L. Nace	To review and advise on IAEA plans and budget for IHD work on nuclear techniques in hydrology.	UNESCO/IHD.	July 29–Aug. 3, 1967.	----do	Working Group on Nuclear Techniques in Hydrology.

USGS scientitsts and engineers participating in IAEA-sponsored water resources symposia, training courses and working groups, 1961–70—Continued

USGS attendee	Role	Symposium, training course or working group			
		Co-sponsor	Date	Place	Subject
L. L. Thatcher	To assist in drafting of Guide for Nuclear Techniques in Hydrology.	UNESCO/ IHD.	Mar. 18–23, 1968.	Vienna, Austria	Working Group on Nuclear Techniques in Hydrology.
W. S. Keys	Advisor and consultant.	UNESCO/ IHD.	June 23–27, 1969.	----do	Fourth Session of Working Group on Nuclear Techniques in Hydrology.
Do	Contributor	----do	Sept. 30–Oct. 1, 1969.	----do	Preparation of IAEA Guide on Nuclear Logging.
B. B. Hanshaw	Lecturer in environmental isotopic hydrology.	UN	Oct. 15–Nov. 30, 1969.	São Paulo, Brazil.	Regional Training Course on Application of Isotope Techniques in Hydrology.
B. B. Hanshaw, F. T. Pearson.	Participants	UNESCO/ IHD.	Mar. 9–20, 1970.	Vienna, Austria	Symposium on Use of Isotopes in Hydrology.
B. B. Hanshaw	Advisor	UNESCO/ IHD.	Mar. 16–20, 1970.	----do	IAEA Panel on Carbon Isotopes in Subsurface Hydrology and Rôle of Paleoclimates in their Interpretation.
G. H. Davis	U.S. representative	UNESCO/ IHD.	Sept. 28–Oct. 5, 1970.	----do	Fifth Session of Working Group on Nuclear Techniques in Hydrology.
L. L. Thatcher	Participant	UNESCO/ IHD.	Oct. 24–Nov. 5, 1970.	Harwell, England, and U.K.; Salzburg and Vienna, Austria; Ispra, Italy.	Symposium on Use of Nuclear Techniques in Measurement and Control of Environmental Pollution.

drology, attached to the IAEA Secretariat in Vienna, Austria through the auspices of the U.S. Atomic Energy Agency. The first such specialist was A. E. Peckham, who was headquartered at Vienna from July 1963 to July 1965. Mr. Peckham's functions during his 2-year tour included review of requests for technical assistance, chiefly from developing countries, in nuclear raw materials prospecting, and ore processing as well as in hydrological projects using radioisotopes. Among other activities, Mr. Peckham participated in (1) radiohydrologic study of the relationships of Lake Chala to the groundwater system in the Taveta area on the slopes of Mt. Kilimanjaro in Kenya; (2) an isotopic survey of lakes, streams, and springs in the Anatolia region of Turkey; (3) hydrogen and oxygen isotope studies in the Vienna Basin of Austria; (4) coordination of IAEA activities with UNESCO in the International Hydrological Decade; (5) representation of IAEA on missions related to designing new IAEA technical assistance projects in radiohydrology in several developing countries as well as UN interagency meetings and conferences at Paris, Rome and Geneva.

The second USGS specialist assigned to IAEA was G. H. Davis, who was headquartered at Vienna from March 1966 until March 1968. Among other assignments, Mr. Davis participated in (1) preparation of IAEA's Guide on Nuclear Techniques in Hydrology (IAEA Technical Reports Series No. 91, 1968); (2) study of the isotope hydrology of the Styrian Basin, Austria; (3) dating by the tritium methods of ground waters of the Vienna Basin, Austria; (4) study of the environmental isotope hydrology of East Jordan; (5) design of IAEA technical assistance projects in radiohydrology in Jamaica, Peru, Chile, Brazil, Jordan, and elsewhere; and (6) representation of the IAEA at UN interagency meetings and conferences. He also provided technical review of project proposals and advisory activities in radiohydrology at the IAEA Secretariat in Vienna.

At the request of IAEA, J. T. Callahan, USGS hydrogeologist, then on assignment with US AID in Korea, was detailed during March 1967 to undertake a hydrogeologic reconnaissance of the island of Cheju, which lies south of the Korean peninsula. The object of the assignment was to evaluate the results of applying environmental isotopes and artificially introduced tracers to hydrologic studies on a volcanic island. Mr. Callahan recommended additional hydrogeologic study, collection of isotope data at rain gages, and more precise measurements of spring discharges to improve the accuracy of data interpretation.

Edward Bradley is the USGS specialist currently (1970) assigned to the IAEA Secretariat, having arrived in Vienna on a long-term assignment in February 1969. Since then, he has provided (1) technical advice in isotope hydrology for the IAEA on UNESCO, FAO, UN, and UNDP projects in Senegal, Greece, Chile, the Chad Basin of west-central Africa, and elsewhere; (2) interpretations of environmental isotope data from several IAEA projects; and (3) assistance in organizing meetings and technical training courses for IAEA in isotope hydrology.

INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT

The International Bank for Reconstruction and Development (World Bank or IBRD) was established with headquarters at Washington in 1945. The Bank's principal purposes are to promote investment for reconstruction and development and balanced growth of international trade. It achieves these purposes by lending funds for developing of productive economic facilities and by providing a wide variety of technical assistance services to member countries. The USGS direct participation in World Bank technical assistance activities oriented toward water-resources development has been relatively small; however, several USGS technical assistance water-resources projects under US AID sponsorship have been closely associated with subsequent World Bank loans for capital development. Such USGS/US AID projects include, among others: the Water Resources Investigations in the Aconcagua River Valley, Chile; the New Valley Project in Egypt; the Range Water Development Project in Kenya; the Surface-Water Research Project in Afghanistan; the Proposed Water-Resources Investigation Program for the Upper Gangetic Plain in India; the West Pakistan Hydrologic Monitoring and Research Project; and the East Pakistan Ground Water Survey.

The USGS has also provided short-term water-resources specialists to the World Bank for pre-investment studies on two occasions. During April–June 1960, G. F. Brown, USGS hydrogeologist, served as consultant member of a World Bank Economic Mission to Saudi Arabia. Mr. Brown provided first-hand knowledge of the ground-water resources of the country with reference to their development potential for agriculture.

Again, during January–February 1966 P. H. Jones, USGS hydrogeologist, served as a consultant on a World Bank Mission that visited India to review operations of irrigation tubewells in the Ganges Plains put down with World Bank financing. The Mission also reviewed a proposal for funding of a new project for construction of approximately 1,000 tubewells. On this mission Mr. Jones provided detailed and first-hand knowledge of the ground-water potential of the Ganges Plains essential to evaluations by Mission economists and engineers.

UNITED NATIONS EDUCATION, SCIENTIFIC, AND CULTURAL ORGANIZATION

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) was founded in 1946 with headquarters in Paris. The basic mission of UNESCO is the furtherance of world peace and security through exchange and cooperation among nations in education, science, and culture.

Committee on Arid Zone Research

UNESCO first became actively involved in scientific and applied hydrology in 1951, when it sponsored establishment of a Committee on Arid Zone Research, which emphasized international cooperation and research in the natural resources, including water, of the World's arid regions. Between 1951 and 1964, UNESCO's activities in hydrology were chiefly directed through this Committee toward the water problems of the arid zones. To strengthen international exchange of communication in arid-zone research, UNESCO began publication in 1958 of a quarterly newsletter, "Arid Zone," with worldwide circulation. With the start of the International Hydrological Decade (IHD) in January 1965, however, the Arid Zone Committee was dissolved; publication of "Arid Zone" was discontinued as of December 1964; and publication of a newsletter, "Nature and Resources," was begun in January 1965 to serve the information-exchange requirements of the IHD, as well as other UNESCO scientific programs.

Between 1960 and 1964, USGS hydrologists were actively involved in symposia, conferences, training courses, and other activities sponsored by UNESCO's Committee on Arid Zone Research. These activities are summarized in the following table.

International Hydrological Decade

The International Hydrological Decade (IHD) was conceived in the early 1960's by American hydrologists in collaboration with the U.S. Federal Council for Science and Technology. Among the U.S. leaders of the founding movement were R. L. Nace, L. B. Leopold, and W. B. Langbein, all senior USGS

USGS water scientists and engineers participating in UNESCO Committee on Arid Zone Research symposia, conferences, and training courses, 1960–64

USGS attendee	Role	Symposium, conference, training course			
		Co-sponsor	Date	Place	Subject
W. B. Langbein	Lecturer in hydrology.	----------	May 11–18, 1960.	Paris, France	Symposium on problems of the arid zone.
L. B. Leopold	U.S. member of committee.	----------	May 19–20, 1960.	----do ----------	Fifteenth session of UNESCO Committee on Arid-Zone Research.
Do	Lecturer on scientific hydrology.	WMO ----	Oct. 2–9, 1961.	Rome, Italy -----	Symposium on changes of climate with special reference to arid zones.
Do	U.S. member of committee.	----------	----do ----	----do ----------	Seventeenth Session of UNESCO Committee on Arid-Zone Research.
H. E. Thomas, L. C. Dutcher.	Lecturers in hydrogeology.	ECA -----	Oct. 23–Nov. 19, 1961.	Tunis, Tunisia	UNESCO regional training course in underground water prospection in arid zones and evaluation of ground-water resources.
W. T. Stuart	Lecturer in groundwater hydraulics.	ECAFE --	Mar. 26–Apr. 20, 1962.	Lahore, Pakistan.	Do.
L. B. Leopold	Committee member	----------	Aug.13–15, 1962.	Tashkent, U.S.S.R.	Eighteenth Session of UNESCO Committee on Arid-Zone Research.
R. L. Nace	Advisor to committee.				
R. L. Nace, L. B. Leopold.	Participants -------	----------	Aug. 6–9, 1962.	----do ----------	Seminar on relation between irrigation, salinity and ground water.
R. L. Nace, H. E. Skibitzke, J. A. daCosta.	Participants ------	ECLA ----	Sept. 16–21, 1963.	Buenos Aires, Argentina.	Scientific Conference on Arid Regions of Latin America.
J. A. daCosta	Director ----------	ECLA ----	Sept. 30–Oct. 26, 1963.	Antofogasta, Chile.	UNESCO Regional Training Course in Underground Water Prospection in Arid Zones and Evaluation of Ground-Water Resources.
R. L. Nace	U.S. member ------	ECLA ----	Sept. 23–25, 1963.	Santiago, Chile	Nineteenth Session of UNESCO Committee on Arid-Zone Research.
D. A. Phoenix	Advisor to Nigerian delegate.	ECA -----	May 12–15, 1964.	Tunis, Tunisia	Conference on Proposed Regional Study of the Artesian Basins of North Africa.
V. C. Fishel	Consultant for UNESCO.				
H. E. Thomas	U.S. observer -----	ECA -----	July 28–Aug. 6, 1964.	Lagos, Nigeria	Conference on Organization of Research and Training in Africa in relation to the Study, Conservation, and Utilization of Natural Resources.
D. A. Phoenix	Participant --------				
S. A. Schumm, S. W. Lohman.	Participants ------	----------	Sept. 21–28, 1964.	Toulouse, France.	Conference on Principles and Methods of Integrating Aerial Survey Studies of Natural Resources for Potential Development.
R. L. Nace	U.S. Member ------	ECAFE --	Nov. 28–Dec. 8, 1964.	Jodhpur, India	Twentieth Session of UNESCO Committee on Arid Zone Research.

hydrologists. The concept was carried forward in the U.S. by the National Academy of Sciences—National Research Council—and the American Geophysical Union and overseas by the International Association of Scientific Hydrology (IASH).

Through the overtures of the U.S. Department of State and the diplomatic missions of other countries, UNESCO assumed responsibility for planning, coordinating, and guiding a worldwide IHD program. International planning meetings, sponsored by UNESCO, were held in Paris and elsewhere during 1962, 1963, and 1964. J. A. da Costa, senior USGS hydrologist, was assigned to UNESCO in 1964 to serve as Secretary of the IHD Coordinating Council and continued in 1970 to hold the post as a permanent member of UNESCO's staff at Paris. Also between January and April 1967, T. E. A. Van Hylckama, USGS hydrologist, was temporarily detailed to

the IHD Secretariat to assist in the coordination and administration of IHD projects.

Since the beginning of the IHD in January 1965, 107 countries joined the program. Each member country has had an IHD national committee responsible for operating and financing its own program. The international agencies in the UN family, FAO, IAEA, WHO, and WMO, also have participated in the IHD program, and each has been financed from its own funds derived from assessments against member countries. The IHD Coordinating Council Secretariat at UNESCO headquarters has sponsored international symposia, conferences, training courses and working groups and prepared guides and training materials on various topics of interest in scientific and applied hydrology—all for the benefit of member countries. UNESCO also has provided the technical secretariat for 7 of the 12 IHD Working Groups, including World Water Balance; Floods and their Computation; Representative and Experimental Basins; Exchange of Information; Hydrologic Education; Hydrological Mapping; and Standardization Problems.

The U.S. National Committee for the IHD was appointed by the National Academy of Sciences—National Research Council—which also has provided the U.S. secretariat in Washington, D.C. The U.S. Committee has had 21 members from research institutions, universities, and State and Federal agencies. The Executive Secretary of the U.S. IHD Committee in 1970 was L. A. Heindl, a USGS hydrologist, detailed to the staff of the National Academy of Sciences. USGS domestic projects oriented toward IHD objectives in 1970 were largely within the scope of the study of the World Water Balance. Emphasis in the late 1960's was given to glacier variations and heat balances; the hydrological, chemical, and sediment regimens of principal river systems; hydrologic benchmarks; the Vigil Network; experimental and research basins; and historical hydrology (using radioisotopes, archeological and botanical evidence).

The general activities of the overall IHD program have included: (1) basic-data collection and analysis; (2) data interpretation to derive water inventories, water balances, and hydrologic regimens; (3) special data and research related to hydrologic phenomena, processes, and methodology; (4) education and training, including graduate fellowships, on-the-job training and exchange of research scientists and professors; and (5) supporting activities. Moreover, the IHD Coordinating Council has established 12 Working Groups which included: Network Planning and Design; World Water Balance; Floods and their Computations; Hydrological Mapping; Representative and Experimental Basins; Hydrology of Carbonate Rocks of the Mediterranean Basin; Nuclear Techniques in Hydrology; Exchange of Information; Hydrological Education; Influence of Man on the Hydrological Cycle; Hydrological Forecasting; and Standardization Problems. In addition, Panels of Experts were formed on Systems for Acquisition, Transmission and Processing of Hydrological Data (SAPHYDATA); Preparation of a Handbook for Activities on Ground Water Exploration; Hydrological Problems related to Artificial and Natural Changes in Quality of Water; Directors of UNESCO-sponsored International Post-Graduate Training Courses in Hydrology; Design of Water Resources Projects with Inadequate Data; Hydrological Problems of Saline Waters; Network Planning and Design; Hydrological Forecasting; Editors for a Guide for Research on Representative and Experimental Basins; Scientific Framework of the World Water Balance; Review of Published Works on the World Water Balance; Exchange of Information; and IHD Publications. The USGS has participated actively since 1965 in the work of more than half these groups as well as in the general conferences of the Coordinating Council. The scope of these and related activities is summarized in the following table.

The U.S. and Canadian National IHD Committees have also agreed to collaborate on an International Field Year for the Great Lakes (IFYGL) as part of the IHD program. The objective of the work is to improve observational, experimental, and theoretical techniques in lake research leading to increased knowledge of the hydrology and ecology of the Great Lakes Basins. The Field Year, April 1971 to September 1972, is concentrated on Lake Ontario and its basin, with basic-data collection planned to continue through 1973.

Technical Support for UNESCO-sponsored Projects

During 1960–70 the USGS also provided consultants, advisors, experts, and technical support through 30 assignments for hydrologic and water-resources investigations projects in 36 countries, under the direction of UNESCO as executing agency and, for the most part, with the United Nations Development Programme (UNDP) as financing agency. Since 1965 most of these projects have been identified with the UNESCO/IHD program. The scope of USGS technical support to these activities and projects is summarized in the following table.

