A History of the Water Resources Division, U.S. Geological Survey: Volume V, July 1, 1947 to April 30, 1957

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A History of the Water Resources Division, U.S. Geological Survey: Volume V, July 1, 1947, to April 30, 1957

By George E. Ferguson and others

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MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
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Carl G. Paulsen 1887–1961
Chief Hydraulic Engineer 1946–1957
Volume V: ''The Paulsen Years''

FOREWORD

This volume is the fifth in a series of chronological summaries of the activities and achievements of the Water Resources Division of the U.S. Geological Survey, but it is the first to be published as a public document. As explained in the Preface which follows, the first volume was published in 1939 through private subscription by interested personnel. The manuscripts for the following three volumes were reproduced by the Division for internal use only in the 1950's.

Volume V is largely a product of volunteer effort on the part of Division retirees, not only by the primary author but by the more than 200 individuals who provided information for, drafted, or reviewed summaries of district, regional, and nationwide activities. Their contributions are acknowledged in appropriate places in the text. The magnitude of this volunteer effort is unique to the Division and perhaps to the Geological Survey.

Volume VI, already under preparation, will add an additional decade of Division history. The publication for public use of the first four volumes also remains one of the Division's goals.

Philip Cohen
Chief Hydrologist

PREFACE

This is the fifth in a series of volumes that record the history of the Water Resources Division of the U.S. Geological Survey. The first four volumes were prepared by Robert Follansbee (1879–1952), district engineer for Montana (1906–8), for the Upper Mississippi District (1909–11), and for Colorado-Wyoming (1912–48).

Volume I covers the activities of the U.S. Geological Survey and predecessor groups in water-resources investigations from 1866 through June 30, 1919. Completed in 1938, it was privately printed by a large number of interested colleagues of the author and distributed in 1939 (memorandum dated August 24, 1954, from the CHE to District supervisors and staff officials). Volume II, which extends the coverage to June 30, 1928, was completed about 1939. Volume III, which covers the time from July 1, 1928, to June 30, 1939, shows an apparent completion date of 1944. Follansbee, who continued to reside in Denver, finished Volume IV after his retirement in June 1949 (Foreword, v. II). It covers July 1, 1939, to June 30, 1947. He forwarded the completed manuscripts for Volumes II, III, and IV to the Washington, D.C., office in late 1949. Follansbee died in 1952 at age 73. His memoir, prepared by his successor, F.M. Bell, is published in *WRD Retirees* newsletter no. 13.

The then Division Chief, by memorandum dated August 24, 1954, distributed copies of the manuscript for Volume II to District supervisors and others. That memorandum also indicated that a similar distribution of manuscript copies of Volumes III and IV would be made "later in the year." The recipients were advised that the manuscripts "were approved by the Director for internal use." The memorandum further stated that "each man receiving a volume is urged to review the parts of the history describing persons and events with which he is familiar and to note in the volume such revisions, corrections, and additions that are appropriate. At some future time, all revisions will be requested and then integrated into the final edition of the History." As of 1989, this had not been done; however, the manuscript copies have been used extensively through the years in meeting the needs of the Division.

Each of these earlier volumes bears the title "A History of the Water Resources Branch of the United States Geological Survey." As explained later, the term "Water Resources Branch" was revised to "Water Resources Division" on January 1, 1949, by Survey Order No. 173, which specified that the term "branch" would henceforth denote an organizational level subordinate to all divisions. The term "Water Resources Division" is used throughout this fifth volume, even when referring to the earlier years.

This fifth volume of the history of the Water Resources Division begins on July 1, 1947, the day following the terminal date of Volume IV, and continues through April 30, 1957, the retirement date of Carl G. Paulsen, who was Division Chief for all of that period. The cutoff date, 3 months prior to the end of the fiscal year (ending June 30), was chosen because of the considerable number of changes in organization and management patterns the new Division administration made during that 3-month period. These changes can be recorded and put into perspective more effectively in a subsequent segment of the history. The period covered by Volume V is referred to as "the decade" numerous times in the text.

Volume V provides much greater coverage of the national program and organization of the Division than preceding volumes, which were essentially accounts of activities of the District offices. This shift in emphasis was not an arbitrary one by the author, but rather reflects the Division's response to a public awareness during and after World War II that water problems and water supply had become national problems. The impact of the nationwide water consciousness on the Division's organization and program is covered in greater detail later.

The field activities of the Division are presented here in a different pattern from earlier volumes in that the programs, organization, personnel, and other local activities of each branch are described as such, but are arranged under the State as the primary heading. This is because of the emergence and growth of the District-level Water Resources Division Council as a local programming and coordinative entity during this period. The new arrangement also is more meaningful to readers because the earlier branch-directed programs at State level have been integrated since the mid-1960's into a single program administered by the Division.

The availability of historical information for the present volume is obviously not comparable to that available to Follansbee in the preparation of Volumes II, III, and IV. More than 40 years have passed since the beginning of the 1947–57 decade. In the meantime, the Division has discarded much material, particularly when preparing to move the National Headquarters from Washington, D.C., to Reston, Va., during 1973–74. Moreover, the use of the long-distance telephone in the transaction of Division business between the Washington office and the District offices grew rapidly during the decade, a practice that does not normally provide the written documentation of events and decisions which was formerly available when such communications were carried on by memorandums.

Through an announcement in the *WRD Retirees* newsletter dated November 1981, Division personnel active during the decade were invited to send in summaries of noteworthy achievements. The more than 100 responses were carefully considered.

Acronyms and other abbreviations were used throughout the volume as a means of space conservation and readability. Most follow the full name of the agency, program, or publication series that appears earlier on the page or within the immediate subject. Some acronyms are used so frequently throughout the text, however, that a general identification is desirable. Most relate to organizational entities: "USDI" and "the Department" refer to the U.S. Department of Interior; "USGS," "GS," and "the Survey" to the U.S. Geological Survey; "WRD" to the Water Resources Division; "SW," "GW," "QW," and "TC" to Surface Water, Ground Water, Quality of Water, and Technical Coordination branches in that order. References to USGS publications or issuances are condensed to "WSP" (Water-Supply Papers), "PP" (Professional Papers), and "Circ." (Circulars). The term "CBR" denotes the collection of basic records. "Chief Hydraulic Engineer," the title of the chief of the Water Resources Division during the decade (later Chief Hydrologist), is referred to as "CHE." Personnel on less than full-time assignments are in places described as "WAE" (when actually employed). Readers of Volume V who find major errors in the text are invited to report such to the Chief Hydrologist.