USGS water scientists and engineers participating in UNESCO/International Hydrological Decade symposia, conferences, seminars, working groups, and training courses, 1964–70

USGS attendee	Role	Symposium, conference, seminar, working group			
		Co-sponsor	Date	Place	Subject
W. J. Drescher	Cochairman of Steering Committee for IFYGL.	----------	1965–1970	Toronto, Ontario, Canada and elsewhere in Great Lakes Region.	Meetings to organize Working Groups on Atmospheric Water Budget, Surface-Water and Ground-Water Budget, Energy Balance and Water Movement for International Field year of the Great Lakes (IFYGL).
R. L. Nace	Member. To examine decisions with respect to exchange of national, regional, and international publications in hydrology.	----------	Jan. 17–21, 1966.	Paris, France	First Session of IHD Working Group on Exchange of Information.
Alfonso Wilson	Lecturer ----------	----------	Feb. 2–5, 1966.	Belo, Horizonte, Brazil.	Symposium on Hydrological Networks.
L. L. Thatcher	Technical secretary	IAEA	Mar. 21–25, 1966.	Vienna, Austria	First session of IHD Working Group on Nuclear Techniques to determine Water Content in Saturated and Unsaturated Zones.
R. L. Nace	Chairman. To work up three-phased study plan for estimation of the gross distribution of water in the total environment.	----------	Apr. 13–15, 1966.	Paris, France	First session of IHD Working Group on the World Water Balance.
Do	U.S. Delegate, to establish Working Groups of IHD Council.	----------	Apr. 19–25, 1966.	----do	Second session of Coordinating Council of IHD.
R. F. Hadley	Panel member -----	----------	Sept. 29–Oct. 3, 1966.	----do	Meeting of panel from Working Group on Representative and Experimental Basins for preparation of IHD "Guide for Establishment and Operation of Representative and Experimental Basins."
R. L. Nace	----do ----------	----------	Oct. 5–7, 1966.	Paris, France	Meeting of panel from Working Group on World Water Balance to examine adequacy of distribution of IHD river discharge, precipitation, and evaporation stations.
J. D. Winslow	Codirector and lecturer.	ECLA	Oct. 31–Nov. 30, 1966.	Medellîn, Colombia.	Regional training course in applied geology with special emphasis on problems in hydrology.
R. F. Hadley	Member ----------	----------	Mar. 2–4, 1967.	Paris, France	Second session of IHD Working Group on Representative and Experimental Basins.
R. L. Nace	Chairman ----------	----------	Mar. 7–10, 1967.	----do	Second session of IHD Working Group on World Water Balance.
Do	U.S. delegate ------	----------	June 6–16, 1967.	----do	Third session of coordinating council of IHD.
G. W. Whetstone	Lecturer in automatic processing of hydrologic data.	ECLA	June 19–Sept. 15, 1967.	Barcelona, Venezuela.	Training course in engineering hydrology at Universidad del Oriente.
L. L. Thatcher	Member ----------	IAEA	July 24–28, 1967.	Vienna, Austria	Second session of IHD Working Group on Nuclear Techniques in Unsaturated and Saturated Zones.
D. B. Bogart, H. E. LeGrand, L. A. Heindl, and V. T. Stringfield.	Members ----------	FAO	Oct. 8–15, 1967.	Kingston, Jamaica.	Fourth meeting of Panel on Hydrology of Limestone Terranes.
M. A. Benson and W. B. Langbein	----do ----------	WMO	Oct. 10–13, 1967.	Paris, France	First session of IHD Working Group on Network Planning and Design.

USGS water scientists and engineers participating in UNESCO/International Hydrological Decade symposia, conferences, seminars, working groups, and training courses, 1964–70

USGS attendee	Role	Symposium, conference, seminar, working group			
		Co-sponsor	Date	Place	Subject
R. W. Carter and G. G. Parker.	Member	WMO	Oct. 16–18, 1967.	Toronto, Canada.	Session of IHD Working Group on Terrestrial Water (Steering Committee for International Field Year of the Great Lakes).
R. H. Brown	Panel member		Feb. 4–11, 1968.	Paris, France	Meeting of IHD Panel on Handbooks of Hydrological Practices.
R. M. Vice	do	WMO	Mar. 2–12, 1968.	do	Meeting of IHD Panel on Hydrological Forecasting.
G. W. Whetstone.	do	do	do	do	First Meeting of IHD Panel on Systems for Acquisition, Transmission, and Processing of Hydrological Data SAPHY DATA.
R. F. Hadley	Member		Mar. 10–16 1968.	Madrid, Spain	Third session of IHD Working Group on Representative and Experimental Basins.
R. L. Nace	U.S. delegate. To establish agreement on the form of a "Guide on SAPHY DATA."		May 6–19, 1968.	Paris, France	Fourth session of Coordinating Council of IHD.
G. E. Harbeck, Jr.	Member	WMO	Jan. 7–8, 1969.	Toronto Canada	Meeting IFYGL Working Group on Lake Meteorology.
R. H. Brown	Member and editor.		Jan. 20–31; June 30–July 11; Aug. 25–Sept. 5, 1969.	Paris France	Meetings of editors of "Guide for Activities in Ground-Water Exploration" of IHD Panel of Handbooks on Hydrological Practices.
R. L. Nace	Chairman of panel.		Jan. 26–Feb. 2, 1969.	do	Meeting of panel on Scientific Framework of IHD Working Group on World Water Balance.
G. W. Whetstone.	Panel member		Feb. 10–14, 1969.	Paris, France	Second meeting of panel on SAPHY DATA.
R. F. Hadley	Members	FAO	Mar. 25–28, 1969.	Rome, Italy	Session of IHD Working Group of Influence of Man on Hydrological Cycle.
G. H. Davis	do	WMO	Apr. 14–18, 1969.	Geneva Switzerland.	Second session of IHD Working Group on Network Planning and Design.
R. F. Hadley	do		May 26–30, 1969.	Oslo, Norway	Fourth session of IHD Working Group on Representative and Experimental Basins.
H. E. Thomas	Consultant		June 17–20, 1969.	Paris, France	Meeting of International Law Association and IHD Committee on International Water Resources Law.
G. W. Whetstone.	Member and editor.		Sept. 8–12, 1969.	do	Meeting of editors of "Guide for SAPHY DATA."
R. L. Nace	U.S. delegate		Dec. 17–19, 1969.	do	Fifth session of Coordinating Council of IHD.
E. L. Hendricks	U.S. delegate	WMO	Dec. 8–16, 1969.	Paris, France	Middecade Conference on Practical and Scientific Results of the International Hydrological Decade and International Cooperation in Hydrology.
R. L. Nace	Member of U.S. Delegation.				
N. C. Matalas	Lecturer		Feb. 1–15, 1970.	Zagreb, Yugoslavia.	Seminar on Application of Mathematical and Statistical Methods in Hydrology.
E. L. Hendricks	U.S. Delegation	WMO	July 6–11, 1970.	Geneva, Switzerland.	Sixth session of Coordinating Council of IHD.
R. L. Nace	Member of U.S. Delegation.				
R. L. Nace and T. E. A. van Hylckama.	Delegates	IASH	July 15–23, 1970.	Reading England, U.K.	Symposium on the Water Balance of the World.
R. L. Nace	Chairman				Working Group on World Water Balance.
M. E. Moss	Codirector	ECLA	July 20–28, 1970.	Lima, Peru	Regional seminar on the Hydrology of Droughts.

USGS water scientists and engineers participating in UNESCO/International Hydrological Decade symposia, conferences, seminars, working groups, and training courses, 1964–70

USGS attendee	Role	Symposium, conference, seminar, working group			
		Co-sponsor	Date	Place	Subject
G. E. Harbeck, Jr	Member	----------	Aug. 31–Sept. 3, 1970.	Hamilton, Ontario, Canada.	Meeting of IFYGL Panel on Evaporation.
R. J. Dingman, E. J. Pluhowski, K. V. Slack, J. M. Whipple, and E. C. Rhodehamel.	Delegates	----------	----do----	----do----	First International Workshop of IFYGL.
H. H. Barnes, Jr., M. A. Benson, R. W. Carter, Jacob Davidian, C. F. Nordin, and G. F. Smoot	----------	IASH WMO.	Sept. 13–19, 1970.	Koblenz, Germany.	Symposium on Hydrometry.
R. L. Nace	Consultant	----------	Apr. 7–17, 1963.	Paris, France	Conference of Inter-Governmental Experts to plan for IHD.
Alfonso Wilson	Codirector and lecturer on hydrometry.	ECLA	Oct. 17, Nov. 14, 1964.	Lima, Peru	Regional training course in surface-water hydrology at Universidad Agraria.
R. L. Nace	U.S. delegate	----------	May 24–June 3, 1965.	Paris, France	First session of Coordinating Council of IHD.
R. F. Hadley	Member	----------	Sept. 29–Oct. 2, 1965.	Budapest, Hungary.	First session of IHD Working Group on Representative and Experimental Basins.
J. D. Winslow	Codirector and lecturer in quantitative techniques in ground-water hydrology.	ECLA	Oct. 4–29, 1965.	Buenos Aires, Argentina.	Regional training course in ground-water hydrology.

USGS water scientists and engineers participating in UNESCO-sponsored projects, 1960–70

USGS assignee	Purpose of assignment	Date	Country or region	Project or activity
W. S. Keys and Joe Sena.	To train personnel of the Geological Survey of Canada and the Provinces of Saskatchewan and Manitoba in electrical and nuclear well logging and borehole geophysics, as applied to ground-water investigations.	May 15–Oct. 30, 1967.	Canada	Technical support of UNESCO/IHD program in education and training in hydrology.
Alfonso Wilson	To assist IHD national committees of Costa Rica, Nicaragua, Guatemala, Honduras, Panamá, and El Salvador in implementation of IHD projects.	Oct. 28–Dec. 2, 1968.	Central America.	Technical support of UNESCO/IHD program.
G. E. Harbeck, Jr	To consult with IHD national committees of Spain, Italy, Tunisia, Greece, and Hungary on studies in water balances, evaporation, and evaportranspiration.	Mar. 27–June 2, 1967.	Europe and North Africa.	Do.
T. G. McLaughlin	To coordinate results in antecedent hydrologic and hydrogeologic surveys in Greece; to make recommendations for hydrologic research and training as part of Greek participation in the IHD; to assist in preparation of long-term Greek IHD program; and to prepare special report on Hydrologic Monitoring in the Spercheios Basin.	Mar. 27–July 21, 1966.	Greece	Technical support of UNESCO/IHD program.

USGS water scientists and engineers participating in UNESCO-sponsored projects, 1960–70—Continued

USGS assignee	Purpose of assignment	Date	Country or region	Project or activity
P. E. Dennis	To guide development of geohydrologic research of the Central Arid Zone Research Institute.	Mar. 15–June 30, 1965.	India	Technical support of the UNESCO-sponsored Central Arid Zone Research Institute at Jodhpur.
R. L. Nace	To review Iranian plans for establishment of a Water-Research Institute.	July 21–26, 1967.	Iran	Technical support for proposed UNESCO-sponsored Water Research Institute at Teheran.
J. F. Poland	To study causes of land subsidence in the Venice area.	Mar. 24–Apr. 4, 1969.	Italy	UNESCO Project for Investigation of the Subsidence of Venice and Suggested Steps toward its Control.
J. F. Poland	To discuss with Italian authorities, programs, procedures, and problems of planned test and observation wells needed in the Venice area for subsidence studies.	May 25–June 1, 1970.	Italy	UNESCO Project for Investigation of the Subsidence of Venice and Suggested Steps toward its Control.
O. M. Hackett	To study organization of scientific research in Jordan with respect to arid-zone development.	October–November 1964.	Jordan	UNESCO/UNDP Project for Development of Natural Resources in Jordan.
Alfonso Wilson	To assist IHD national committees in Latin America in implementation of IHD projects.	Mar. 21–June 20, 1966.	Latin America.	Technical support of UNESCO/IHD program.
A. S. Post	To assist IHD national committees of Chile, Peru, and Argentina in cooperative research for monitoring behavior of Andean glaciers.	Jan. 15–Mar. 1, 1967.	----do	Technical support of UNESCO/IHD program in glaciological research.
Alfonso Wilson	To assist IHD national committees of Brazil, Argentina, Paraguay, Chile, Bolivia, Peru, Ecuador, Colombia, Venezuela, El Salvador, and Mexico in implementation of IHD projects.	July 1967	Latin America.	Technical support of UNESCO/IHD program.
H. E. Skitbitzke	For consultations with UNESCO/IHD Secretariat in Paris on Chad Basin Project.	June 20–27, 1966.	North Central Africa.	UNESCO/UNDP Project for Study of Water Resources in the Lake Chad Basin.
H. E. Skibitzke and William Meyer.	To conduct tests and undertake hydrologic studies on Chad Basin analog model at UNESCO/IHD Secretariat.	May 13–26, 1967.	----do	Do.
H. E. Skibitzke and H. T. Chapman.	To undertake aerial reconnaissance and a remote-sensing study in the Chad Basin in Chad, Niger, Cameroon, and Nigeria.	Feb. 23–Mar. 19, 1968; Apr. 1–21, 1968.	----do	Do.
A. E. Robinson	To assist in construction and instrumentation of analog model of Chad Basin.	Mar. 3–Apr. 25, 1968.	North Central Africa.	UNESCO/UNDP Project for Study of Water Resources in the Lake Chad Basin.
William Meyer	To undertake analog model studies of hydrologic phenomena of the Chad Basin at UNESCO/IHD Secretariat.	Sept. 30–Dec. 5, 1968.	----do	Do.
H. E. Skibitzke	To carry out further tests on Chad Basin analog model at UNESCO/IHD Secretariat.	May 13–25, 1969.	----do	UNESCO/UNDP Project for Study of Water Resources in the Lake Chad Basin.
V. C. Fishel	To evaluate status of knowledge and support capabilities in Egypt, Sudan, Chad, Upper Volta, Niger, Mauritania, Mali, Morocco, Algeria, Tunisia and Libya for regional studies of artesian basins of North Africa.	Mar. 11–Apr. 30, 1963.	North Africa	UNESCO Reconnaissance Study Mission of Artesian Basins of North Africa.
J. R. Jones	To evaluate status of knowledge and support capabilities in Egypt, Sudan, and Libya and to design a possible project.	Oct. 29–Nov. 20, 1966.	North Africa	UNESCO Exploratory Mission for a possible Regional Hydrogeologic Project for the Nubian Sandstone Basin of North Africa.

USGS water scientists and engineers participating in UNESCO-sponsored projects, 1960–70—Continued

USGS assignee	Purpose of assignment	Date	Country or region	Project or activity
F. E. Clarke	To study well casing, screen corrosion, and encrustation problems in Algeria and Tunisia.	Sept. 15–30, 1969.	----do	UNESCO/UNDP Survey of Ground Water Resources in the Northern Sahara.
R. J. Dingman	To evaluate technical aspects of a proposed water-resources investigation of the Canary Islands.	Apr. 22–May 26, 1967.	Spain	UNESCO/UNDP Project for Scientific Study of the Water Resources of the Canary Islands.
Do	To review work plan for Canary Islands water-resources investigation project.	Nov. 18–28, 1968.	----do	Do.
Do	To review work progress on Canary Islands water-resources project.	Feb. 13–Mar. 6, 1971.	----do	Do.
B. H. Lowell	To advise on the application of digital computer methods to the processing of hydrologic data, on the formulation of the data prior to computerization, and on programming geohydrologic data from the Canary Islands project for handling and systematic analysis.	Sept. 13–Oct. 13, 1970.	Spain	UNESCO/UNDP Project for Scientific Study of the Water Resources of the Canary Islands.
A. S. Post	To study from aerial photography Peruvian and Chilean glaciers and permanant snowfields.	June 25–July 25, 1967.	Western South America.	Technical support of UNESCO/IHD program in glaciological studies.
A. I. Johnson	To assist in the development of a curriculum in hydrology at the Middle East Technical University (METU) and the establishment of an UNESCO-sponsored Irrigation and Arid Zone Research Laboratory of METU in Ankara.	January, 1965.	Turkey	Technical support of UNESCO/IHD program in education and training in hydrology.

UNITED NATIONS

Whereas the United Nations specialized agencies and regional commissions play the leading roles in water-resources investigations and development and in scientific hydrology, the United Nations (UN) itself is, in effect, a residual legatee, filling in the gaps in the water-resources field not covered by other UN agencies. The UN's work in water resources is coordinated by its Department of Economic and Social Affairs, Resources and Transport Division headquartered in the Secretariat at United Nations, New York City. The main areas of United Nations interest are economic and institutional development (water administration and law), flood control, hydropower, navigation, and ground-water exploration and development. Also, the UN has fostered political and economic cooperation among countries in international river basins, as for example the Mekong basin in southeast Asia and among the riparian countries of the Senegal, Niger, Mono, and Logone River basins in Africa. The UN, somewhat in contrast to the mission-oriented agencies, has adopted a multipurpose approach and stresses the need for water policy and economic considerations in the planning, development, and management of water resources.

Many water-resources investigations projects, largely of a preinvestment and technical-assistance nature, have been undertaken in the developing countries during the past 20 years by the United Nations, as executing agency, with the United Nations Development Programme (UNDP) as financing agency. The USGS has provided technical assistance through 16 assignments, mostly on a short-term basis, to 9 UN/UNDP projects in 7 countries during 1949–70. In addition, USGS personnel have participated in several UN-sponsored water-resources conferences and related working groups. These activities are summarized in the following table.