ACKNOWLEDGEMENTS

More than 200 persons, nearly all WRD retirees, assisted in the preparation of this volume. The extent of assistance varied from guidance in locating prospective writers of District statements and providing recollections of single events, to actual preparation of manuscript for segments of the volume. The writers, reviewers, and those providing substantial amounts of information are identified at appropriate places in the text.

One person whose assistance deserves special recognition is W.B. Langbein, who spent many hours during the final years of his life recording the activities of the TC Branch, including the soil and moisture (S&M) program and early studies that identified the need for and led to the National Flood Insurance Program. His statements are less than complete in only one sense: his modesty, well known to his associates, kept him from expressing the vital role he played in many of the achievements for which the Division is known in this decade.

The author is grateful to the many secretaries of Division officials who, in addition to their regular duties, found time to type segments of this volume from handwritten manuscripts. No typists or secretarial personnel were specifically and formally assigned, full-time, to the history projects.

Former Director T.B. Nolan kindly reviewed many of the segments of the manuscript and verified or assisted the author in the revision or completion of references to Bureau-Division relationships and situations involving higher-level policy and forces that had an impact on Division programs and procedure. The final full manuscript was kindly reviewed during 1986 by J.C. Cragwall, O.M. Hackett, and W.W. Hastings. Portions were later reviewed by H.H. Barnes, Jr., R.H. Brown, and A.G. Fiedler. The suggestions for revisions were gratefully used.

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Introduction—A Vigorous Economy Makes Heavy Demands on the Nation's Water Resources

The policies, programs, and achievements of the Division that are documented in this volume were greatly influenced by forces of change in the Nation's economy, as well as by specific events national in scope that the Division had to adjust or respond to during the 1947–57 decade. The Division's goal of investigating and reporting on the water resources of the Nation was long range; however, many of the segments of that relatively stable but rapidly growing program were subject to change. Floods, droughts, sudden industrial expansion, changes in water-use patterns, water-development programs, and new water-resources commissions each required program adjustments to ensure that water data were available to meet specific, short-term as well as more general needs.

The Nation's economy during 1947–57 was both vigorous and resource-oriented. By 1947, the production capacity for peacetime needs was beginning to exceed World War II production levels. Further expansion of the economy was sought as the best assurance of national strength needed to preserve the peace that was made ever more uncertain because of international developments. During the 5 years prior to the start of hostilities in Korea in June 1950, U.S. production had expanded rapidly, as had the standard of living, despite substantial assistance to other free nations of the world.

By the beginning of the 1950's, the Nation was once again changing from a strictly peacetime economy to one that could be readily shifted toward military striking power should the need arise. The Korean Armistice was signed in July 1953. The Administration's change from Democratic to Republican in January 1953 had only a minor impact on the Division. The new Administration's policy of greater teamwork between the Federal Government and the States merely supported the Division's long-standing emphasis on its well-established Federal-State cooperative program.

By the 1950's, the robust industrial economy, stimulated by a record growth in the Nation's population, had identified limitations on readily available mineral and other resources. The need for resource conservation measures was expressed by public officials and the news media and was reflected in the annual reports of the Secretary of the Interior. By 1957, a more serious effort was underway toward a better definition of the Nation's resources base. It was estimated from a graph by W.L. Picton (U.S. Department of Commerce, 1960) that total water use for the Nation increased by about 70 percent from 1947 to 1957. It was estimated also from the same graph that this increase in water use was about equal to the additional amount of water used by the Nation from near the beginning of the century to 1947.

Water requirements during the decade continued to increase even beyond the demands of the World War II economy. Water, the "universal raw material," had become critically limited in several local areas during World War II. For example, the water supply of the huge Air Force recruit training facility at Miami Beach, Fla., was threatened by the intrusion of saline water into the coastal supply wells on the mainland. Such incidents showed that the Nation had serious water problems, even if problems were local in nature.

The public seemed suddenly aware of the national scope of the water problem when New York City officials imposed emergency water-use measures on residents and commercial establishments in fall 1949. The problem was not the shortage of water within reasonable reach; rather, it was a situation in which the completion of additional stream reservoirs—delayed in deference to materials priorities for war industries—had been overtaken by rapidly increasing domestic and commercial water use in a city operating without the constraints typically imposed by water meters.

This event brought intense and lasting public scrutiny to the adequacy of the Nation's water resources and one national periodical after another gave attention to the problem. Initially, the articles were directed to public officials and the engineering profession. Later, the national water problem was brought to the attention of the general public through such widely read magazines as *Fortune Magazine*, which ran an article entitled "How Are We Fixed for Water?" in the March 1954 issue. President Harry S Truman considered the general situation so serious that he appointed a commission to develop a national water policy (see pt. VII, President's Water Resources Policy Commission). The distinction was soon made, quite wisely, between a nationwide water problem and a series of regional and local water problems. The general consensus was that only the local problems were a matter for concern.

Because of this growing awareness of water problems during the decade, the Division grew rapidly in size. Although its activities and objectives had not changed appreciably from earlier years, the Division's water data and investigative reports were in demand, to be used by a now water-conscious Nation. Hydrology was a relatively new science and as yet had no status as a profession or academic specialty. Those who practiced it were identified by their basic professional training, engineer-geologist, chemist, or other. They were concentrated in a few Federal agencies, but mostly in the Water Resources Division of the U.S. Geological Survey.