UNITED NATIONS DEVELOPMENT PROGRAMME

The United Nations Development Programme (UNDP) was established in 1965 at the United Nations in New York City through consolidation of the former Expanded Programme of Technical Assistance (EPTA) and the United Nations Special

USGS water scientists and engineers participating in UN-sponsored projects, conferences, and working groups, 1949–70

USGS assignee	Purpose of assignment	Date	Country	Project or activity
D. J. Cederstrom	To appraise ground-water conditions for siting of water-supply wells along proposed highways in the Federation of South Arabia (Aden).	Jan.-Mar. 1967.	Aden	UN/UNDP Economic and Hydrologic Survey of proposed highway system in South Arabian Federation.
J. P. Reed	To assist in establishment of regional water-quality laboratory San Juan, Argentina under auspices of the Argentine Investment Council.	Oct. 1966–Jan. 1967; Aug.–Sept., 1967.	Argentina	UN/UNDP Northwestern Argentina Ground-Water Project.
J. E. McCall	To review existing facilities, equipment, and methods for collection of hydrologic data on the Paraná River between Corrientes and Rio Plata and to make recommendations for improvements and equipment requirements.	June 1970	----do	UN/UNDP Project for Improvement of Navigation on the Paraná River.
P. H. Jones	To instruct and train 15 Indian geophysicists and geologists of the Central Arid Zone Research Institute at Jodhpur in borehole geophysics analysis, and interpretation, thereof, as applied to ground-water exploration.	Oct.–Nov., 1970.	India	UN/UNDP Project for Ground-Water Surveys in Rajasthan and Uttar Pradesh.
T. E. Eakin	To design a project for ground-water investigations and training of Jamaican personnel.	Nov. 1953	Jamaica	UN/UNDP Water Resources Investigations Project in Jamaica.
C. H. Hardison	To design a project for surface-water investigations and training of Jamaican personnel.	----do	----do	Do.
C. C. Yonker	To undertake selection of sites and construction of 25 stream-gaging stations on the island of Jamaica; to train personnel in operation of instruments, computation and compilation of data, and publication of records.	Feb. 1954–Feb. 1955.	----do	Do.
G. C. Prescott	To undertake type-area ground-water investigations in the Clarendon Plain of southern Jamaica and to train personnel in methods and techniques of ground-water investigations.	May 1956–May 1957.	----do	Do.
T. G. McLaughin	To advise the UN/UNDP project manager and the Government of Jordan on hydrogeologic problems in the Azraq Basin of Jordan.	Sept.–Oct., 1963.	Jordan	UN/UNDP Ground-Water Investigation of the Azraq Basin.
J. G. Ferris	To advise UN/UNDP project manager on problems in ground-water hydraulics and well construction in karstic limestone terrane of the Coastal Plain and Bekaa area of Lebanon.	Nov.–Dec., 1964; June 1965.	Lebanon	UN/UNDP Ground-Water Investigations Project in Lebanon.
G. F. Smoot and H. H. Barnes.	To evaluate instrumentation needs, including stream-gaging, telecommunications, reservoir and precipitation stations, and power and communication linkages.	July 1970	Poland	UN/UNDP Project for Experimental Hydrometeorological System in Sola River Basin.
G. F. Smoot	To review hydrologic-instrumentation needs and make recommendations to project manager.	Sept. 1970	----do	UN/UNDP Project for Development of Vistula River.

USGS water scientists and engineers participating in UN-sponsored projects, conferences, and working groups, 1949–70 —Continued

USGS assignee	Purpose of assignment	Date	Country	Project or activity
E. L. Hendricks	U.S. delegate to the Water and River Basin Development Section.	Feb. 4–20, 1963.	Switzerland	United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Countries (UNCAST) held at Geneva.
C. G. Paulsen	U.S. delegate	Aug. 17–Sept. 9, 1949.	U.S.A.	United Nations Conference on the Conservation and Utilization of Natural Resources held at Lake Success, N.Y.
T. E. Eakin	Member of working group	1958–60	----do	United Nations Working Group on Large-Scale Ground-Water Development. Published in 1960.
W. B. Langbein and G. C. Taylor, Jr.	Members of U.S. Technical Advisory Group.	1962–63	----do	U.S. Technical Advisory Group on Water and River Basin Development for UNCAST. Published in 1963.
C. J. Robinove	To present paper on "Space Applications in Water Resources Development."	Aug. 14–27, 1968.	Austria	United Nations Conference on Exploration and Peaceful Uses of Outer Space held at Vienna.
P. H. Jones	To present paper on "Geothermal Resources of the Northern Gulf of Mexico Basin."	Sept. 22–Oct. 1, 1970.	Italy	United Nations Symposium on Development and Utilization of Geothermal Resources held at Pisa.

Fund (UNSF). The UNDP with its working funds, serves chiefly as a financing agency for preinvestment surveys, technical assistance projects, and feasibility studies for natural-resources development carried out by the United Nations (UN) itself (generally through the Resources and Transportation Division) and by the 11 participating agencies of the UN family. Among UNDP-financed projects, the USGS has provided technical support for those in the water-resources sector carried out by IAEA, FAO, UNESCO, World Bank, and WHO. These activities are described under the headings for each of these agencies.

WORLD METEOROLOGICAL ORGANIZATION

The World Meteorological Organization (WHO) was formed in the United Nations family as a specialized agency in 1950 with headquarters at Geneva. It is the successor of the nongovernmental International Meteorological Organization, which had been established in 1873. WHO's basic mission is to further worldwide cooperation in establishment of meteorologic and hydrometeorologic networks and international exchange of data and reports among its 129 member nations. To carry out this mission, WMO's activities are grouped in six regional meteorological associations, which are operationally oriented, and eight commissions, which are technically and scientifically oriented. In addition, WHO sponsors a World Meteorological Congress, which meets at least once every 4 years to determine general policy and to establish technical standards for meteorologic practices among member states, each of which has representation at Congress meetings by delegates of national meteorologic services.

Since its founding, WHO has cooperated closely in symposia and other international conferences on hydrology and hydrometeorologic subjects sponsored by the International Association of Scientific Hydrology (IASH), ECAFE, ECA, UNESCO, FAO, and the United Nations and has itself served as chief sponsor of several of these. In addition, WHO has coordinated the activities of several working groups and preparation of manuals and guides on techniques and methodology.

The WMO has played a major role since 1965 in the program of the International Hydrological Decade (IHD), being represented on 8 of the 12 working groups of the IHD Coordinating Council. WHO also provides the technical secretariat for the following IHD projects: incidence and spread of continental drought; depth-duration-frequency relations of precipitation in various geographic regions; vapor-flux evaluation of the hydrologic budget; radar measurement of rainfall; and measurement of snowfall and snowpack.

The USGS has participated actively in the work of WMO's Commission for Hydrometeorology and also the Commission for Instruments and Methods of Observation since the early 1960's. Also, the USGS has had representatives at two of the five World Meteorological Congresses in the past 20 years. USGS participation in WMO activities since 1960 is summarized in the following tables.

USGS water scientists and engineers participating in WMO-sponsored seminars, symposia, working groups, and other meetings and conferences, 1960–70

USGS attendee	Role	Seminar, symposium, working group, or other meeting			
		Co-sponsor	Date	Place	Subject
W. B. Langbein, R. W. Carter, and M. A. Benson.	Consultant ----do ----do	----------	1961 -----	Washington, D.C., U.S.A.	First session of WMO Commission on Hydrometeorology.
R. W. Carter ---	To assist in development of working group program.	----------	Dec. 1963 -	Geneva, Switzerland.	Meeting of WMO Working Group on Water Levels (stage) and Discharge Measurement and Estimation.
M. A. Benson ---	Chairman of working group.	----------	Sept. 29–Oct. 15, 1964.	Warsaw, Poland-	Second session of WMO Commission on Hydrometeorology, Working Group on Water Levels (stage) and Discharge Measurement and Estimation.
W. B. Langbein, R. M. Richardson, M. A. Benson, R. W. Carter, R. B. Vice, H. A. Swenson, H. P. Guy, G. H. Davis, E. P. Patten, Jr., S. M. Lang, and J. A. Irwin.	----------	IAHS ------	June 15–22, 1965.	Quebec, Canada -	Symposium on Design of Hydrometeorological Networks.
D. R. Wiesnet --- M. F. Meier ----	To present USGS exhibit on orthophotography; to lecture on Cascade glaciers.	IAHS, ICSI.	Sept. 19–23, 1965.	Ottawa, Canada -	Symposium on Glacier Mapping.
G. F. Smott, L. H. Heindl, R. F. Hadley, and W. W. Emmett.		IASH UNESCO/ IHD.	Sept. 28–Oct. 5, 1965.	Budapest, Hungary.	Symposium on Experimental and Representative Watersheds.
R. W. Carter ---	Lecturer on hydrologic instrumentation and observations and network design.	UNDP -----	Sept. 12–30, 1966.	São Paulo, Brazil.	Seminar on Hydrometeorological Instruments and Methods of Observation and on Establishment of Hydrometeorological Networks in WMO Regions III and IV (Latin America).
G. E. Harbeck, Jr	U.S. delegate ------	----------	Apr. 3–28, 1967.	Geneva Switzerland.	Fifth World Meteorological Congress.
W. L. Isherwood, Jr.	Consultant --------	----------	Nov. 2–23, 1967.	----do ---------	Meeting of WMO Working Group on Machine processing of Hydrometeorological Daat
H. C. Riggs ----	Lecturer on hydrological forecasting.	UNESCO/ IHD IASH FAO.	Nov. 29–Dec. 6, 1967.	Surfers Paradise, Queensland, Australia.	Symposium on Hydrological Forecasting.
R. W. Carter and W. B. Langbein	Consultants -------	----------	Sept. 9–21, 1968.	Geneva, Switzerland.	Third session of WMO Commission on Hydrometeorology.
D. R. Dawy -----	Consultant --------	IAHS ------	Dec. 1–16, 1969.	----do ---------	Preparation of WMO Guide on Hydrological Network Design-Needs, Problems, Approaches.
W. L. Isherwood, Jr.	Chairman of Working Group.	----------	June 1–5, 1970.	Geneva Switzerland.	Meeting of Working Group on Machine Processing of Hydrometeorological Data of WMO Commission for Hydrometeorology.
R. W. Carter ----	----do ----------	UNESCO/ IHD.	Sept. 13–17, 1970.	Koblenz, West Germany.	Meeting of WMO Working Group on Measurement of Water Level (Stage) and Stream Discharge Measurements and Estimation.
E. L. Hendricks -	Member of U.S. Delegation.	----------	Sept. 27–Oct. 8, 1970.	Geneva, Switzerland.	WMO Technical Conference of Hydrological and Meteorological Services.
R. W. Carter ---	U.S. Delegate ---	----------	----do ----	----do ---------	Fourth Session of WMO Commission on Hydrometeorology.

USGS water scientists and engineers participating in WMO-sponsored projects 1960–70

USGS assignee	Purpose of assignment	Date	Co-sponsor	Project or activity
M. A. Benson	Principal contributor and author of WMO guide.	1964–68	UNESCO/ IHD.	Preparation of WMO Technical Note no. 90 on "Measurement of Peak Discharge by Indirect Methods." 1968.
W. B. Langbein	Author and principal contributor to WMO guide.	1964–68	----do	Preparation of WMO Report no. 8 on "Hydrological Benchmarks," 1968.
G. E. Harbeck, Jr	Contributor to WMO guide.	1964–66	----do	Preparation of WMO Technical Note no. 83 on "Measurement and Estimation of Evaporation and Evapotranspiration," 1966. Commission for Instruments and Methods of Observation.
W. B. Langbein and D. R. Dawdy.	Contributors	1968–69	----do	Preparation of WMO Report no. 12 on "Hydrological Network Design—Needs, problems, approaches." 1969.
W. L. Isherwood, Jr	Consultant on hydrometeorological data processing.	Dec. 10, 1968–Jan. 7, 1969.	UNESCO/ IHD.	Consultation on hydrometeorological data processing at WMO secretariat, Geneve, Switzerland.
Do	----do	Jan. 7–Feb. 19, 1969.	UNDP	Assistance on WMO/UNDP Hydrometeorological Survey of the Catchments of Lake Victoria, Kioga and Albert at Entebbe, Uganda.

REGIONAL INTERGOVERNMENTAL AGENCIES

USGS participation in water-related activities of regional intergovernmental agencies (table 3) has been minor during 1961–71, as compared with involvement in activities of agencies in the United Nations family. Most important are the Organization of American States (OAS) and its affiliated agencies, the Pan-American Health Organization (PAHO) and the Pan-American Institute of Geography and history (PIAGH). USGS hydrologists have also participated in water-oriented meetings, symposia, expert and working groups sponsored by Central Treaty Organization (CENTO)—which includes Turkey, Iran, Pakistan, the United Kingdom and the United States, and the Organization for Economic Cooperation and Development (OECD)—which includes the countries of Western Europe, the United States, Canada, and Japan. Also, on one occasion, USGS water scientists participated in a study group sponsored by the Scientific Affairs Division of the North Atlantic Treaty Organization (NATO). These activities are summarized in the following table.

USGS water scientists and engineers participating in projects, working groups, symposia, seminars and training courses sponsored by Regional Intergovernmental Agencies, 1961–71

		Projects, working groups, symposia, seminars, and training courses			
USGS assignee	Purpose of assignment	Sponsoring agency	Date	Place	Project or activity
R. L. Nace, F. A. Kohout, Thomas Maddock, Jr.	To present papers in hydrology.	CENTO	Feb. 5–12, 1966.	Ankara, Turkey	Symposium on Hydrology and Water Resource Developments.
R. L. Nace	To plan for symposium on evaluation of water resources with scarce data.	----do	July 17–20, 1967.	Teheran, Iran	Planning for symposium.
R. L. Nace	To present papers in hydrology and to lead technical discussion groups.	----do	Mar. 4–8, 1969.	Teheran, Iran	Symposium on Evaluation of Water Resources with Scarce Data.
Do	To participate as member of working group.	----do	July 17–20, 1969.	----do	Meeting of CENTO Working Group on Hydrology and Water Resources Development.

USGS water scientists and engineers participating in projects, working groups, symposia, seminars and training courses sponsored by Regional Intergovernmental Agencies, 1961–71—Continued

USGS assignee	Purpose of assignment	Projects, working groups, symposia, seminars, and training courses			
		Sponsoring agency	Date	Place	Project or activity
M. A. Benson, D. R. Dawdy, and N. C. Matalas.	To participate in technical discussions.	NATO	Sept. 18–27, 1967.	Faro, Portugal	NATO Scientific Affairs Division. Meeting of Advanced Study Institute on Applications of Statistical Extremes.
W. W. Doyel	To assist in development of hydrologic-data system for Argentina and for regional needs of OAS Rio Bermejo Investigation.	OAS	Mar. 14–Apr. 14, 1971.	Buenos Aires, Argentina.	Hydrologic Investigations in La Plata River Basin.
D. A. Phoenix	To advise Nigerian delegation.	OAU	Apr. 4–7, 1964.	Maiduguri, Nigeria.	Drafting Convention to establish the Chad Basin Commission (Nigeria, Niger, Chad, and Cameroon) under the aegis of the OAU.
H. A. Swenson	U.S. representative	OECD	Mar. 7–8, 1961.	Paris, France	Meeting of Expert Group on Scientific Research in Water Pollution
Do	----do	----do	Nov. 5–6, 1962.	----do	Do.
Do	U.S. delegate	----do	Nov. 30–Dec. 2, 1964.	----do	Meetings on Cooperative Water Pollution Research.
S. L. Schoff	Observer and consultant.	PAHO	Aug. 1–28, 1966.	Fortaleza, Brazil.	Ground water course at Federal University of Ceará.
J. D. Winslow	To lecture on practical aspects of ground-water hydrology.	----do	Dec. 12–23, 1966.	Santiago, Chile	Ground water course at Universidad de Chile.
L. E. Carroon	To lecture on practical aspects of stream gaging.	----do	June 5–9, 1967.	Bridgetown, Barbados.	Seminar on surface-water hydrology.
G. C. Taylor, Jr.	To prepare report on water-resources investigations as an aid to economic development.	PIAGH	May 1–10, 1961.	Caracas, Venezuela.	Working Group on Hydrology of the PIAGH Commission on Cartography.

NONGOVERNMENTAL INTERNATIONAL ORGANIZATIONS

USGS water scientists and engineers have participated through the years in symposia, seminars, meetings, conferences, and working groups of a large number of nongovernmental international organizations as well as in U.S. organizations' activities in hydrology and related fields in foreign countries. These organizations are given in table 5. The preponderance of this activity for more than 20

TABLE 5.—*Nongovernmental international organizations in which USGS water resources personnel have participated, 1950–70*

American Geophysical Union (AGU)
Arctic Institute of North America (AINA)
American Association of Petroleum Geologists (AAPG)
American Water Resources Association (AWRA)
American Association for the Advancement of Science (AAAS)
American Society for Testing and Materials (ASTM)
Eastern Snow Conference (ESC)
Gelogical Society of America (GSA)
International Association of Scientific Hydrology (IASH)
International Association of Hydrogeologists (IAH)
International Association of Water Pollution Research (IAWPR)
International Astronautical Federation (IAF)
International Commission on Snow and Ice (ICSI)
International Council of Scientific Unions (ICSU)
International Federation of Information Processing Societies (IFIPS)
International Geographical Union (IGU)
International Glaciological Society (IGS)
International Mineralogical Association (IMA)
International Organization of Standards (IOS)
International Society for Soils Mechanics and Foundation Engineering (ISSMFE)
International Society for Photogrammetry (ISP)
International Union for Conservation of Nature and Natural Resources (IUCNNR)
International Union of Geodesy and Geophysics (IUGG)
International Union of Geological Sciences (IUGS)
International Union for Quaternary Research (INQUA)
International Water Supply Association (IWSA)
Pacific Northwest Pollution Control Association (PNWPCA)
Pacific Science Congress (PSC)
Water Conditioning Association. International (WCAI)
World Petroleum Congress (WPC)

years has been centered in the International Association of Scientific Hydrology (IASH), which is one of seven component associations of the International Union of Geodesy and Geophysics (IUGG). The IUGG, in turn adheres to the International Council of Scientific Unions (ICSU). Another nongovernmental organization, the International Commission on Snow and Ice (ICSI), which is dedicated to glaciologic research, affiliates with the IUGG and IASH.