PART I—THE DIVISION, ITS ROLE AND STRUCTURE

One of four functional segments of the U.S. Geological Survey (USGS), the Water Resources Division (WRD) had existed as a separate organizational entity for more than 40 years at the beginning of the 1947–57 decade. Its stream-gaging program began earlier than that—in 1888 when the Geological Survey's Irrigation Survey was established. Prior to January 1, 1949, the WRD was known as the Water Resources Branch. By Survey Order No. 173 dated December 15, 1948, (and supplemented by WRD Circular dated Dec. 23, 1948), the terms "division" and "branch" were interchanged. Thus the Ground Water (GW) Division, the Quality of Water (QW) Division, and the Surface Water (SW) Division of the Water Resources Branch became the GW, QW, and SW Branches of the WRD. This step was in compliance with a Government-wide directive from a congressional committee to establish a standard terminology to indicate organizational level. For purposes of clarity, this volume of the history will refer only to the new terms.

ORGANIZATION AND LATITUDE

The WRD headquarters personnel and facilities were inadequate to handle the postwar program expansion of the Division so that by early 1946, work began on a revised plan of organization, primarily for the Washington, D.C., office. It was completed, cleared by the Director and the Civil Service Commission, and announced by circular to the District offices on April 1, 1948. The chart accompanying the circular is shown in figure 1. Although some of the needed new positions were filled immediately, the statutory limitation on personal services in the District of Columbia was such that other hirings and the activation of the new structural units were delayed.

The new plan retained the three operating branches, the SW Branch, the GW Branch, and the QW Branch, and grouped the staff functions of each into a number of sections. The Water Utilization Branch, a long-standing staff unit, was renamed the Technical Coordination (TC) Branch to describe more accurately its current and planned functions. A new staff unit, the Program Control (PC) Branch, was provided for the purpose of developing and operating a coordinated modern system of defining, planning, budgeting, allocating, and accounting of all programs and projects within the Division. It was formally activated in November 1951. A second major reorganization, which was primarily a transition into a structure for use beyond the decade, took place in 1956 and is described later.

The field organization continued under its traditional structure and each branch maintained its District and Subdistrict offices. Rapid growth occurred in both the number of such offices and the personnel in each. The number of employees and location by State as of January 1949 is shown in table 1. The appendix to this volume shows the location of District offices as of January 1, 1956. Late in the decade, however, an intermediate level of administration was added between the Districts and the Washington headquarters. This change will be described later in Part I (see "Growth of interbranch activities and organization") as will the series of steps taken during the decade to strengthen the capability of the Division through inter-branch coordination.

Table 2 lists the personnel of the Washington, D.C., office as of January 1948. Personnel in each District office at the beginning of the decade can be determined from listings in summaries of District operations for each branch given in Volume IV of the WRD history series. Personnel on duty near the end of the decade at various locations, field and headquarters, are shown in Appendix B of this volume. Other official listings of field and headquarters personnel for the Division were prepared for administrative use as of January for each of the years of the decade except for 1951. They are not reproduced in this volume.

Using funds as a yardstick, the Division nearly tripled in size during the decade, a growth that closely paralleled that of the entire U.S. Geological Survey. (The actual program growth, however, more nearly doubled because of the 26-percent inflation during the decade.) During fiscal year 1947, the Division's total budget of approximately $6,300,000 was about 34 percent of that of the entire Survey and was exceeded in size only by the Topographic Division, funds for which were about 5 percent greater. By mid-decade (fiscal year 1952), however, the WRD ranked third among the Divisions in dollar obligations because of a rapid expansion in the national mapping

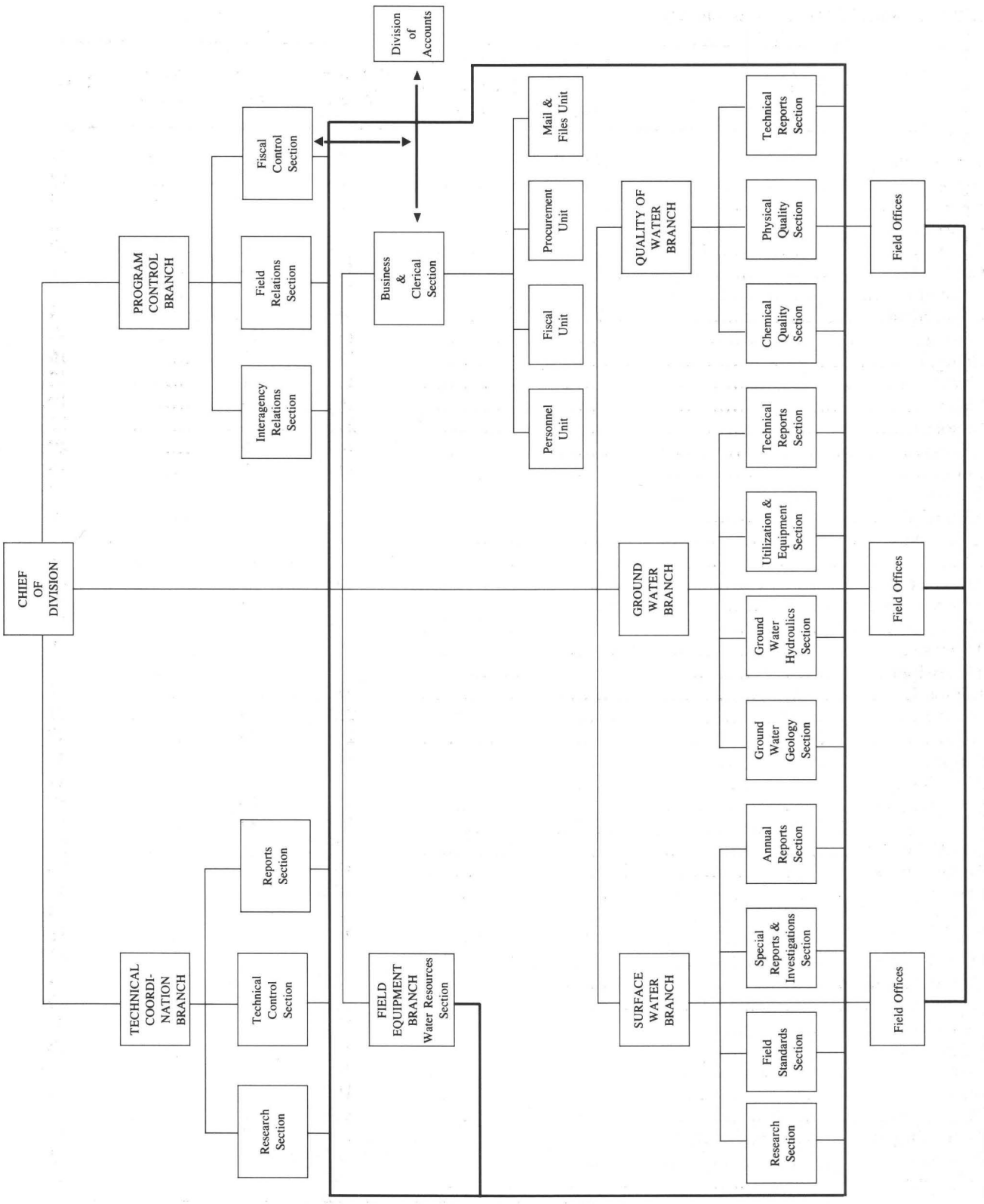


Figure 1. Plan of organization, 1948 (from WRD Circular, April 1, 1948).