Since the early 1950's, IASH symposia, conferences, and assemblies have been closely coordinated with UNESCO, IAEA, and WMO activities in hydrology and hydrometeorology. Also, the IASH has provided a publication vehicle for the scientific and technical proceedings of virtually all joint symposia and conferences with UNESCO's Arid Zone program between 1951 and 1964 and since 1965 with the IHD program. The USGS activities in the IASH and affiliated IUGG and ICSI activities are summarized in the following table.

USGS water scientists and engineers participating in IASH conferences, committees, working groups, commissions, and general assemblies, 1951–70

USGS attendee	Role	Conference, committee, working group, commissions, general assembly			
		Co-sponsor	Date	Place	Subject
A. N. Sayre	President of Commission on Ground Water; participant in symposium on Ground Water in Arid Zones.	UNESCO	Aug. 1951	Brussels, Belgium.	General Assembly of Brussels (with IUGG).
W. B. Langbein	Participant in proceedings of Commission on Surface Water.	do	do	do	Do.
A. N. Sayre	President of Commission on Ground Water.	do	Sept. 14–25, 1954.	Rome, Italy	General Assembly of Rome (with IUGG).
W. B. Langbein	Participant in proceedings of Commission on Surface Water.	do	do	do	Do.
R. W. Stallman, Tate Dalrymple, and L. B. Leopold.	Presented papers on hydrology.	do	Sept. 20–26, 1956.	Dijon, France	Darcy symposia.
T. W. Robinson, J. G. Ferris, A. N. Sayre, Robert Schneider, G. E. Harbeck, Jr., H. E. Skibitzke, Tate Dalrymple, W. H. Durum, W. B. Langbein, and M. F. Meier.	do	do	Sept. 3–14, 1957.	Toronto, Canada	General Assembly of Toronto (with IUGG).
W. B. Langbein, W. H. Durum, J. A. DaCosta, P. E. Lamoreaux, Thos. Maddock, Jr., A. N. Sayre, H. E. Skibitzke, J. F. Poland, and M. F. Meier.	Presented papers on hydrology.	UNESCO	July 25–Aug. 6, 1960.	Helsinki, Finland.	General Assembly of Helsinki (with IUGG).
E. V. Peterson, H. A. Waite, H. G. Rodis, H. E. Thomas, L. C. Dutcher, C. S. Conover, H. E. Skibitzke, and J. A. daCosta.	do	do	Sept. 10–18, 1961.	Athens, Greece	Symposium on Ground Water in Arid Zones.
R. L. Nace	Represented U.S. scientific support of proposed IHD.	AGU	do	do	Do.
J. A. daCosta	Committee member.	IAH	Mar. 5–8, 1962.	Paris, France	Meeting of Committee on Hydrogeological Maps of IASH Commission on Ground Water.

USGS water scientists and engineers participating in IASH conferences, committees, working groups, commissions, and general assemblies, 1951–70—Continued

USGS attendee	Role	Conference, committee, working group, commissions, general assembly			
		Co-sponsor	Date	Place	Subject
W. B. Langbein, C. G. Parker, W. C. Rasmussen, W. V. Tangborn, T. E. A. van Hylckama, E. A. Sammel, H. C. Riggs, M. I. Rorabaugh, J. D. Bredehoeft, P. H. Jones, E. A. Moulder, C. T. Jenkins, and G. M. Robinson.	Presented papers on hydrology.	IUGG	Aug. 19–31, 1963.	Berkeley, Calif., U.S.A.	General Assembly of Berkeley (with IUGG).
R. L. Nace	Promote IUGG sponsorship of IHD.	AGU	----do	----do	Do.
M. F. Meier and D. R. Wiesnet.	Presented opening address. Presented exhibit on the orthoscope.	UNESCO/ IHD.	Sept. 20–25, 1965.	Ottawa, Canada	IAHS Commission on Snow and Ice. Symposium on glacier mapping.
W. W. Emmett, R. F. Hadley, G. F. Smoot, and L. A. Heindl.	Presented papers on hydrology.	UNESCO/ IHD WMO	Sept. 28–Oct. 1, 1965.	Budapest, Hungary.	Symposium on Representative and Experimental Basins.
J. T. Callahan, H. E. LeGrand, John Vecchioli, L. A. Heindl, B. B. Hanshaw, and I. S. Papadopulos.	----do	UNESCO/ IHD, FAO, and IAH.	Oct. 7–14, 1965.	Dubrovnik, Yugoslavia.	Symposium on the Hydrology of Fractured Rocks.
R. L. Nace	Assist UNESCO with plans for IHD.	IUGG UNESCO.	Jan. 12–20, 1966.	Paris, France	Thirteenth General Assembly (with IUGG).
Do	Member of committee.		Jan. 13–15, 1966.	----do	Meeting of Committee on Reorganization of IUGG.
M. F. Meier	Participated in meeting.	UNESCO/ IHD.	May 2–3, 1966.	----do	Meeting IASH Commission on Snow and Ice.
T. E. A. van Hylckama, Jacob Rubin.	Presented papers on hydrology.	UNESCO/ IHD, FAO, ISSA.	June 19–25, 1966.	Wageningen, Netherlands.	Symposium on Water in the Unsaturated Zone.
E. W. Coffay, G. E. Harbeck, Jr., H. C. Riggs, and B. F. Jones.	----do	UNESCO/ IHD.	Oct. 9–15, 1966.	Lake Garda, Italy.	Symposium on the Hydrology of Lakes and Reservoirs.
A. M. Piper	Consultant	----do	Aug. 26-29, 1966.	Tokyo, Japan	Preliminary Meeting on Land Subsidence.
Philip Cohen, F. A. Kohout, A. I. Johnson, and Robert Schneider.	Presented papers on artificial recharge.	----do	Mar. 19–26, 1967.	Haifa, Israel	Symposium on Artificial Recharge and Management of Aquifers.
M. F. Meier	Participated in meeting.	----do	May 2–3, 1967.	Paris, France	Meeting IASH Commission on Snow and Ice.
G. E. Harbeck, Jr., W. J. Campbell, E. L. Hendricks, A. N. Sayre, W. B. Langbein, J. D. Hem, Thos. Maddock, Jr., L. R. Mayo, R. H. Meade, M. F. Meier, J. F. Wilson, Jr., and W. V. Tangborn.		IUGG UNESCO IHD.	Sept. 25–Oct. 7, 1967.	Berne, Switzerland.	Fourteenth General Assembly (with IUGG).
W. B. Langbein	Member of committee.		Apr. 19–22, 1968.	Budapest, Hungary.	Meeting of IASH Committee on Organization and International Hydrology.
M. F. Meier	Commission member.	UNESCO/ IHD.	Apr. 23–24, 1968.	Paris, France	Meeting of IASH Commission on Snow and Ice.

USGS water scientists and engineers participating in IASH conferences, committees, working groups, commissions, and general assemblies, 1951–70—Continued

USGS attendee	Role	Conference, committee, working group, commissions, general assembly			
		Co-sponsor	Date	Place	Subject
T. D. Steele, T. W. Anderson, Chintu Lai, D. R. Dawdy, R. W. Lichty, and J. M. Bergmann.	Presented papers on applications of computers in hydrology.	----do ----	Dec. 1968--	Tucson, Arizona, U.S.A.	Symposium on the Use of Analog and Digital Computers in Hydrology.
Ted Arnow and P. H. Jones.	U.S. delegates ----	UNESCO/ IHD.	May 6–13, 1969.	Bucharest, Romania.	Symposium on the Hydrology of Deltas.
M. F. Meier ---------	Commission member.	----do ----	Sept. 3–5, 1969.	----do ---------	Meeting of IASH Commission on Snow and Ice and Working Group on Glaciology of Special Committee on Antarctic Research (SCAR).
Do ----------	Participated in discussions.	----do ----	Sept. 8–12, 1969.	Cambridge, England, United Kindgom.	Symposium on the Hydrology of Glaciers.
H. H. Schumann, A. I. Johnson, J. T. Callahan, and J. F. Poland.	Presented papers on land subsidence.	UNESCO/ IHD, ISSMFE.	Sept. 17–22, 1969.	Tokyo, Japan --	Symposium on Land Subsidence.
D. R. Dawdy, N. C. Matalas, and G. F. Pinder.	Participated in discussions on mathematical modelling.	UNESCO/ IHD.	July 15–23, 1970.	London and Reading, England, United Kingdom.	Meetings of IASH Committee on Mathematical Models in Hydrology.
M. F. Meier ---------	Commission member.	----do ----	Sept. 6–12, 1970.	Budapest, Hungary.	Meeting of IASH Commission on Snow and Ice.
W. B. Langbein ------	Committee chairman.		Sept. 7–12, 1970.	----do ---------	Meeting of IASH Committee on Reorganization.
E. W. Coffay -------- H. C. Riggs --------- R. F. Hadley -------- L. B. Leopold -------	Presented papers participated in discussions.	UNESCO/ IHD.	Dec. 1–8, 1970.	Wellington, New Zealand.	Symposium on Representative and Experimental Basins.

Since its founding in 1956, USGS hydrogeologists have also been intermittently active in the International Association of Hydrogeologists (IAH) which affiliates with International Union of Geological Sciences (IUGS). Other nongovernmental international organizations of particular interest to USGS hydrologists include the Pacific Science Congress (PSC) which meets every 5 years in one of the circum-Pacific countries, the International Geographical Union (IGU), Eastern Snow Conference (ESC), and International Water Supply Congress (IWSC). USGS participation in these and other water-related organizations during 1965–70 is summarized in the following table.

USGS water scientists and engineers participating in conferences, committees, working groups, commissions, and assemblies of Nongovernmental International Organizations, 1965–70

USGS attendee	Purpose of attendance	Conferences, committees, working groups, commissions, and assemblies			
		Sponsor	Date	Place	Subject
R. F. Hadley and J. E. Upson.	To present papers	INQUA ----	Aug. 30–Sept. 4, 1965.	Boulder, Colorado, U.S.A.	Seventh International Congress.
T. W. Robinson ------	To present paper on "Effects of Phreatophytes in Ground-Water Balance."	IAH -------	Sept. 14–25, 1965.	Hanover, West Germany.	General Congress.
C. H. Hardison ------	To participate in discussions of methods of analyzing streamflow records.	----------	Sept. 20–Oct. 4, 1965.	Oxford, England, U.K.	Symposium on reservoir yield.

USGS water scientists and engineers participating in conferences, committees, working groups, commissions, and assemblies of Nongovernmental International Organizations, 1965–70—Continued

USGS attendee	Purpose of attendance	Conferences, committees, working groups, commissions, and assemblies			
		Sponsor	Date	Place	Subject
J. D. Stoner and J. F. Santos.	To present paper on water-quality monitoring and on changes in water quality in the estuarine environment resulting from waste disposal.	PNWPCA	Nov. 2–5, 1965.	Vancouver, B.C., Canada.	General Meeting.
L. B. Leopold	To chair commission conferences.	IGU	June 8–26, 1966.	Liege and Leuven, Belgium.	Joint meetings of Commissions on Applied Geomorphology and on Evolution of Slopes.
S. A. Schumm	To present paper on "Erosion Rates and River Morphology."				
R. E. Oltman	To present paper on 'Reconnaissance Investigations of the Discharge and Water Quality of the Amazon."		June 6–11, 1966.	Belem, Pará Brazil.	Symposium on Amazonian biota organized by the Brazilian Association for Tropical Biology and the Brazilian National Research Council.
M. F. Meier	To study surges of Steele Glacier.	AINA	July 25–29, 1966.	Kluane Lake, Yukon Territory, Canada.	Meeting of Ice Ranges Advisory Committee.
A. M. Piper, J. T. Callahan, and R. C. Vorhis.	To present papers and participate in discussions.	PSC	Aug. 22–Sept. 10, 1966.	Tokyo, Japan	Eleventh meeting. Symposium on Terrestrial Waters with special reference to Environmental Factors.
R. L. Nace and H. A. Swenson.	To present papers and participate in discussions.	WCAI	Aug. 25–26, 1966.	Montreal, Quebec, Canada.	Second International Water Quality Symposium.
B. F. Jones		IMA	Aug. 30–Sept. 3, 1966.	Cambridge, England, U.K.	Meeting.
R. L. Wershaw	To present paper on "Hydrogen Isotopic Fractionization in Water Passing through Trees."		Sept. 26–28, 1966.	London, England, U.K.	Third International Meeting on Organic Chemistry.
S. K. Love	To present paper and participate in discussions.	IWSA	Oct. 3–7, 1966.	Barcelona, Spain	Seventh International Water Supply Congress.
R. S. Sigafoos	To participate in discussion on vegetation in relation to hydrology and streamflow.		Oct. 12–15, 1966.	Antigonish, Nova Scotia, Canada.	Symposium on Terrestrial Plant Ecology organized by St. Xavier University.
C. E. Knox and G. S. Hayes.	To participate in discussions on snow—its origin, precipitation, accumulation, physical character, melting, and runoff.	ESC	Feb. 9–10, 1967.	Niagara Falls, Ont., Canada.	Annual Meeting.
W. S. Eisenlohr	To present paper		Feb. 20–22, 1967.	Saskatoon, Sask., Canada.	Seminar on Small Water Areas in the Prairie Pothole Region.
L. B. Leopold	To present paper and participate in panel on air and water conservation.	WPC	Apr. 2–9, 1967.	Mexico City, Mexico.	Seventh International World Petroleum Congress.
Alfonso Wilson	To present paper on U.S. trends in urban, industrial, and recreational use of the arid zone.	IGU UNESCO/IHD.	Apr. 3–21, 1967.	Lima, Peru	Commission on the Arid Zone. Symposium on Coastal Deserts and on Changes in the Occupancy of Arid Areas of Peru.

USGS water scientists and engineers participating in conferences, committees, working groups, commissions, and assemblies of Nongovernmental International Organizations, 1965–70—Continued

USGS attendee	Purpose of attendance	Conferences, committees, working groups, commissions, and assemblies			
		Sponsor	Date	Place	Subject
M. F. Meier	To participate as vice president.	IGS	May 4–5, 1967.	Cambridge, England, U.K.	Annual general meeting.
T. G. McLaughlin, E. S. Davidson, and R. V. Cushman.	To present papers.	IAH	Sept. 7–25, 1967.	Istanbul, Turkey.	General congress.
W. J. Campbell	----------	----------	Oct. 25–30, 1967.	Cambridge, England, UK.	Meeting of Scott Polar Research Institute, Cambridge University.
G. F. Smoot	----------	IOS	July 1–13, 1968.	Paris, France	Meeting of Work Group 5, Technical Committee 113 of IOS.
A. M. Piper, P. H. Jones, N. J. King, C. L. McGuinness, Robert Schoen, and Fred Kunkel.	To present papers.	IUGS	Aug. 19–28, 1968.	Prague, Czechoslavakia.	23d International Geological Congress.
M. F. Meier	To participate as vice president.	IGS	Apr. 25–26, 1968.	Cambridge, England, U.K.	Annual general meeting.
Harry Hulsing and W. W. Barnwell.	To present papers.	AAAS	Aug. 26–30, 1968.	Whitehorse, Yukon Territory, Canada.	Alaska Science Conference.
William Back, Alfred Clebsch, Jr., W. W. Doyel, P. A. Emery, B. B. Hanshaw, E. L. Hendricks, J. H. Irwin, D. C. Jorgenson, V. C. Kennedy, B. F. Lofgren, I. W. Marine, T. G. McLaughlin, R. H. Meade, Gerald Meyer, R. L. Nace, R. C. Newcomb, J. F. Poland, F. S. Riley, E. A. Sammel, G. C. Taylor, Jr., C. V. Theis, W. E. Wilson, R. G. Wolff, and F. T. Mannheim.	To present papers and to participate in activities of GSA Committee on Hydrogeology.	GSA	Nov. 11–13, 1968.	Mexico City, Mexico.	Annual Meeting.
J. R. Jones	To present paper on "Ground Water Provinces of Libya."	----------	Apr. 14–18, 1969.	Tripoli, Libya	Symposium on the Geology of Libya organized by the University of Libya.
M. C. Goldberg	To present paper.	AWRA	May 23–28, 1969.	Montreal, Quebec, Canada.	General conference.
F. A. Kohout, Alfonso Wilson, A. M. Spieker, and A. I. Johnson.	To present paper.	----do	June 21–29, 1969.	Banff Alberta, Canada.	Symposium on Water Balance in North America.
T. G. McLaughlin		AAPG	June 24–30, 1969.	Brighton, England, U.K.	Joint meeting of the American Association of Petroleum Geologists and the British Institute of Petroleum.
L. B. Leopold	To participate in discussions.	IGU	Aug. 20–Sept. 1, 1969.	Paris, France	Meeting of Commission for Investigating Present-Day Geomorphological Processes.
Ronald Malcolm	To present paper on clay mineralogy.	----------	Sept. 5–10, 1969.	Tokyo, Japan	International Clay Conference.
W. S. Keys	To participate as expert in borehole geophysics.	IAH, UNESCO/IHD.	Oct. 2–5, 1969.	Budapest, Hungary.	Expert meeting on Cooperative Role of Hydrology and Geophysics in Ground Water Exploration.

USGS water scientists and engineers participating in conferences, committees, working groups, commissions, and assemblies of Nongovernmental International Organizations, 1965–70—Continued

USGS attendee	Purpose of attendance	Conferences, committees, working groups, commissions, and assemblies			
		Sponsor	Date	Place	Subject
O. M. Hackett	To present paper on "Water Data for Progress."		Jan. 19–24, 1970.	Bangkok, Thailand.	Water Supply and Sanitation Exhibition and Seminar organized by U.S. Department of Commerce.
Thos. Maddock, Jr			May 12–14, 1970.	Wellington, New Zealand.	Conference on Development and Management of Water Resources organized by New Zealand Institution of Engineers and Royal Society of New Zealand.
F. E. Clarke, A. I. Johnson, B. A. Malo, and M. W. Skougstad.	To present papers.	ASTM	June 21–26, 1970.	Toronto. Ontario, Canada.	Meeting of Sub-Committees on Nomenclature and on Permeability and Capillarity.
S. M. Lang	To participate in discussions.	AAPG	June 22–24, 1970.	Calgary, Alberta, Canada.	Meeting of Advisory Committee on Stratigraphic Coding.
G. R. Ayer	----do	ESC	July 1–2, 1970.	Ottawa, Ontario, Canada.	Annual Meeting.
W. H. Durum	----do		Aug. 22–30, 1970.	Caracas, Venezuela.	12th Interamerican Sanitary Engineering Congress.
G. P. Kraker, Jr			Aug. 22–29, 1970.	Otanlemi, Finland.	TRIGA Research Reactors Seminar.
M. C. Goldberg	To patricipate in discussions.		Aug. 25–Sept. 20, 1970.	Tokoyo, Nagoya and Ibaraki, Japan.	Symposium on Hydrogeochemistry and Hydrobiochemistry organized by Ibaraki and Nagoyo Universities.
Gerald Meyer and R. T. Sniegocki.	To present papers.		Sept. 19–26, 1970.	Reading, Berkshire, England, U.K.	Conference on Artificial Ground Water Recharge organized by British Water Research Associations.

GOVERNMENTAL SCIENTIFIC AND TECHNICAL EXCHANGE AND COOPERATION

The U.S. National Academy of Sciences (NAS)—National Research Council (NRC), through cooperative arrangements with counterpart organizations in foreign governments, have sponsored for many years task forces, working groups, international conferences, panels, and seminars dedicated to the furtherance of pure and applied research as well as to scientific and technical education and training, both in the developed and developing countries. USGS specialists in hydrology have participated in NAS–NRC activities relating to hydrologic education and research on several occasions during the past 19 years, notably in Latin America, Africa, Canada, and the U.S.S.R. These activities are summarized in the following table.

Since the early 1960's the systematic negotiation by the U.S. Department of State, Bureau of International Scientific and Technological Affairs, of formal bilateral agreements between the United States and foreign governments for scientific and technical exchange and cooperation has also gained impetus. The first such agreement came in 1961, when the United States and Japan negotiated a Cooperative Science Program. This was soon followed in 1963 by agreement for the U.S.-Japan Cooperative Program on Natural Resources Development and in 1965 by a U.S.-Japan Cooperative Medical Program. Since 1965, agreements for cooperation in science and natural resources have been negotiated with Germany, India, Italy, Iran, Australia, China (Taiwan), U.S.S.R., and most recently (1970) Spain. Informal agreements also exist with France, Romania, Yugoslavia, Poland, and Czechoslovakia. Such agreements (1) give impetus to cooperation, (2) enhance the prestige of local scientists, (3) strengthen local support, (4) facilitate exchange of personnel and (5) permit exchange of materials and equipment. The United States' shares of these agreements are administered mostly by the National Science Foundation (NSF): however the U.S. Department of the Interior administers the U.S.-Japan Cooperative Program on Natural Resources Development and also the U.S.-German Cooperative Program in Natural Resources.

USGS participation in the water-resources or hydrologic sectors of programs covered by these agreements have thus far (1970) been limited to the U.S.-Japan Cooperative Program on Natural Resources

Development. This program at present includes 19 panels, which meet periodically to discuss topics of interest in particular areas of resources-development research. F. E. Clarke, USGS hydrologist, participated in a meeting of the Desalting Panel held at Tokyo, Japan, during October 23–31, 1966, and twice in meetings of the Water Pollution Panel held in Tokyo during October 23–28, 1967, and March 23–April 4, 1970. The Pollution Panel meetings were directed to comparison of research programs, data-collection networks, methods development, advanced waste treatment, and institutional aspects of pollution evaluation and control. The Desalting Panel meeting was dedicated to comparison of research programs, advances in desalting techniques, and demineralization of inland brackish waters, where sources of fresh water are not available.

USGS water scientists and engineers participating in NAS-NRC-sponsored conferences, task forces, and work shops, 1960–70

USGS assignee	Purpose of assignment	Conferences, task forces, and work shops		
		Date	Place	Subject or activity
Walter Hofmann	To participate as expert in hydrology on Task Force which visited Costa Rica, Panamá, Venezuela, Colombia, Ecuador, Peru, Brazil, and Trinidad.	Oct.–Dec. 1964.	Latin America.	NAS-NRC Latin America Science Board; 18-man interdisciplinary Task Force to identify needs for 4 Regional Research-Training Institutes in Latin America based on climatic agricultural zones.
H. E. Thomas	To participate as expert in hydrology.	Aug. 18–26, 1965.	Bellagio (Lake Como), Italy.	NAS-NRC Africa Science Board. Workshop on Science and Development in Africa.
N. C. Matalas	To present paper on aspects of time series analysis in hydrologic studies.	Feb. 24–25, 1966.	Montreal, Quebec, Canada.	NAS-NRC and Canadian NRC. Symposium on Statistical Methods in Hydrology.
M. F. Meier	To participate as panel member.	Apr. 24–26, 1966.	St. Hilaire, Quebec, Canada.	NAS-NRC and Canadian NRC. Conference of Panel on Glaciology, Committee on Polar Research.
F. T. Mannheim	U.S. delegate	May 30–June 9, 1966.	Moscow, U.S.S.R.	NAS-NRC Committee on Oceanography. Second International Oceanographic Congress.
H. E. Skibitzke, W. S. Keys, and R. T. Hurr.	To present papers in infra-red techniques in water-resources investigations; in borehole geophysics in ground-water investigations; and in water management.	Oct. 22–27, 1967.	Niagara Falls, Ont., Canada.	NAS-NRC and Geological Survey of Canada. Canadian Centennial Conference on Mining and Ground-Water Geophysics.
H. E. Thomas	To participate as expert in hydrology in Mobile Conference held in Ghana, Nigeria, and Niger.	Mar.–May 1968.	West Africa	NAS-NRC Africa Science Board. Mobile Conference on Ecologic Effects on Man-Made Lakes in Africa.
W. J. Campbell and M. F. Meier.	To participate in discussions	Sept. 10–11, 1968.	St. Hilaire, Quebec, Canada.	NAS-NRC and Canadian NRC. Seminar on Causes and Mechanics of Glacier Surges.
Alfonso Wilson	To participate as expert in hydrology.	July 28–Aug. 1, 1969.	Mar de Plata, Argentina.	NAS-NRC Latin America Science Boards. Workshop on Science and Development in Latin America.
J. F. Daniel and Morris Deutsch.	To participate as experts in space applications in hydrology.	June 7–11, 1970.	Burlington, Ontario, Canada.	NAS-NRC and Canadian NRC Conference of Committee on Space Program for Earth Observation.
J. D. Winslow	To review Argentine hydrogeologic research in the Pampean region of western Buenos Aires Province.	Aug. 21–30, 1970.	Argentina	NAS-NRC Cooperative Research Program with the Argentine Consejo Nacional de Investigaciones Científicas Técnicas.

As a sequel to the U.S.-Canadian Boundary Waters Treaty of 1909, an International Joint Commission was established to maintain continuing surveillance over the flow, water quality, and sediment loads of international rivers and lakes along the U.S.-Canadian boundary. The USGS is designated as in the U.S. Federal Government for the cooperative exchange of hydrologic data and research and of technical and scientific reports pertaining to international waters along the U.S.-Canadian boundary. In addition, the USGS participates in the activities of several international boards, committees, and working groups set up under the aegis of the Joint Commission to establish standards, to study the hydrologic problems of particular international basins, and to regulate water quantity and quality in individual rivers basins. Those in which USGS personnel have been active during 1960–70 include the following:

Great Lakes Basin Commission
International Columbia River Board of Control
International Kootenay Lake Board of Control
International Osoyoos Lake Board of Control
International Pembina River Engineering Board
International St. John River Engineering Board
International Souris River Board of Control
International Souris-Red River Engineering Board
International St. Mary and Milk River Board of Control

USGS hydrologists were also intermittently active during 1962–70 in an informal U.S.-Canadian organization known as the North Atlantic Hydrologic Group, which includes engineers and hydrologists from the Government of Canada, and the Governments of Quebec and the Maritime Provinces as well as from U.S. Federal and State government agencies. The group meets about once every 2 years to discuss technical problems related to ground water, streamgaging, water-quality and sediment measurement in international streams of Eastern Canada and Northeastern United States.

The USGS also has been designated as the managing agency for the Department of the Interior's EROS (Earth Resources Observation System) program, including a Data Center which has been constructed in the vicinity of Sioux Falls, S.D. This center is the key installation in the use of remote sensing data obtained from aircraft and space vehicles for purposes of national and worldwide resources and environmental surveys. Under USGS direction the center serves as a repository for information and for data processing, interpretation, and dissemination. The principal source of data to be processed at the center is NASA's (National Aeronautics and Space Administration) ERTS (Earth Resources Technology Satellite) series.

The first experimental ERTS was to be launched July 23, 1972. USGS water scientists and engineers were active during the late 1960's and in early 1970 in the planning for instrumentation needed to record and measure the earth's hydrologic phenomena and for ground-truth observations needed to quantify remote-sensing data. These activities were carried out not only in the United States but also in 27 other cooperating countries in North and South America and Asia.

WATER FOR PEACE PROGRAM

Perhaps the most ambitious effort during the 1960's to focus attention of the world community on the scope and nature of mankind's water problems and the need for cooperation in their solution was the Water for Peace program. President Johnson launched the program in a public address on October 7, 1965, in which he pledged U.S. participation in a "massive cooperative international effort to find solutions for man's water problems." Based on this mandate, an Interdepartmental Committee on Water for Peace, representing interested agencies of the Federal Government, was organized under the sponsorship of the Department of State and the Department of the Interior. The mission of the committee was to survey current world water problems and to prepare a report recommending actions that could be taken to advance international cooperation in finding solutions for these problems. The committee, active during late 1965 and through all of 1966, was divided in several working groups designated to identify goals. These included: water for living; water for food; water for international cooperation; international rivers; regional centers for water-resources development; education and training; research and surveys; information, data, and publications; the International Hydrological Decade; United Nations programs; foreign bilateral programs; water laws and legal institutions; strengthening U.S. capabilities to support overseas water development; and the International Water for Peace Conference. The report of the Interdepartmental Committee entitled—"Water for Peace—a report of background considerations and recommendations on the Water for Peace program" was published in

March 1967. USGS hydrologists, active in the committee working groups during 1965–66 and in the preparation of the report, included T. E. Eakin, G. C. Taylor, Jr., H. A. Swenson, W. J. Schneider, and L. A. Heindl.

One of the basic objectives of the Interdepartmental Committee was to lay the groundwork for the International Conference on Water for Peace held in Washington, D.C., on May 23–31, 1967. The conference was directed toward identifying water problems, exchanging knowledge, discussing goals, and considering cooperative action in the furtherance of worldwide objectives of the Water for Peace program. One of the largest international meetings ever held in Washington, the conference was attended by some 6,400 participants, including 94 country delegations and representatives of 24 international organizations. USGS representation included W. B. Langbein, R. L. Nace, S. K. Love, and L. A. Heindl as rapporteurs or chairmen of expert sessions. H. A. Swenson served as vice-chairman of the Conference Program Committee. G. H. Davis, F. E. Clarke, G. W. Whetstone, T. W. Robinson, and C. J. Robinove presented technical papers at expert sessions. All these individuals also served as experts in the U.S. delegation. O. M. Hackett, W. H. Durum, and C. L. McGuinness served as summation officers for the Conference Secretariat. In addition, 70 hydrologists from USGS registered at the conference as observers. The proceedings of the Water for Peace Conference, including all speeches and papers presented at plenary and expert sessions, were published in late 1967 in a 2-foot set of eight volumes.

A Water for Peace Office in the Department of State to provide followup guidance for the program was established by President Johnson during his welcoming address to the conference on May 23, 1967. This office supported a modest overseas program until mid-1969 but was then disbanded.

INVESTIGATIONS AND RESEARCH ABROAD IN EXTENSION OF DOMESTIC RESEARCH

USGS scientists and engineers have long been permitted to attend international meetings under authorization provided by the Organic Act of 1879. Authorization for use of Federal program funds to carry out hydrologic investigations and research outside the national domain in extension of domestic research did not come into being, however, until passage by Congress of Public Law 87–626 on September 5, 1962. This law made possible far wider scope for scientific and information exchange between USGS water scientists and engineers and the world scientific community than ever before. The law also made it possible for the USGS to support and participate actively in the IHD program. In addition, USGS water-resources personnel are enabled to pursue independent hydrologic investigations and research and to establish scientific exchange outside the national domain that redound to the benefit of the USGS domestic program. These activities during 1965–70 are summarized in the following table. During this period there were some 47 assignments abroad, ranging from a few days to as much as a year's duration.

USGS water scientists and engineers participating in investigations abroad in extension of domestic research, 1965–70

USGS water scientist	Purpose of overseas assignment	Date	Country or place
S. A. Schumm	To study ancient and recent slopes and channels of the Murrumbidgee River system in Australia.	Oct. 1964–July 1965.	New South Wales, Australia.
I. S. Papadopulos	To confer with Dutch and French specialists on problems in the quantification and mechanics of ground-water flow.	Oct. 15–30, 1965.	Netherlands; France.
R. M. Turner	To study botanical assemblages of the Sonoran Desert with respect to their hydrologic implications.	Oct. 1–31, 1965.	Northern Mexico.
F. A. Kohout	To observe submarine springs in the coastal areas of the eastern Mediterranean and to consult with Israeli, Lebanese, and Greek hydrologists on problems related to submarine springs in limestone.	Feb. 12–28, 1966.	Israel, Greece, and Lebanon.
William Back and B. B. Hanshaw.	To carry out hydrogeochemical research of the ground-water system of the Yucatan peninsula for comparative study with the Florida peninsula.	Mar. 4–Apr. 16, 1966.	Yucatan, Mexico.
R. J. Pickering	To consult with scientists at the IAEA Laboratory of Marine Radioactivity.	May 20–25, 1966.	Monaco.
Jacob Rubin	To discuss with Swiss and British specialists laboratory research in water movement in the unsaturated zone.	June 1966	Switzerland; United Kingdom.
T. E. A. van Hylckama	To discuss research with Dutch and German specialists in lysimeter and evapotranspiration studies.	----do	Netherlands, West Germany.