Table 1. Number and location of employees in each of the branches of the Water Resources Division, U.S. Geological Survey, as of January 1949[1]

Location	Office of Division Chief	Technical Coordination Branch	Surface Water	Ground Water	Quality Water	Total
Washington, D.C.	23	9	22	24	16	94
Alabama	.....	.....	8	4	.....	12
Alaska	.....	.....	2	1	.....	3
Arizona	.....	.....	12	11	.....	23
Arkansas	.....	.....	7	2	7	16
California	.....	7	44	24	.....	75
Colorado	.....	.....	17	10	.....	27
Connecticut	.....	.....	4	.....	.....	4
Florida	.....	.....	19	13	.....	32
Georgia	.....	.....	13	3	.....	16
Hawaii	.....	.....	11	1	.....	12
Idaho	.....	.....	16	3	.....	19
Illinois	.....	.....	21	.....	.....	21
Indiana	.....	.....	14	6	.....	20
Iowa	.....	.....	11	5	.....	16
Kansas	.....	.....	11	8	.....	19
Kentucky	.....	.....	14	6	.....	20
Louisiana	.....	.....	12	7	1	20
Maine	.....	.....	4	.....	.....	4
Maryland	.....	.....	16	6	.....	22
Massachusetts	.....	.....	25	5	.....	30
Michigan	.....	.....	14	13	.....	27
Minnesota	.....	.....	15	.....	3	18
Mississippi	.....	.....	6	.....	.....	6
Missouri	.....	.....	21	.....	.....	21
Montana	.....	4	22	5	.....	31
Nebraska	.....	.....	24	23	.....	47
Nevada	.....	.....	16	7	.....	23
New Jersey	.....	.....	7	4	.....	11
New Mexico	.....	.....	18	10	20	48
New York	.....	.....	34	32	.....	66
North Carolina	.....	.....	17	3	5	25
North Dakota	.....	.....	15	11	4	30
Ohio	.....	.....	37	7	3	47
Oklahoma	.....	.....	14	2	12	28
Oregon	1	.....	21	6	.....	28
Pennsylvania	.....	.....	17	8	17	42
South Carolina	.....	.....	7	.....	.....	7
South Dakota	.....	.....	13	.....	.....	13
Tennessee	.....	.....	17	17	.....	34
Texas	.....	.....	30	19	9	58
Utah	.....	.....	28	5	9	42
Virginia	.....	.....	16	5	2	23
Washington	.....	2	33	.....	.....	35
West Virginia	.....	.....	11	2	.....	13
Wisconsin	.....	.....	8	7	.....	15
Wyoming	.....	.....	6	6	.....	12
TOTAL	24	22	770	331	108	1,255

[1]Compiled by Mary Jackson, WRD, from Organization and Personnel Directory of WRD as of January 1949.

Table 2. List of headquarters personnel as of January 1948[1]

ADMINISTRATIVE

OFFICE OF BRANCH CHIEF

Carl G. Paulsen, P-8, Chief of Branch
Royal W. Davenport, P-7, Chief, Technical Coordination Division
George E. Ferguson, P-6, Staff Officer (Program Control)
Ms. R. Helen Jones, Clk-Steno CAF-5

FISCAL CONTROL SECTION

Curtis E. Staudte, Admn Asst CAF-9
Alvin L. Smith, Clk CAF-5
Robert C. Gray, Clk CAF-3
Ms. Helen J. Lenzen, Clk-Typ CAF-2

BUSINESS AND CLERICAL SECTION

Ms. Helen Kiesel, Branch Chief Clk CAF-9
Ms. Marjorie E. Allen, Admn Asst CAF-7
Mrs. Elsie L. Yeatman, Clk-Steno CAF-4
Mrs. Rose Mary Smith, Clk-Steno CAF-3

PERSONNEL UNIT

Edward A. Erdmann, Jr., Clk CAF-5

FISCAL UNIT

Charles P. Sleeper, Clk CAF-5
Mrs. Lucile M. Clarke, Clk CAF-4

PROCUREMENT UNIT

Mrs. Catherine E. Nonamaker, Clk CAF-5
Mrs. Elouise K. Fletcher, Clk CAF-3
Ms. Kathryn Irwin, Clk-Steno CAF-2

MAIL AND FILES UNIT

Ms. R. Annette Berube, Clk-Steno CAF-3
Ms. Gertrude A. Shappy, Clk-Typ CAF-2

DIVISION OF SURFACE WATER

Joseph V.B. Wells, Engr P-6, Chief
Adrian H. Williams, Engr P-6, Asst Chief
Charles H. Pierce, Engr P-5
Ms. Laura M. Merrell, Secy (Steno) CAF-5
Ms. Eleanor M. Moscaritolo, Clk-Typ CAF-3

ANNUAL REPORTS SECTION

B.J. Peterson, Engr P-5
Francis J. Flynn, Engr P-3
Mrs. Helen S. Dame, Clk CAF-4
Mrs. Lucy M. Miller, Clk-Steno CAF-3
Ms. Marion M. Miller, Clk-Steno CAF-3
Mrs. Gertrude K. Smith, Clk-Typ CAF-3
Ms. Mary K. Dean, Clk-Typ CAF-2 WAE