USGS water scientists and engineers participating in investigations abroad in extension of domestic research, 1965–70 —Continued

USGS water scientist	Purpose of overseas assignment	Date	Country of plase
S. A. Schumm	To exchange information on techniques and applications of terrain analysis and geomorphic mapping with British and French specialists.	June 16–26, 1966.	United Kingdom, France.
W. B. Langbein	To exchange research knowledge with British and German scientists in studies relating stream-channel dimensions to annual yield of rivers.	June 9–July 13, 1966.	United Kingdom, West Germany.
R. L. Wershaw	To discuss research in sorption of herbicides and pesticides on clay minerals and degradation of these compounds by soil micro-organisms with Dutch, British, and Canadian specialists.	Sept.–Oct. 1966.	Netherlands, United Kingdom, and Canada.
B. F. Jones	To confer with European scientists on hydrogeochemical problems of closed-lake basins and lacustrine sediments.	Oct. 1966	United Kingdom, Netherlands, France, Germany, and Switzerland.
G. P. Williams	To exchange information with European scientists on methods of measuring bed loads in rivers.	Dec. 10, 1966–Jan. 15, 1967.	United Kingdom, West Germany, Switzerland, and Sweden.
E. A. Jenne	To discuss with Canadian scientists research on determination of heavy-metal organic complexes and field measurement of oxidation-reduction potentials.	Apr. 20–22, 1967.	Ottawa, Ont., Canada.
D. M. Thomas	To discuss with Canadian scientists newly developed procedure for aerial photograph interpretation.	July 21–24, 1967.	Do.
W. J. Schneider	To confer with Canadian scientists on methods of flood-plain delineation.	July 21–24, 1967.	Do.
B. F. Jones	To discuss research with Canadian scientists on silicate-water reactions.	July 23–29, 1967.	Ottawa and Hamilton, Ont., Canada.
M. F. Meier, A. S. Post, and W. J. Campbell.	To carry out comparative glaciological studies in British Columbia and Yukon Territory.	Fiscal year 1967.	Canada.
W. H. Durum	To discuss problems in hydrochemical and sediment research with European scientists.	Aug. 4–Sept. 25, 1967.	United Kingdom, Norway, Germany, Austria, and France.
F. A. Kohout	To investigate hot water discharge from submerged limestone sink or "blue hole" near Andros, Bahama Islands.	Sept. 5–13, 1967.	Bahama Islands.
Thos. Maddock, Jr	To discuss problems in research on the hydraulics of natural channels with European scientists.	Sept. 10–25, 1967.	United Kingdom, Netherlands, and Denmark.
T. G. McLaughlin	To exchange information with Thai hydrogeologists on ground-water problems in limestone and deltaic terrains and with Japanese hydrogeologists on water management and land subsidence problems in the Tokyo area.	Sept. 25–Oct. 7, 1967.	Bangkok, Thailand, Tokyo, Japan.
R. M. Turner	To carry out research aimed at relating climate and vegetation patterns in the Sonoran Desert (both in Mexico and southwest United States) to past, present, and future availability of water and to establish new plots for study of vegetation assemblages.	Oct. 1–Nov. 1, 1967.	Northwestern and Pacific Coastal region of Mexico.
W. J. Campbell	To discuss research in glaciology with Austrian scientists.	Oct. 7–24, 1967.	Innsbruck, Austria.
L. B. Leopold H. E. Skibitzke.	To carry out hydrologic research in the Northwest Territory.	Apr. 26–May 5, 1968.	Canada.
Robert Schoen	To visit hot springs in Europe for study of the rôle of sulfur-oxidizing bacteria in formation of sulfuric acid in thermal waters.	July 22–Aug. 19, 1968.	Toulouse, France; Basel, Switzerland; Pisa, Italy; Lenz, Austria; Greifswald, West Germany.
P. H. Jones	To exchange information with Belgian scientists on the hydrology of clay.	Aug. 26–31, 1968.	Mol, Belgium.
N. J. King	To confer with Spanish scientists on geohydrologic research related to control of accelerated erosion and sedimentation and to restoration of deteriorated lands to their former productivity.	Aug. 26–Sept. 3, 1968.	Madrid, Spain.
A. M. Piper	To confer with British and German scientists on technology and policies for managing water supplies in densely populated industrial areas.	Aug. 26–Sept. 15, 1968.	United Kingdom; Germany.
H. E. Skibitzke	To participate in joint U.S.-Mexican coordination and planning meetings for remote sensing program in Mexico under NASA sponsorship.	Dec. 7–20, 1968.	Veracruz and Mexico City, Mexico.
H. E. Skibitzke J. D. Friedman.	To participate in joint U.S.-Brazilian coordination and planning meetings for remote sensing program in Brazil under NASA sponsorship.	Jan. 18–Feb. 1, 1969.	Rio de Janeiro, Brazil.

USGS water scientists and engineers participating in investigations abroad in extension of domestic research, 1965–70
—Continued

USGS water scientist	Purpose of overseas assignment	Date	Country or place
F. T. Mannheim	To participate in oceanographic expedition to the Black Sea and to design and carry out pore-water studies of bottom samples using the Kullanberg "interval" corer.	Mar. 10–Apr. 25, 1969.	Italy, Turkey, and Bulgaria.
R. G. Wolff	To exchange information with French and Dutch scientists on the hydrology of clays and clay mineralogy.	May 211–July 16, 1969.	Netherlands; France.
L. B. Leopold	To confer with European scientists on problems in arid-zone hydrology.	Sept. 1–Oct. 10, 1969.	France, Switzerland, Spain, Sweden, and United Kingdom.
J. T. Callahan	To exchange information with Japanese scientists on hydrogeology and to study land-subsidence problems in the Tokyo area.	Sept. 17–22, 1969.	Tokyo, Japan.
F. T. Pearson	To discuss applications of tritium and radiocarbon research to hydrologic problems with European scientists.	Mar. 20–Apr. 4, 1970.	Denmark, West Germany, United Kingdom, Netherlands, and Switzerland.
W. J. Sando	To attend field seminar on environments of deposition of carbonate sediments.	June 4,	Bahama Islands.
W. J. Campbell	To participate in oceanographic expedition of the University of Washington in the Bering and Chuckchee Seas.	July 8–Aug. 10, 1970.	Tokyo, Japan.
D. R. Dawdy	To confer with European hydrologists on problems in mathematical models.	July 10–20, 1970.	United Kingdom; Denmark.
E. V. Giusti	To discuss problems in karstic hydrology with Italian and Yugoslav scientists.	July 15–22, 1970.	Italy; Yugoslavia.
W. J. Campbell	To attend seminar with Canadian scientists on thickness measurements of floating ice by remote sensing.	Oct. 26–28, 1970.	Ottawa, Canada.
B. H. Lowell	To attend seminar with Canadian scientists on methods of storing, retrieving, and processing ground-water data.	Nov. 16–18, 1970.	Do.
R. L. Cory	To visit marine laboratories and confer with Spanish and British scientists on problems in marine hydrobiology.	Dec. 20–30, 1970.	Barcelona, Spain, and Plymouth, England, U.K.

PROBLEMS AND OUTLOOK

The USGS now (1970) has been participating in overseas water-resources technical assistance projects for three decades and more recently also has been deeply involved in international exchange related to scientific and applied hydrology. Among these activities, projects oriented toward specific scientific and technical goals of evaluating areal water-resources problems or measuring hydrologic parameters in the developing countries have generally achieved a high measure of success. In the more intangible goals of building hydrologic and water-resources institutions, which generally accompany project-oriented activity, progress is often difficult to measure over spans of a few months or even several years. Yet viable scientific and technical institutions, including those directed toward water problems, are vital components of political stability and economic growth in the developing countries or, for that matter, any country that pretends to be current with the 20th century.

The road called progress in technical assistance, unhappily, is a rocky one—that is strewn with cobbles and chuckholes—to name a few, instability of governments, wars, and insurgency. All too often, the patient efforts of years of institution building can be set back indefinitely or even thwarted by unforseen political events. Typical examples of such events that have affected, directly or indirectly, overseas USGS water-resources projects during the past two decades include: the Suez incident of November 1956; the military coup in Iraq in July 1958; the Indo-Pakistani war of August-September 1965; the Arab-Israeli war of June 1967; civil war in Nigeria during 1966–70; more recently, civil war in East Pakistan (now Bangladesh) during 1971; and last but not least the Vietnam conflict. Then again, there are age-old social and cultural constraints such as still exist in the Arab World, Black Africa, South Asia, and the Far East. These constraints place bonds on goals of institution building that are sometimes more negative than short-term political events.

In spite of obstacles and setbacks, the USGS has left a notable and positive record of achievement and has contributed substantially to the stream of economic advancement in many developing countries. Among examples that might be cited are: hydrologic investigations and research for salinity control and reclamation in the Indus Plains of West Pakistan; ground-water appraisal and development of the Nubian aquifer in the Western Desert of Egypt; countrywide ground-water investigations and pilot

development in Chile, Peru, India, and Libya; countrywide surface-water investigations in Turkey, Iran, Brazil, Afghanistan, and Nepal; and regional surface-water and (or) ground-water investigations in Korea, Sudan, Tunisia, the Philippines, and Nigeria.

Projects in all these countries have also been accompanied by modest to intensive efforts in institutional development—with mixed measures of success. Perhaps the highest levels of success, in the writer's subjective judgment, have been achieved in Pakistan, India, Turkey, the Philippines, Chile, Iran, Egypt, and more recently Brazil and Korea. Modest success can perhaps be claimed for efforts in Afghanistan, Sudan, Tunisia, and Nepal. On the other hand the seeds of institutional development which have been sown in Peru, Libya, Nigeria and a number of other countries have yet (1970) to germinate and grow in recognizable form. If there is any lesson to be learned from past experience, it is the importance of continuity in the institution-building process. The USGS has sought to maintain continuity of scientific and informational contact with counterpart organizations in the developing countries, even through the vicissitudes of adverse political events and even after termination of direct technical assistance. Such contacts are maintained through correspondence, exchange of publications, occasional official details, or personal visits.

In the more esoteric realm of scientific hydrology, the USGS has played a lead role since the early 1960's in the gestation, birth, and growth of the International Hydrological Decade, now (1970) in its 6th year under the aegis of UNESCO. This enterprise has involved the coordination of efforts and cooperation in water-oriented research, education, and training among 107 countries and more than a dozen international governmental agencies and nongovernmental scientific organizations. In mid-course as of 1970, the IHD has already stimulated significant advances in hydrologic knowledge, vitally needed to cope with environmental problems of the late 20th century. Moreover, the impact of the IHD program in applying the scientific method to solution of water problems is already evident in many developing countries.

Since 1963, involvement in Southeast Asia has engaged much of U.S. foreign-aid resources. In addition annual Congressional appropriations have declined and in 1970 reached their lowest level since 1948. The compelling need for continuing technical and economic aid in the developing countries still persists, however. Hopefully, with reorganization of the foreign aid program, as recommended by President Nixon's Task Force on Foreign Aid, it may be possible to redirect and revitalize past efforts toward more fruitful goals in the future. Scientific and applied hydrology as well as more basic water-resources investigations and institution building will play a vital and important role in these efforts.

TABLE 6.—*Glossary of place names used in this report with equivalents of the Board on Geographic Names*

Report Name	*Coordinates* Lat	Long	*Board on Geographic Names (BGN)*
Argentina:			
Bahía Blanca area	38°43′	62°17′	Bahía Blanca.
Cañadon El Trebol ----canyon--	45°50′	67°50′	Cañadón de El Trébol.
Catamarca Province	27°00′	67°00′	Provincia de Catamarca.
Comodoro Rivadavia	45°52′	67°30′	Comodoro Rivadavia.
Pampa del Castillo ----plain--	45°58′	68°24′	Pampa del Castillo.
Santa María Valley	26°03′	65°50′	Río Santa María.
Bahama Islands:			
Eleuthra	25°15′	76°30′	Eleuthera Island.
Grand Bahama	26°36′	78°30′	Grand Bahama Island.
Grand Turk	21°27′	71°07′	Grand Turk Island.
Mayaguana	22°18′	72°57′	Mayaguana Island.
San Salvador	24°02′	74°28′	San Salvador Island.
Brazil:			
Açu Valley	2°10′	34°50′	Açu
Araguaia	5°21′	48°41′	Araguaia-
Tocantins	5°21′	55°58′	Tocantins.
Amazon River	0°10′	49°00′	Amazon River.
Alto Araguaia	17°19′	53°12′	Alto Araguaia.
Belo, Horizonte	21°25′	47°56′	Belo Horizonte.
Belém	1°27′	48°29′	Belém.
Irece area	11°18′	41°52′	Irecê.
Manaus	3°08′	60°01′	Manaus.
Minas Gerais	18°00′	44°00′	Estado de Minas Gerais.
Niteroi	22°53′	43°07′	Niterói.
Olinda	8°52′	42°40′	Olinda.
Obidos	1°55′	55°31′	Óbidos.
Pernambuco	8°00′	37°00′	Estado de Pernambuco.

TABLE 6.—*Glossary of place names used in this report with equivalents of the Board on Geographic Names*—Continued

Report Name	*Coordinates* Lat	Long	*Board on Geographic Names (BGN)*
Brazil:—Continued			
Pirapora	17°21′	44°56′	Pirapora.
Recife	8°03′	34°54′	Recife.
Rio Araguaia	5°21′	48°41′	Rio Araguaia.
Rio São Francisco	10°30′	36°24′	Rio São Francisco.
Rio de Janeiro	22°54′	43°14′	Rio de Janeiro.
São Paulo	23°32′	46°37′	São Paulo.
Salvador	12°59′	38°31′	Salvador.
Teresina	5°05′	42°49′	Teresina-
Campo Maior area	4°49′	42°10′	Campo Maior.
Upper Capibaribe Basin	8°03′	34°52′	Capibaribe.
Chile:			
Andes	24°00′	68°00′	Andes Mountains.
Atacama Desert	23°30′	68°30′	Atacama Desert.
Azapa Valley	18°30′	70°30′	Valle de Azapa.
Algarrobal valley	28°05′	70°40′	Quebrada Algarrobal.
Aucó Valley	31°34′	71°07′	Estero Aucó.
Arica Valley	18°30′	70°30′	Arica valley.
Aconcagua Valley	33°00′	70°00′	Río Aconcagua valley.
The Concordia region	18°24′	70°21′	Quebrada de la Concordia.
Calama area	22°30′	68°57′	Calama.
Copiapó valley	27°41′	70°14′	Río Copiapó.
Chillan area	31°33′	72°20′	Chillán area.
Chacabuco valley	33°13′	70°56′	Estero de Chacabuco.
Casablanca valley	33°20′	71°25′	Estero de Casablanca.
Catému valley	32°47′	70°59′	Estero Catemu valley.
Chañaral Alto valley	26°30′	72°00′	Quebrada de Chañaral Alto.
Camarónes valley	19°30′	70°45′	Río Camarones valley.
Chaca valley	18°45′	70°25′	Quebrada de Vitor (Chaca).
Domeyko valley	28°57′	70°56′	Domeyko.
Hijuelas	32°50′	79°50′	Quebrada de Hijuelas de Conchali.
Huachipato	36°36′	73°10′	Hauachipato-
Talcahuano	36°43′	73°05′	Talcahuano.
Lluto valley	18°25′	70°07′	Valle Lluta.
La Ligua valley	32°26′	71°14′	Río de La Ligua.
Los Choros valley	29°10′	71°21′	Quebrada de los Choros.
Lagunillas valley	30°05′	71°15′	Quebrada Lagunillas.
La Serena	29°54′	71°16′	La Serena.
Melón valley	32°47′	71°12′	Estero Melón.
Pampa del Tamarugal	19°45′	69°45′	Pampa del Tamarugal.
Pica Oasis	20°30′	69°45′	Pica oasis.
Paipote valley	27°20′	71°00′	Quebrada de Paipote.
Pocuro valley	32°46′	70°45′	Estero Pocuro.
Putaendo valley	32°44′	70°26′	Río Putaendo.
Petorca valley	32°23′	71°25′	Rio Petorca.
Pangue valley	33°37′	71°19′	Estero de Puangue.
Puntas Arenas region	53°10′	70°50′	Puntas Arenas.
Puchuncaví valley	32°38′	71°25′	Puchuncaví valley.
Quebrada de Tarapacá	20°00′	69°40′	Quebrada de Tarapacá.
Quebrada de Los Choros	29°18′	71°21′	Quebrada de los Choros.
Quilimarí valley	32°05′	71°32′	Río Quilimarí.
Río Loa valley	22°00′	69°32′	Río Loa.
Río Elqui valley	29°55′	71°06′	Río Elqui.
Santiago	33°30′	70°45′	Santiago.
San Pedro de Atacama	22°55′	68°13′	San Pedro de Atacama.
Tana valley	19°30′	70°15′	Quebrada de Tana valley.
Tierra del Fuego	53°30′	69°30′	Tierra del Tuego.
Tongoy area	30°15′	71°30′	Tongoy.
Temúco area	38°33′	72°36′	Temuco.
Valdivia area	39°45′	73°30′	Valdivia.
Yali valley	33°53′	72°23′	Estero Yali.
Costa Rica:			
Las Cañas	10°30′	85°15′	Las Cañas.
Limón	10°00′	83°02′	Limón.
La Libertad			Nv.
Meseta Central Occidental	18°07′	66°30′	Meseta Central.
Nicoya Peninsula	9°30′	85°00′	Península de Nicoya.
Ojo de Agua			Nv. (not verified).
Puntarenas	10°00′	84°50′	Puntarenas.
Potrerillos			Nv.
Puente Mulas			Nv.
Siquirras	10°07′	87°30′	Siquirres.
San José region	9°50′	84°10′	San José.

TABLE 6.—*Glossary of place names used in this report with equivalents of the Board on Geographic Names*—Continued

Report Name	*Coordinates* Lat	Long	*Board on Geographic Names (BGN)*
Cuba:			
Arroyo Blanco			Arroyo Blanco.
Cuzco area	22°44′	81°36′	Cuzco area.
Guatanamo Bay	20°07′	75°07′	Guantanamo Boy.
Guaso River	20°02′	75°09′	Río Guaso.
Nicaro Area	20°40′	75°35′	Nicaro area.
"Pearl of the Antilles"	21°00′	80°00′	Nv. (Sobriquet applied to Cuba)
Río Lerisa	20°41′	75°31′	Río Levisa.
Río Culebra	22°51′	82°15′	
Yateras River	19°58′	74°57′	Río Yateras.
El Salvador:			
San Miguel valley	13°15′	88°15′	Valle del Río Grande de San Miguel.
San Salvador	13°37′	89°12′	San Salvador.
Haiti:			
Arcahaie	18°46′	72°27′	Plaine de l'Arcahaie.
Cul-de-Sac Plain	18°30′	72°20′	Plaine du Cul-de-Sac.
Forêt des Pins	18°19′	71°49′	Forêt des Pins.
Gonaives Plain	19°30′	72°45′	Nv.
Jacmel-Meyer Bench	18°40′	72°30′	Nv.
Moustiques Plain	19°14′	73°05′	Nv.
Plaine du Nord	19°40′	72°10′	Plaine du Nord.
Port-au-Prince	18°30′	72°20′	Port-au-Prince.
Rivière Froide	18°30′	72°30′	Rivière Froide.
Nicaragua:			
Casa Colorado	11°59′	86°19′	Casa Colorada.
Diramba	11°50′	86°17′	Diriamba.
Jinotepe	11°50′	86°17′	Jinotepe.
Lake Nicaragua	11°40′	85°25′	Lago de Nicaragua.
Lake Managua	12°15′	86°15′	Lago de Managua.
Lake Asososca	12°09′	86°20′	Laguna de Asososca.
Lake Tiscapa	12°09′	86°16′	Laguna Tiscapa.
Las Sierras plateau	12°00′	86°30′	Meseta de Los Pueblos.
Managua	12°07′	86°15′	Managua.
Masaya	12°00′	86°15′	Masaya.
Río San Juan	10°56′	83°42′	Río San Juan.
Panama:			
Azuero Peninsula	7°30′	80°30′	Península de Azuero.
Coclé	8°40′	80°30′	Provincia de Coclé.
Herrera Province	7°50′	80°50′	Provincia de Herrera.
Los Santos province	7°30′	80°30′	Provincia de Los Santos.
La Flora	7°57′	80°29′	La Flora.
Las Flores	7°55′	80°34′	Las Flores.
Peru:			
Arequipa	16°24′	71°31′	Arequipa.
Huancayo	12°03′	75°14′	Huancayo.
Ilo	12°03′	75°14′	Nv.
Lambayeque Valley	6°45′	79°45′	Río Lambayeque.
La Granja San Jorge	12°03′	75°14′	Nv.
Moquegua valley	17°10′	71°10′	Río Moquegua.
Majes valley	16°35′	72°48′	Río de Majes.
Matarani	16°57′	72°07′	Matarani.
Mollendo	17°00′	72°02′	Mollendo.
Pampa de La Joya	16°41′	71°55′	Pampa de La Joya.
Pampa de Sihaus	16°22′	72°05′	Pampas de Sihuas.
Pampa de Ñoco	13°22′	76°08′	Pampa de Ñoco.
Puno	15°45′	70°07′	Puno.
Río Rimac	12°03′	77°09′	Río Rimac.
Sama valley	18°10′	70°44′	Río Sama.
Tumbes	3°33′	80°28′	Tumbes.
Tacna valley	16°02′	70°15′	Tacna valley.
Tambo valley	17°00′	71°25′	Rio Tambo valley.
Tacna	18°02′	70°15′	Tacna.
Belgium:			
Brussels	50°21′	4°23′	Brussels.
Mol	51°10′	5°08′	Mol.
Netherlands:			
Leiden	52°10′	4°30′	Leiden.
Utrecht	52°05′	5°06′	Utrecht.
Portugal:			
Lisbon	38°45′	9°08′	Lisbon.
Terceira Island	38°30′	127°20′	Ilha Terceira.
Chad:			
Fort Lamy	12°07′	15°03′	Fort-Lamy.
Lake Chad	13°20′	14°00′	Lake Chad.
Logone River	12°06′	15°02′	Logone river.

TABLE 6.—*Glossary of place names used in this report with equivalents of the Board on Geographic Names*—Continued

Report Name	*Coordinates* Lat	Long	*Board on Geographic Names (BGN)*
Congo:			
Batéké Plateau	2°00′	17°00′	Nv.
Congo River basin	6°00′	12°05′	Congo River.
Kinshasa	4°18′	15°18′	Kinshasa (Léopoldville).
Kimpese	5°33′	14°26′	Kimpese.
Kasai Oriental Province	6°00′	25°00′	Province du Kasai—Oriental.
M'buji Mayi area	6°00′	24°00′	Mbaji Mayi.
Egypt:			
Bahariya Oasis	28°15′	28°57′	Al Wāhāt al Bahīyah.
Cairo	30°03′	31°15′	Al Qāhirah (Cairo).
Dakla Oasis	25°30′	29°10′	Wāhāt ad Dākhilah.
Damietta	31°25′	31°48′	Dumyāt (Damietta).
Fuka	30°04′	27°55′	Fūkah.
Farafra Oasis	27°15′	28°10′	Al Wāhāt al Farāriah.
Kharga Oasis	25°20′	30°35′	Al Wāhāt al Khārijah.
Mersa Metruh	31°20′	27°05′	Matrūh (Mersa Metruh).
Nile	30°10′	31°06′	Nile River.
Nile Valley	31°00′	28°00′	Nv.
Nile Delta	39°00′	21°00′	Nile Delta.
Rosetta	31°24′	30°25′	Rashīd (Rosetta).
Ras el Hekma	31°08′	27°50′	Ra's al Hikmah.
Sinai Peninsula	29°30′	34°00′	Sinai Peninsula.
Wadi el Arish	31°09′	33°49′	Wādī al Ārīsh-
Rafah	31°17′	34°14′	Rafah.
Wadi el Araba	39°07′	32°29′	Wādī Arabah.
Wadi Laquita			
Wadi Nagamish			
Zifta	30°47′	27°05′	Ziftá.
Ethiopia:			
Addis Ababa	9°02′	38°42′	Addis Ababa.
Aysha	10°45′	42°37′	Ayshā.
Arero area	4°33′	38°50′	Arēro.
Ajjy	7°17′	38°22′	Nv.
Assele	7°57′	39°05′	Asalā.
Awash	11°35′	41°40′	Awash.
Asmara	15°15′	38°57′	Āsmara.
Alledeighy Plain	9°32′	41°30′	Nv.
Baro	8°26′	33°16′	Baro Wenz (Baro).
Blue Nile River Basin	10°00′	38°00′	Blue Nile (Abbai).
Chercher Awraja	9°08′	41°12′	Ch'erch'er.
Dire Dawa	9°35′	31°52′	Dirēdawā.
Debra Zeit	11°48′	38°37′	Dabrazabit.
Erer	9°32′	41°30′	Yarar (Erer)-
Gota	9°32′	41°20′	Gota.
Gondar	12°34′	37°06′	Gonder.
Gimma	7°40′	36°50′	Jimä.
Harar	9°19′	42°09′	Hārer.
Jijjija	9°18′	42°46′	Jijiga.
Keter			Nv.
Mega	4°03′	38°16′	Mēga.
Mekele	13°30′	39°30′	Mak'alē.
Nekemti	9°05′	36°33′	Nak'amet.
Omo	4°32′	36°04′	Omo Bottego.
Qoshe	8°00′	38°30′?	
Robi	7°51′	39°38′	Robì-
Salole	4°31′	39°34′	Salole.
Sidamo Province	5°48′	38°50′	Sidāmo.
Tora	7°58′	38°30′?	Nv.
Tekessie	14°20′	35°50′	Tekeze.
Wabi Shebelli	8°50′	40°40′	Wābi Shabalē.
Yabelo	4°55′	38°05′	Yabēlo (Iavello).
Ghana:			
Akosombo dam	6°16′	0°03′	Akosombo Dam.
Accra	5°33′	0°13′	Accra.
Akwapim	7°	0°	Akwapim-
Togo Hills.			Togo Ranges.
Volta River	5°46′	0°40′	Volta.
Kenya:			
Garissa Dist	0°30′	40°15′	Garissa District.
Lake Chala	3°19′	37°42′	Lake Chala.
Mandera Dist	3°30′	40°45′	Mandera District.
Mado Gash—Kalalut area	0°34′	39°10′	Mado Gashi.
Nairobi	1°17′	3°49′	Nairobi.
North-Eastern Province	1°00′	40°15′	North-Eastern
Taveta area	3°30′	37°42′	Taveta.
Wajir	1°45′	40°15′	Wajir District.

TABLE 6.—*Glossary of place names used in this report with equivalents of the Board on Geographic Names*—Continued

Report Name	*Coordinates* Lat	Long	*Board on Geographic Names (BGN)*
Libya:			
Al Marj (Barce)	32°30′	20°54′	Al Marj (Barce).
Al Mayah	32°47′	12°54′	Al Māyah.
Az Zawiyah	32°45′	12°43′	Az Zāwiyah.
Benghazi	32°07′	20°03′	Banghāzī (Benghazi).
Cyrennaica	31°00′	22°30′	Cyrenaica.
Derna	32°46′	22°39′	Darnah (Derna).
Fezzan region	26°00′	14°00′	Fezzan.
Gefara	32°30′	11°45′	Al Jifarah.
Ghat	24°58′	10°11′	Ghāt.
Hun-	27°07′	15°06′	Hūn-
Waddan	29°10′	16°08′	Waddān.
Jebel Nefusa	31°50′	12°00′	Jabal Nafūsah.
Jabal al Akhdar	32°30′	21°30′	Al Jahal al Akhdar.
Kufra Basin	24°20′	23°15′	Al Kufrah.
Leptis Magna	32°28′	14°18′	Leptis Magna.
Murzuk basin	26°10′	12°45′	Hammādat Marzūq.
Qarahbulli	32°45′	20°54′	Qasr al Qarābūllī.
Sirte area	31°12′	16°35′	Surt (Sirte).
Surman	32°45′	12°54′	Surmān.
Sabba	27°03′	14°26′	Sabba-
Semnu	27°17′	14°53′	Samnū.
Sahara	26°00′	13°00′	Sahara.
Tripolitania	31°00′	15°00′	Tripolitania.
Tripoli	32°54′	13°11′	Tripoli.
Tobruk	32°05′	23°59′	Tobruk.
Wadi ash Shati	27°30′	13°15′	Wādī ash Shati.
Morocco:			
El Jadida	33°15′	9°50′	El Jadida.
Fes Plain	34°30′	5°30′	Plaine du Saïs(?).
Haut Atlas	29°30′	6°00′	Haut Attas.
Meknes	33°52′	5°36′	Meknès.
Moyen Atlas	33°00′	5°36′	Moyen Atlas.
Oued Draa	28°28′	10°10′	Oued Draa.
Oued Sebou	32°20′	6°45′	Oued Sebou.
Rabat	33°48′	13°00′	Rabat.
Safi	32°15′	9°15′	Safi.
Nigeria:			
Anambra Basin	6°11′	6°46′	River Anambra (Basin).
Benue Province	8°00′	9°00′	Benue-Plateau State.
Bornu Emirate	12°00′	13°00′	North-Eastern State.
Bornu Ranch	11°35′	13°17′	Nv.
Beni Sheik	11°48′	12°29′	Benisheikh.
Birnin Kebbi	12°28′	4°12′	Birnin Kebbi.
Bauchi	10°19′	9°50′	Bauchi.
Chad Basin	13°00′	14°00′	Chad (Basin).
Cross River Basin	4°33′	8°23′	Cross River.
Dikwa Emirate	11°30′	14°00′	North-Eastern State.
Damakuli	12°26′	13°23′	Damakuli.
El Beid River	12°32′	14°12′	Ebeju (El Beid).
Eastern Region	6°00′	7°30′	East-Central State.
Hunkuyi	11°16′	7°39′	Hunkuyi.
Ibadan	7°23′	3°54′	Ibadan.
Kurdula	13°35′	14°12′	Kurdula.
Kaduna	10°31′	7°26′	Kaduna.
Kerri-Kerri	11°00′	11°00′	Nv.
Kaduna—	10°31′	7°26′	Kaduna.
Zaria area	11°04′	7°42′	Zaria.
Kano	12°00′	8°31′	Kano.
Lagos	6°27′	3°23′	Lagos.
Lake Chad	13°20′	14°00′	Lake Chad.
Lafia	8°29′	8°31′	Lafia.
Manchok	9°30′	8°31′	Manchok.
Maiduguri	11°51′	13°09′	Maiduguri.
Mongonu	12°31′	13°36′	Mòngunu.
Northern Region	11°00′	8°00′	North-Western State. North-Eastern State. North-Central State.
Niger River Basin	4°30′	6°00′	Niger River.
Ngala	12°20′	14°11′	Ngala.
Sokoto River	11°24′	4°07′	Sokoto.
Western Region	7°30′	4°00′	Western State.
Wulgo	12°29′	14°11′	Wulgo Momaduru (Wulgo).
Yobe River system	13°42′	13°20′	Komadugu Yobe.
Zaria Province	10°20′	7°40′	Zaria Province.

TABLE 6.—*Glossary of place names used in this report with equivalents of the Board on Geographic Names*—Continued

Report Name	*Coordinates* Lat	Long	*Board on Geographic Names (BGN)*
Rhodesia:			
Gwaai region	19°45′	27°30′	Gwaai Purchase Land.
Kalahari sands	24°00′	22°00′	Kalahari Desert.
Salisbury	17°50′	31°03′	Salisbury.
Sabi River Valley	21°05′	35°02′	Sabi River.
Sebungwe	17°45′	28°30′	Sebungwe Tribal Trust Land.
Senegal:			
Dakar	14°42′	17°30′	Dakar.
Senegal River basin	16°00′	15°00′	Sénégal River.
Sudan:			
Darfur Province	13°00′	25°00′	Darfur Province.
Equitorial Province	5°00′	31°00′	Al Mudīrīyah al Istiwā īyah.
En Nahud	12°48′	28°26′	An Nahūad (En Nahud).
Gash River delta	16°48′	35°51′	Nahr al Qāsh (Gash River).
Jebal Kassala	15°25′	36°26′	Jabal Kassalā.
Juba	4°51′	31°37′	Jūbā.
Khartoum	15°36′	32°32′	Al Khurtūm (Khartoum).
Kordofan Province	13°00′	30°00′	Mudīrīyat Kurdufān.
Kassala Province	18°00′	36°00′	Mudīrīyat Kassalā.
Kassala	15°28′	36°24′	Kassalā.
Khuwei	13°05′	29°14′	Khuwayy (Khuwei).
Port Sudan	19°37′	37°14′	Būr Sūdān (Port Sudan).
Red Sea Hills	23°00′	35°00′	Red Sea Hills.
Suakin	19°07′	37°20′	Sawākin (Suakin).
Tunisia:			
Bled Sisseb area	36°00′	10°04′	Bilād Sīsab.
Djerba Island	33°48′	10°54′	Jazīrat Jarbah.
Kairouan	35°41′	10°07′	Al Qavrawān (Kairouan).
Medjerda Valley	37°07′	10°13′	Wadi Majardah.
Oued Nebana	35°57′	10°03′	Wādī Nabhānah.
Oued Meliz	36°29′	8° 3′	Wādī Malīz.
Sahel de Sfax region	34°45′	10°45′	Sāhil Safaqis (Sahel de Sfax).
Sahel de Sousse region	35°45′	10°35′	Sāhil Sūsah.
Teboulbah	35°39′	10°58′	Tabulbah.
Tunis	36°48′	10°11′	Tūnis.
Zarzis peninsula	33°30′	11°07′	Jarjīs peninsula (Zarzis).
Zambia:			
Lusaka	15°25′	28°17′	Lusaka.
Afghanistan:			
Arghandab Reservoir	31°53′	65°55′	Band-e Arghandāb.
Hari Rud	37°24′	60°38′	Harīrūd.
Helmand River Basin	31°12′	61°34′	Daryē-ye Helmand.
Kabul	34°31′	69°12′	Kābul.
Kajakai Reservoir	30°19′	65°09′	Band-e Kajakaī.
Kabal River	33°55′	72°14′	Daryā-ye Kabul (Kābul River).
Lashkar Gah	31°25′	64°21′	Lashkar Gāh.
Tangi Garu Gorge	34°34′	69°30′	Tang-e Ghāru (Tangi Garu Gorge).
Cambodia:			
Battambang Province	13°06′	103°12′	Khêt Bătdâmbâng.
Grand Lac	13°00′	104°00′	Tonle Sap (Grande Lac).
Kampot Province	10°45′	104°15′	Khêt Kâmpôt.
Kompong Cham Province	12°09′	105°06′	Khêt Kâmpóng Cham.
Kompong Speu Province	11°30′	104°30′	Khêt Kâmpóng Spoe.
Phnom Penh	11°33′	104°55′	Phnom Pénh.
Prek Thnot	11°29′	104°57′	Prêk Tnaôt (Prek Thnot).
India:			
Assam	26°00′	93°00′	State of Assam.
Azamgarh	26°04′	83°11′	Azamgarh.
Ballia	25°45′	84°10′	Ballia.
Baguati	25°46′	85°59′	Bāghmati Nadī.
Bihar	25°00′	86°00′	State of Bihār.
Bengal	24°00′	90°00′	State of West Bengal.
Bhawi	26°13′	73°36′	Bhawi.
Barakhshetra	26°52′	87°13′	Barahakshetra.
Chisapani	26°56′	86°08′	Chisapani.
Calcutta	22°32′	88°22′	Calcutta.
Coimbatore	11°00′	26°58′	Coimbatore.
Ganges River	23°20′	90°30′	Ganges River.
Gujarat	23°00′	72°00′	State of Gujarat.
Gandak	25°39′	85°13′	Gandak River.
Ganges Plain	26°00′	84°00′	Gangetic Plain.
Gulf of Kutch	22°36′	69°30′	Gulf of Kutch.
Hanumannagar	29°35′	74°19′	Hanumangarh.
Hoshiapur area	31°32′	75°54′	Hoshiāpur.
Jamtara	23°57′	86°48′	Jamtara.