SPECIAL REPORTS SECTION

Guy C. Stevens, Engr P-5

DIVISION OF GROUND WATER

A. Nelson Sayre, Geol P-6, Chief
Albert G. Fiedler, Engr P-6, Asst Chief
Ms. Jane Daniel, Secy (Steno) CAF-5
Ms. Bertha A. Densmore, Clk-Steno CAF-4

GROUND WATER HYDRAULICS SECTION

William F. Guyton, Engr P-4
William O. Smith, Physicist P-4
Russell H. Brown, Engr P-3
Rodney Hart, Engr Aid SP-8
Mrs. Marie T. Davis, Clk-Steno CAF-4
Mrs. Leona M. Landgren, Clk-Typ CAF-2

GROUND WATER GEOLOGY SECTION

Victor T. Stringfield, Geol P-5
Ms. Jean M. Berdan, Geol P-2 WAE (detailed to New York)
Ms. Helen L. McNew, Clk-Steno CAF-3

TECHNICAL REPORTS SECTION

Charles Lee McGuinness, Geol P-4
Ms. Margaret M. Saunders, Sci Aid SP-6
Ms. Dorothy M. Ireland, Clk-Steno CAF-4
Mrs. Frances G. Thompson, Clk-Steno CAF-4
Ms. Mamie Baker, Clk-Steno CAF-3
Ms. Louisa T. McAnallen, Clk-Steno CAF-3

DIVISION OF WATER QUALITY

S. Kenneth Love, Chem P-6, Chief
Warren W. Hastings, Chem P-4
Walter F. White, Jr., Chem P-4
Edwin W. Lohr, Chem P-3
Neill K. McShane, Chem P-2
Mrs. Dorothy M. Parrish, Chem P-2
Merle E. Schroeder, Chem P-2
Miss Sarah E. Brien, Chem P-1
George E. DeLaitsch, Chem P-1
Alexander L. White, Chem P-1
Ivan H. Barlow, Sci Aid SP-5
Mrs. Martha L. Keith, Secy (Steno) CAF-5
Mrs. Anna J. Reynolds, Clk-Steno CAF-4
Mrs. Ajelon Atkins Kinan, Clk-Steno CAF-3
J. Pressley Magee, Clk-Steno CAF-3
Emanuel Samuel Brown, Laborer CPC-2
Theodore Walker, Laborer, CPC-2

DIVISION OF WATER UTILIZATION

Royal W. Davenport, Engr P-7, Chief
Walter B. Langbein, Engr P-5
William S. Eisenlohr, Jr., Engr P-4
Hollister Johnson, Engr P-4
G. Earl Harbeck, Jr., Engr P-3
Ms. Ethel M. Wilson, Engr P-2
Mrs. Eva M. Patton, Engr Drftsmn SP-6
Mrs. May E. Thiesen, Secy (Steno) CAF-5
Mrs. Sara E. Panarese, Clk-Typ CAF-3
Ms. Catherine V. Creel, Clk-Steno CAF-3

[1]The organizational structure indicated for the Washington Office represents initial steps in the transition toward the recently developed plan of reorganization (from list of classified personnel of the Water Resources Branch as of January 1948).

activity and also a nearly fivefold growth of the Geologic Division. By fiscal year 1957, the water resources activity had expanded to an annual level of nearly $18 million to become the largest activity in the Survey.

The national headquarters of the Survey remained throughout the decade in the middle wing of the Federal Works building which was located on F Street between 18th and 19th Streets in northwest Washington, D.C. The Division occupied the second floor. In 1949, the building became known as the General Services Administration (GSA) building when it also served as the headquarters of that newly created agency. The Interior building, just to the south, housed the offices of the Secretary and the headquarters staffs of the other Department of the Interior agencies. In fall 1956, space was leased in the George Washington building of the Arlington Towers apartment complex (renamed River House in the early 1980's) across the Potomac River in Rosslyn, Arlington County, Va. These facilities housed the headquarters staff of the Division's newly organized Atlantic Coast area and segments of the staffs of the operating branches that had outgrown the available space in the GSA building.

William E. Wrather was Director during the greater part of the decade, having been appointed to that position in 1943. He retired for reasons of health early in 1956. Dr. Wrather was succeeded by Thomas B. Nolan who had been assistant director since 1944. Dr. Nolan continued as Director beyond the end of the decade.

During the decade, the Division continued to operate with the considerable latitude that was traditional in the Survey and for reasons well expressed by Director Wrather in his letter dated December 21, 1950, to the Secretary of the Interior. He stated that "the four divisions, even though dependent on each other in many ways, differ so widely from each other in the character of their work and the training of their personnel that each must maintain an organizational pattern best suited to its needs; yet because of the community of objectives and interrelationships of the products of work, close liaison must be attained to keep the overall program in balance." It was vital that these differences in programs and organization among the Survey's several divisions be known to the Secretary because of current efforts then exerted by certain of his staff members to set up regional line organizations at departmental level which would have jeopardized the Survey's national goals and responsibilities.

Liaison between the personnel of the Division and their counterparts in the Survey's other Divisions was routine and mutually advantageous. The WRD was a major user of the quadrangle maps produced by the Topographic Division and was given the opportunity to suggest priorities for areas scheduled for remapping. Hydrogeologists of the GW Branch used the geologic maps of the Geologic Division as a base for ground-water investigations. Hydrologic data from the public domain were used by water-resources specialists of the Conservation Division.

Importance in Water-Resources Development

The Division's national stature in the field of water resources, especially water supply, was particularly strong during the decade. Its earlier, as well as current, investigational and data-collection programs had been planned and aggressively conducted to meet future needs, and the public and private officials responsible for water supply and development in the strong postwar economy used these water data to good advantage. At the time, there were relatively few private consultants in hydrology. The Survey's hydrologists frequently were under pressure to interpret water data and investigative findings for consulting engineering companies and for private and other public officials, which had to be accomplished without the Geological Survey's becoming a party to decision-making phases of water development that were outside the boundaries of its authorized functions. The Division's hydrologists were required to limit their opinions to the probable physical effects of each of the given alternatives for development on the natural or existing hydrologic system. In doing so they avoided nonhydrologic aspects such as economic or political factors.

Reliance on the Survey's water-resource appraisals by those responsible for municipal water supply was noteworthy. During the decade, many municipal water departments were nearing the limits of their existing sources and were searching for additional supplies. In the 1950's, in contrast to the 1970's and later, primary attention was on the quantity of water available; water quality was a secondary problem. Though existent, water pollution was local in nature, and laboratory methods and drinking water standards were less refined. H.E. Jordan and W.W. Brush, long-time Secretary and Treasurer, respectively, of the American Water Works Association (AWWA), were familiar with the water-resources activities of the Division and its value to the water-supply industry. Not only did they welcome articles by Survey hydrologists for publication in the AWWA journal, a WRD official was invited to participate in the development of programs for AWWA annual conferences and to take a leading part in the establishment of the AWWA Water Resources Division. The Survey granted Jordan permission to publish its second national water-use appraisals in the AWWA journal without prior appearance in a Survey publication. This report later became USGS Circular 298 by K.A. MacKichen.

Industrial expansion also created a need for additional water supplies, and the use of the thousands of special reports by Survey hydrologists by the War Production Board and the Munitions Board during World War II

was apparently remembered with appreciation in the years following the war. The U.S. Chamber of Commerce also remained a strong advocate of the Survey's programs throughout the decade, and a statement of support appeared in the Chamber's annual policy brochures.

When new types of information or new elements of data about water resources were needed, the Geological Survey usually was considered to be the proper agency from which to obtain it. For example, the Bureau of Reclamation approached the Survey regarding Reclamation's need for stream-temperature data. After a study revealed a national interest, the Division added stream temperature as a new element in its data base (WRD Circular, Feb. 3, 1948). Likewise, the Department of Agriculture felt that the Geological Survey should accept leadership in the program for collecting data on the chemical quality of surface water used for agriculture (F.W. Parker, Soils Division, U.S. Department of Agriculture, written commun., 1949).

Looking back from the standpoint of the mid-1980's, the 1947–57 decade may well have been a period in which the Division played a more prominent role in the water-oriented, non-Federal segments of the national economy than at any other time in its history. Prior to that period, the country had yet to become nationally water-conscious. Subsequently, in ever larger numbers, the universities began to graduate hydrologists who became associated with private consulting firms, and with State and other Federal agencies. Thus non-Survey hydrologists became available to respond to the ''service-type'' work, which allowed Survey scientists to place their emphasis on research and more scientifically advanced project work.

Office of the Division Chief

Carl G. Paulsen was chief of the Water Resources Division and chief hydraulic engineer (CHE) of the Survey throughout the decade, having succeeded Glenn L. Parker who died on February 12, 1946, while in that position. Paulsen had been assistant chief of the Division since 1939 and chief of the SW Branch beginning in 1931. Earlier in his career, he was district engineer of the SW Branch Districts in Atlanta, Ga., and later in Boise, Idaho. A strong advocate of Federal-State cooperative programs, Paulsen had already accomplished a great deal in strengthening the support in Congress and with the States for 50-50 financing of cooperative projects. He was equally effective in having water-resources agencies at the Federal level engage the Survey to collect the water data that they needed.

One of Paulsen's greatest achievements during the decade is best described by J.V.B. Wells. Wells stated that Paulsen, ''by his friendly, considerate, and quietly aggressive leadership, and because of his ability to gain the loyalty of the key personnel in all the Branches, . . . was able, really for the first time, to bring all of the segments of the Division together to work as a unit.''

Despite his surface-water background, personnel from all Branches felt comfortable with Paulsen, and his carefully considered decisions met with an unusually high degree of acceptance (Memoir, *WRD Retirees* newsletter, May 1975, p. 3). The word ''problem'' was not in his vocabulary. Difficult situations seemed to yield to his forebearance and judgement. Paulsen retired from the Survey at age 70 in April 1957, but continued to serve as Delaware River Master until this death in January 1961 following a lengthy illness.

The Division's national Headquarters staff more than doubled in size during the decade. As of July 1947, the staff numbered about 80 people and, by 1957, had increased to more than 160. Somewhat less than half were in professional categories; the balance were in secretarial, clerical, fiscal, and technical-support activities. About 20 percent of the Headquarters personnel were located in the office of the Division Chief at the beginning of the decade, and the others were assigned to the branches. Partly because of the gradual transfer of accounting activities to the Survey's Administrative Division, the Division Chief's immediate staff at the end of the decade was only about 12 percent of the total headquarters personnel of the Division and branches.

Shortly before his death early in 1946, Parker had arranged for G.E. Ferguson to leave his district engineer position in Florida as soon as he could free himself from local commitments and join the immediate staff of the CHE. Ferguson spent most of 1946 and 1947 on a series of details to Washington, D.C., and transferred officially in 1947. During that period, he was developing a plan of reorganization under which the Washington, D.C., office would be staffed to administer its rapidly growing program. Ferguson later was placed in charge of the newly created PC Branch, the functions of which are described later. He continued to draft most of the Division directives issued by the CHE on program, organizational, and WRD Council matters.

N.C. Grover, CHE from 1913 to 1939, who had been recalled from retirement in 1942 to assist the temporary Military Geology Division and the WRD, continued his association with the WRD during the early part of the decade (Follansbee, v. IV, p. 2). His long experience and sound judgement were widely sought and used by Division and Branch chiefs and on occasion by the Director's office. Grover gave considerable time to a review of the manuscript for Volume IV of Follansbee's history of the Division, and his advice was sought also in planning the current reorganzation of the Division headquarters staff. Grover again retired in 1947 at age 78. (See pt. VII for special recognition of Grover).

H.F. Hill, Jr., a hydraulic engineer who had served essentially as the Division administrative officer since 1930 (when Division Chief Grover had him transfer from the Albany, N.Y., District), resigned in November 1946. (Hill once told the author that when he transferred to the Washington, D.C., office to assist in the growing administrative workload, he asked the CHE what his assigned duties were. Grover's advice was that he should look around and find out what things were not being done—and do them! The advice apparently was sound; he became an effective and respected administrative officer and carried a heavy workload.)