TABLE 6.—*Glossary of place names used in this report with equivalents of the Board on Geographic Names*—Continued

Report Name	*Coordinates* Lat	Long	*Board on Geographic Names (BGN)*
India:—Continued			
Jabalpur	21°10′	79°57′	Jubbulpore (Jabalpur).
Kandla Port	23°02′	70°14′	Kandla (Kandla Port).
Kerala	10°00′	77°00′	State of Kerala.
Kutch (now Gujrat)	23°30′	30°00′	State of Gujrat (formerly Kutch).
Kamla	25°37′	86°40′	Kamla Nadī.
Kosi	25°46′	86°26′	Kosi River.
Madras	14°00′	80°00′	State of Tamil Nādu.
Madhya Pradesh	23°00′	80°00′	State of Madhya Pradesh.
Meerut	28°59′	77°42′	Meerut.
Malabar coastal region	10°00′	76°15′	Malabar Coast.
Maharashtra	20°00′	75°00′	State of Mahārāshtra.
Mysore	13°30′	76°45′	State of Mysore.
New Delhi	28°36′	77°12′	New Delhi.
Narmada River	21°38′	72°36′	Narmadā River.
Narmada Valley	21°38′	72°36′	Narmadā River valley.
Neyvel area	11°32′	79°29′	Neyveli.
Punjab (Haryana)	31°11′	77°46′	Punjab (Haryana).
Purna Valley	25°05′	76°00′	Pūrna River.
Pali region	25°46′	73°20′	Pāli.
East Punjab	31°11′	77°46′	East Punjab States Union.
Patiala	30°00′	76°00′	Patiala and
East Punjab States Union	30°00′	76°00′	East Punjab States Union.
Rajasthan	27°00′	74°00′	United States of Rājasthān.
Saurasthra	22°00′	71°00′	State of Gujarat.
Sushiya			Nv.
Cochin (Kerala)	10°25′	76°30′	State of Kerala.
Tapti Valley	21°06′	72°41′	Tāpti valley.
Uttar Pradesh	28°00′	80°00′	State of Uttar Pradesh.
Iran:			
Ahwaz	31°20′	48°45′	Ahvāz.
Abadan	31°15′	38°15′	Abādān.
Bandar Abbas coastal region	27°10′	56°20′	Bandar Abbàs.
Central Iranian Plateau	31°00′	56°00′	Nv.
Caspian Sea	39°00′	81°00′	Caspian Sea.
Ghaz			Nv.
Gulf of Oman	24°00′	60°00′	Gulf of Oman.
Issen Valley	27°10′	57°20′	Nv.
Isfahan	32°45′	51°34′	Esfahān.
Karaj	35°45′	51°22′	Nv.
Shariar Plains	35°37′	51°00′	Nv.
Kermanshah	34°15′	47°05′	Kermanshah.
Meshed	36°15′	59°31′	Mashhad.
Minab River	27°10′	56°20′	Rūdkhāneh-ye Mīnāb.
Shiraz	29°36′	52°37′	Shīrāz.
Strait of Homuz	26°34′	56°15′	Strait of Homuz.
Tabriz	37°58′	46°25′	Tabrīz.
Teheran	36°00′	52°00′	Tehrān.
Takht Valley	27°30′	56°45′	Takht valley.
Varamin Plain	35°20′	51°20′	Nv.
Zagros Mountains	39°00′	47°30′	Zagros Mountains.
Iraq:			
Amara	31°00′	49°09′	Al Amarah-
Mandali	33°45′	45°32′	Mandali.
Euphrates	30°00′	48°30′	Euphrates River.
Jezira	35°10′	42°00′	Al Jazīrah.
Shari Lake	34°23′	34°07′	Buhayrat Shārī.
Tigris River	31°00′	47°30′	Tigris River.
Japan:			
Honshu Island	38°00′	140°00′	Honshu.
Nagoya	35°16′	137°00′	Nagoya.
Osaka	34°44′	135°30′	Ósaka.
Tokyo	35°45′	139°45′	Tokyo.
Jordan:			
Amman	31°55′	36°02′	Amman.
Dead Sea Basin	31°30′	35°45′	Dead Sea (Basin).
Jordan River	31°45′	35°31′	Jordan River.
Jordan Valley	32°30′	35°45′	Emeq Hayarden.
Jericho	31°55′	35°28′	Jericho.
Maqarin	32°43′	35°53′	Maqārin.
South Shuneh area	31°54′	35°37′	Qadā ash Shūnah al Janūbīyah.
Wadi Qilt	31°31′	36°28′	Wadi al Qilāt.
Yarmauk River	32°45′	35°35′	Nahr al Yarmūk.

TABLE 6.—*Glossary of place names used in this report with equivalents of the Board on Geographic Names*—Continued

Report Name	*Coordinates* Lat	Long	*Board on Geographic Names (BGN)*
Korea:			
Chongpyong Dam	36°40′	127°30′	Nv.
Chuncnon Dam	37°58′	127°00′	Nv.
Cheju	32°25′	126°30′	Chuju-do.
Han River Basin	38°31′	126°58′	Han-gang basin (Han River).
Hwachon Dam	38°06′	127°45′	Nv.
Koesan Dam	36°43′	127°51′	Nv.
Manchuria (China)	47°00′	125°00′	Manchuria.
North Han River	37°30′	127°00′	Pukhan-gang. (North Han River).
Ujam Dam	37°50′	127°42′	Nv.
Kuwait:			
Al Quashaniya	29°29′	47°45′	Al Qash 'ānīyah.
Mutla	29°24′	47°42′	Al Matla'.
Persian Gulf	28°00′	50°00′	Persian Gulf.
Raudhatain	29°55′	47°37′	Ar Rawdatayn.
Shatt-al-Arab	29°30′	38°30′	Shatt al Arab.
Shuaiba	20°42′	39°26′	Shu 'aybak.
Shuwaikh	29°22′	47°26′	Ash Shuwaykh.
Umm al-Aish	29°37′	47°45′	Khabrat Umm al Aysh (Umm al Aish).
Laos:			
Pa Mong Dam	18°02′	102°22′	Pa Mong Dam.
Vientiane	18°00′	102°30′	Vientiane.
Nepal:			
Bhairawa	27°30′	83°27′	Bhairhwa.
Chadorge Khola			Nv.
Chadorge	27°51′	86°46′	Tsadorge.
Chisapani	26°56′	86°08′	Chisāpani.
Karnali River	28°45′	81°16′	Karnāli River.
Kathmandu	27°43.	85°19′	Kathmandu.
Mount Everest	27°59′	86°56′	Mount Everest.
Sapt Kosi River	26°31′	86°58′	Sapt Kosi River.
Terai belt	28°30′	81°10′	Tarāi region.
Western Terai	28°30′	81°10′	Tarāi region.
Pakistan:			
Bari Doab interfluve	30°25′	73°00′	Bāri Doāb.
Bahawalpur District	28°50′	71°40′	Bahāwalpur District.
Bannu District	32°45′	70°45′	Bannu Dist.
Bhimbar Nallah	32°38′	74°03′	Bramaputra River.
Barind	25°00′	88°40′	Bārind.
Bramaputra River	24°02′	90°59′	Brampaputra River.
Chaj Doab interfluve	32°15′	73°00′	Chaj Doāb.
Dera Ismail Khan District	32°00′	20°30′	Dera Ismāīl Khān Dist.
Dera Ghazi Khan District	29°50′	70°15′	Dera Ghāzi Khān Dist.
Dacca (East Pakistan)	23°33′	90°25′	Dacca.
Dinajapur	25°38′	88°38′	DināJpur.
Ganges River	23°22′	90°32′	Ganges River.
Guliana	32°48′	73°58′	Guliāna.
Hazara District	35°00′	73°20′	Hazāra District.
Himalaya	28°00′	84°00′	Himalayas.
Indus River	24°20′	67°45′	Indus River.
Kohat District	33°20′	71°10′	Kohāt District.
Khairpur	27°06′	27°42′	Khairpur.
Lahore	31°35′	74°18′	Lahore.
Pachagarh-	26°20′	88°34′	Pachāgarh-
Titalya	26°30′	88°21′	Titālya.
Punjab	30°00′	74°00′	Punjab.
Rechna Doab	31°35′	73°30′	Rechna Doāb.
Rawalpindi	33°36′	73°04′	Rāwalpindi.
Saidu	34°45′	72°21′	Saidu.
Sangla Hill	31°43′	73°21′	Sāngla (Sangla Hill).
Sheikhupura	31°42′	73°59′	Shekhūpura.
Swat River Valley	34°20′	71°34′	Swat River valley.
Thal Doab	33°00′	72°00′	Thal Doāb.
Philippine Islands:			
Angat River	14°53′	120°46′	Angat River.
Atate River			Nv.
Bicol Region	13°24′	123°19′	Bicol River region.
Central Plain	16°00′	158°00′	Central Luzon Valley.
Cavite Peninsula	14°30′	120°54′	Cavite Peninsula.
Luzon Island	16°00′	121°00′	Luzon island.
Manila Bay	14°30′	120°45′	Manila Bay.
Manila	14°32′	121°00′	City of Manila.
Palawan	10°30′	119°45′	Palawan.
Poro Point	16°37′	120°18′	San Fernando Point (Poro Point).

TABLE 6.—*Glossary of place names used in this report with equivalents of the Board on Geographic Names*—Continued

Report Name	*Coordinates* Lat	Long	*Board on Geographic Names (BGN)*
Philippine Islands:—Continued			
Passiq River	14°35′	121°00′	Pasig River.
Pampanga River	14°47′	120°39′	Pampanga River.
Sangley Point Naval Station	14°28′	127°54′	Sangley Point (Naval Station).
San Miguel Naval Communication Station	13°50′	123°10′	San Miguel Bay (Naval Communication Station).
Subic Bay	14°40′	120°12′	Subic Bay.
Saudi Arabia:			
Al Hasa oasis	25°20′	49°30′	Al Hasa Oasis.
Arabian Peninsula	20°00′	46°00′	
Al Kharj District	24°09′	47°30′	
Eastern Province	26°30′	49°30′	Al Mintaqah ash Skarqīyah.
The Great Nafud area	28°45′	41°00′	An Nafūd.
Harad oasis	24°14′	49°11′	Harad.
Jiddah	21°28′	39°12′	Juddah (Jiddah).
Jawf-	29°50′	39°52′	Al Jawf.
Sakakah	29°59′	40°12′	Sakākah.
Mecca	21°25′	39°49′	Mecca.
Medina	24°27′	39°37′	Medina.
Nejd region	24°09′	47°30′	Najd.
Persian Gulf	27°00′	52°00′	
Qatif oasis	26°36′	49°58′	Al Qatīf.
Qassim area	26°10′	44°00′	Al Qasīm.
Red Sea Coast	40°00′	20°00′	Red Sea.
Red Sea	22°00′	38°00′	Red Sea.
Riyadh	24°37′	46°43′	Riyadh.
Taif	21°46′	40°25′	At Tā'if.
Tabouk	28°22′	36°35′	Tabuk.
Wadi Sirhan	31°33′	37°10′	Wādī as Sirhān.
Thailand:			
Bangkok	13°45′	100°31′	Krung Thep (Bangkok).
Central Valley (Chao Phrya basin)	13°32′	100°36′	Nv. Mae Nam Chao Phraya.
Chee River	15°30′	104°45′	Mae Nam Chi.
Chaiyaphum	15°48′	102°02′	Chaiyaphum.
Mun River	15°19′	105°30′	Mae Nam Mun.
Khorat	14°58′	102°07′	Nakhon Ratchasima (Khorat).
Khorat Plateau	15°30′	102°50′	Khorat Plateau.
Nong Tuloom	14°55′	102°04′	
Turkey:			
Ankara	39°56′	32°52′	Ankara.
Anatolia region	39°00′	35°00′	Anatolia.
Adana-	37°00′	35°18′	Adana-
Iskenderun	36°57′	36°07′	Iskenderun.
Bolu	40°44′	31°37′	Bolu.
Beyaz Koy area	41°21′	26°42′	Beyazköy.
Bafra	41°15′	35°30′	Bafra.
Black Sea coast	43°00′	35°00′	Black Sea coast.
Chabuk-	40°15′	33°02′	Çubak (Chabuk).
Esenboga	40°08′	33°00′	Esenboga.
Develi-	38°24′	35°30′	Devli-
Yesilhisar Plain	38°22′	35°05′	Yesilhisan.
Euphrates River	30°00′	48°30′	Euphrates River.
Elazig-	38°40′	39°14′	Elazig.
Ulova	39°30′	39°30′	Nv.
Istanbul	41°01′	28°58′	Istanbul.
Iqdir	39°56′	44°02′	Igdir.
Kayseri	38°43′	35°30′	Kayseri.
Konya plain	37°50′	32°50′	Konya.
Karapinar	37°43′	33°33′	Karapinar.
Konya	37°52′	32°31′	Konya.
Alaskova	37°45′	32°29′	Alakova.
Luleburgaz	41°24′	27°21′	Lüleburgaz.
Merzafon-	40°52′	35°29′	Merzifon.
Gumush	40°52′	35°13′	Gümüshaciköy.
Malatya	38°21′	38°19′	Malatya.
Mediterranean coastal plain	37°00′	36°15′	
Meric-	40°52′	26°12′	Maritsa River (Meric).
Ergene	41°01′	26°22′	Ergene Nehri (Ergene).
Samsun	41°17′	36°20′	Samsun.
Saraykoy plain	41°00′	40°24′	Saraköy.
Thrace region	41°00′	27°00′	Thrace.
Vietnam:			
An Khe	16°00′	107°00′	An Túc (An Khe).
Bien Hoa	10°57′	106°49′	Biên Hoa.

TABLE 6.—*Glossary of place names used in this report with equivalents of the Board on Geographic Names*—Continued

Report Name	*Coordinates* Lat	Long	*Board on Geographic Names (BGN)*
Binh Dinh Province	14°10′	108°50′	Tinh Bình Dinh.
Ba Xuyen Province	9°20′	105°45′	Tinh Ba Xuyên.
Cam Ranh Peninsula	10°52′	109°16′	Mui Cam Linh (Cam Ranh Peninsula).
Cam Ranh Bay	11°54′	109°11′	Nv.
Danang	16°04′	108°13′	Dà Năng.
Gia Dinh Province	10°50′	106°50′	Tinh Gia Dinh.
Kien Tuong Province	10°40′	105°55′	Tinh *Kiên Tuong.*
Mekong Delta	10°00′	106°00′	Mekong Delta.
Mekong River Delta	10°00′	106°00′	Mekong Delta.
Nha Trang	12°15′	102°11′	Nha Trang.
Phu Yen Province	13°10′	109°00′	Tinh *Plú Yên.*
Pleiku	13°58′	108°01′	Pleiku.
Phan Rang	11°34′	108°59′	Phan Rang.
Phu Cat	14°01′	109°03′	Phù Cát.
Qui Nhon	13°46′	109°14′	Qui Nohn.
Quang Nam Province	15°40′	108°00′	Tinh *Quang Nam.*
Quang Tin Province	15°30′	108°15′	Tinh *Qunag Tin.*
Quang Ngai Province	15°00′	108°40′	Tinh *Quang Ngãi.*
Saigon	10°45′	106°40′	Saigon.
Vung Tau	10°21′	107°04′	Vung Tàu.
Australia:			
Adelaide	34°54′	138°40′	Adelaide.
Armidale	30°30′	151°42′	Armidale.
Brisbane	27°30′	153°06′	Brisbane.
Bundaberg	24°54′	152°24′	Bundaberg.
Canberra	35°18′	149°00′	Canberra.
New South Wales	32°00′	147°00′	State of New South Wales.
Northwest Cape	21°48′	114°06′	North West Cape.
Queensland	22°00′	145°00′	State of Queensland.
Western Australia	25°00′	120°00′	State of Western Australia.

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