Helen Kiesel, the Division's chief clerk since 1930, retired in 1948 "owing to fatigue" after a period in which the workload grew more rapidly than the size of the staff available to handle it. (Miss Kiesel moved to Florida and did regain her strength. She was more than 90 years old at the time of her death in the early 1980's.) Frank Barrick, Jr., an accountant by training, joined the Division staff in 1948 and served as the chief administrative officer of the Division through the end of the decade.

Surface Water Branch

The Branch, which has historic roots traceable to the origin of the nationwide stream-gaging program at the 1888 encampment of early Survey hydrographers at Embudo, N. Mex., was the oldest and by far the largest of the branches. Division chiefs during the 44-year period from 1913 to 1957 all had had early careers in the SW Branch. Two of them, N.C. Grover and C.G. Paulsen, were former chiefs of the Branch. Another, G.L. Parker, had served as district engineer for Washington.

The primary activity of the Branch was the operation of a nationwide network of stream-gaging stations that included all of the States and the territories of Alaska and Hawaii. The network grew in size from about 5,800 stations in 1947 to about 6,900 in 1957. The network was administered by personnel of more than 40 District offices located generally in State capitals where cooperating State agency heads were located. The task of computing the collected field data into daily discharge figures was in itself a gigantic endeavor. During fiscal year 1949, for example, about 2 million figures of daily stream discharge were calculated from daily stage and periodic discharge measurements and compiled for publication. This was done, of course, with the aid of only slide rules and mechanical desk-top computers. Daily discharge was published annually in the Water-Supply Paper series throughout the decade.

Branch personnel also were increasingly involved in research into river hydraulics, in statistical interpretations of streamflow data, and in the development of improved techniques and equipment by which stream gaging could be accomplished more accurately and efficiently. The products of such research and interpretation were, like streamflow data, widely used by engineers and others in water-resources development.

The average number of employees with U.S. Civil Service classifications in the Branch during fiscal year 1947 was nearly 700, of which about 420 were hydraulic engineers, 150 subprofessional assistants, and 120 clerical personnel. By 1956, the number had increased to a total of 1,062, including 590 engineers, 300 subprofessionals, and 172 clerical people. The growth in subprofessional employees is noteworthy; there were only 7 in the Branch in 1941. Success in using subprofessional personnel as stream gagers during the engineer-short World War II years led to their becoming a highly respected as well as sizable segment of the District staffs.

HEADQUARTERS ORGANIZATION AND LEADERSHIP

J.V.B. Wells was chief of the SW Branch throughout the decade, having been appointed in 1946 following the death of R.G. Kasel. Wells had been district engineer for Kentucky for the previous 6 years and had prior service in the New York, Pennsylvania, and Indiana districts. He was well known to and had the strong support of the District chiefs of his Branch despite the fact that many of them were considerably older. A.H. Williams, a member of the staff who had transferred from the Montana District in 1946, was appointed to the newly created position of assistant branch chief later that year. Williams served in that capacity through the end of the decade.

The Branch headquarters staff increased from 13 persons as of January 1948, to more than 70 by January 1957. Most of the personnel were in the Annual Reports Section (renamed Basic Records Section in 1956), which grew from 7 to 24 employees during the same period. The increase was necessary in order to review and process for publication the growing number of streamflow records being collected. The section had been directed by B.J. Peterson since 1924. Peterson retired at the end of 1957 and was succeeded by F.J. Flynn, who had been second in charge of the section throughout the decade.

The Special Reports Section, referred to as the Section of Investigations prior to the late 1940's, existed as a one-man operation for many years. G.C. Stevens had handled an increasing variety of inquiries regarding the Nation's surface-water resources until 1951, when he was given several hydraulic engineers as assistants and the name of the section was changed to the Special Reports and Investigations Section. Stevens retired in 1953 and was succeeded by C.D. Bue who had transferred to the

section from the Montana District in 1948. Bue was succeeded in 1954 by C.H. Hardison who remained in charge for the rest of the decade. In 1949, K.B. Young transferred from the Boston District to become special assistant to the Branch chief on programs, budgets, field procedures, and related matters. He joined the PC Branch in 1951.

The Technical Standards Section, activated in 1951 as a part of the 1948 plan of reorganization, was directed by Tate Dalrymple who had been on the Branch chief's staff since his transfer in 1949 from his position as acting district engineer for Ohio. The section gave leadership to the highway program, flood-frequency studies, flood reporting, and use of field-located flood specialists. M.A. Benson was Dalrymple's principal assistant until his transfer to the Research Section in 1956. In 1952, J.S. Cragwall of the Louisiana District staff became a member of the section for the balance of the decade, and succeeded Benson as principal assistant. The Technical Standards Section became the Floods Section in 1958 without significant change in function. Dalrymple remained in charge.

The Research Section, also activated in 1951, initially was staffed by personnel headquartered at field locations. One of the locations was at the hydraulics laboratory of the Georgia Institute of Technology where, in 1952 and under the direction of laboratory director C.E. Kindsvater, R.W. Carter and other researchers of the Branch strove to provide through their research a stronger base for the Survey's surface-water techniques. In 1955, Carter transferred from the Branch research project at Georgia Tech to Washington, D.C., to take charge of the Research Section.

R.E. Oltman transferred from Lincoln, Neb., in fall 1955 for an assignment as special assistant to the branch chief for technical training and personnel management. In 1956, he was placed in charge of the newly established Training Section.

A Planning Section was also established in 1956 and J.E. McCall, who had been on the branch chief's staff, was placed in charge. By November 1956, all of the sections except the Planning Section had moved across the Potomac River to Arlington Towers in Rosslyn, Va., because of critical space limitations in the Washington office.

Despite the assistance from the new staff sections, management analysts of the 1980's may well wonder how one headquarters could effectively manage as many as 40 District offices, especially at a time when communication by memorandum was still more common than by long-distance telephone. Greater delegation of authority was the answer. The District engineers had considerable autonomy. Federal regulations also were relatively simple, as were the District-kept accounts.

BRANCH PROJECTS OF NATIONWIDE SCOPE

In addition to those Branch accomplishments described later under the national program and under research, methodology, and instrumentation, there were a number of other new activities and data-type products that have had lasting nationwide value. As stated by J.E. McCall (written commun., 1976), "One of the more important changes [during the decade] was the outgrowth of W.B. Langbein's inquiry into the value of continued data collection at a given site. This grew into our first attempts to mold our stream-gaging stations into a network of long-term hydrologic stations, short-term hydrologic stations, and water-management stations." He recalled that with Branch Chief Wells' full support of such a critical analysis of the network, McCall and staff spent several years on the study. One of the conclusions was that a national network of about 10,000 stations "would be the maximum number that would ever be needed . . . at any one time" (J.E. McCall, ASCE, Hydraulic Division Journal, March 1961). "The network concept did not stop the construction of new gaging stations but rather provided impetus to discontinuing those where the value of data was beginning to diminish and funds were applied to stations at new locations."

The length of time that a gaging station should be operated continued to be a frequent topic of discussion by Branch hydrologists but, as in earlier years, no solution or policy determination was made. W.B. Langbein, staff scientist of the TC Branch and one of the leaders in the analysis of station-network design, spoke to the subject in a paper prepared for the 10th General Assembly, International Union of Geodesy and Geophysics, Rome, in 1954.

A special compilation began in 1951 which placed in a single volume all of the monthly and annual values of streamflow for gaging stations within each of the basins covered in the annual Water-Supply Papers. The compilation included streamflow records in the United States for 1888–1950. It was 77 percent complete by mid-1957. Heretofore, users of streamflow records had to refer to as many as 50 volumes of the annual report series to obtain long-term discharge data at many river locations. The magnitude of this task is apparent from the findings of W.B. Langbein and E.W. Wilson that, as of September 30, 1946, about 95,000 station years of streamflow records had been collected by the Survey. Of the 9,007 stations established at one time or another, 63 percent were currently in operation in 1947 (WRD Bull., Nov. 1947, p. 178).

The analyses and reporting of the frequency with which floods of various magnitudes had occurred at gaging sites on specific rivers were begun about 1950 in several District offices. The results were of sufficient value to

justify a nationwide project that was well advanced by 1957.

In 1948, a manual was prepared on the "indirect" determination of peak discharges for flooded streams at places and during times when current-meter measurements could not or were not made because of insufficient flood warning, lack of experienced hydrologists, or extremely hazardous measuring conditions. The manual so effectively documented the art of securing, appraising, and applying data on channel friction, configuration, and slope in flow calculations that hydrologists used it in flood investigations throughout the United States. The author of the manual, Hollister Johnson, had been a pioneer in the development of the technique.

The investigation of and reporting on the hydrologic aspects of specific floods, in which the Survey had been engaged since the Passaic, N.J., flood in 1902, continued at an increased rate. The preparation of more than 40 reports on specific floods during the decade was made possible by the growing number of professional personnel skilled in making indirect determinations. These reports described and provided data, for example, for the devastating widespread floods of August through October 1955 that extended from New England to North Carolina. More detailed information on flood studies is given in Part II, the Federal program, and District activity statements (pt. IV) describe many local flood investigations in greater detail.

Another activity emerged that J.S. Cragwall described in a memo to the author in 1986: "The decade spawned the so-called 'cooperative highway programs,' which eventually became a part of virtually all State cooperative programs of the Branch. These programs were designed to enlarge the flood-information base useful to the design of highway drainage structures. Installation and operation of networks of small-stream, crest-stage stations were major components of the programs and greatly added to the information on peak discharges for use in later flood-frequency analyses. Other components of the programs included flood-frequency and bridge-site studies which are described in the statements of District activities. Even though the State-level highway programs were not federally funded, the effort was coordinated and technically supported by the Technical Standards Section with the strong endorsement of the Federal Bureau of Public Roads."

A number of districts made studies of low-flow characteristics of small ungaged streams by means of one or more measurements that were correlated with adjacent gaged streams. This provided, at very reasonable cost, low-flow data on streams on which a standard gaging station could not be justified. A program of collecting flood data on small streams by the use of crest-stage gages also was underway.

The number of lakes studied under the cooperative program increased steadily during the decade. Continuous or periodic records of lake stage were begun at many locations. One of the most advanced studies, that of the lakes of northern Indiana, had begun in 1942 in cooperation with the Indiana Department of Conservation. District engineer D.M. Corbett reported in the WRD Bulletin of November 1955 that, by 1955, data had been collected for 180 lakes.

Many revisions to former determinations of the drainage area above gaging stations were accomplished during the decade with the aid of more modern and often larger-scale topographic maps. This was accomplished in conformance with the specifications developed by the Federal Interagency River Basin Committee to achieve consistency in the use of drainage area data by various agencies.

Ground Water Branch

Intermediate in size among the three operating segments of the Division, the GW Branch, except for one adverse event (pts. II and VII), enjoyed strong support from public and private water-use agencies and organizations during the decade. The great increase in the use of ground water that had occurred during World War II continued during the postwar period because of the industrial, municipal, and agricultural demands arising not only from domestic needs, but from those for the Korean conflict and "cold war" as well.

Within the growth of national interest in all water resources during the decade was a concern about the rapidity with which the country's ground waters were being developed and used. Director Wrather reported at the fiscal year 1950 House hearings in February 1949 that in a little more than a decade, the pumping from groundwater sources in the United States had increased from about 10 billion to more than 20 billion gallons per day. The Survey's fiscal year 1951 annual report to the Secretary mentioned the "continued intense interest in and accelerated development of ground water . . .," and stated that there was an increasing proportion of ground-water investigations that were related to defense activities, accomplished at some sacrifice to nondefense studies.

NATURE AND MAGNITUDE OF PROGRAM

Unlike the SW Branch, which was devoted largely to a systematic data-collection program, the GW Branch was engaged in a large and growing number of project investigations, usually in areas in which the future demands for ground-water withdrawals exceeded the estimated safe

yield of potable waters from local and regional aquifers. Basic research in hydrogeology and hydrochemistry were hallmarks of many of these projects, and numerous papers were published by the national and international scientific press. The findings were documented usually in descriptive reports that were made available to the public.

In the conduct of its investigational program, the Branch maintained a large network of observation wells at which several types of water data were collected. During fiscal year 1949, for example, water levels were measured at nearly 13,000 wells, of which 837 were equipped with continuous recorders. Water discharge was recorded at more than 2,000 wells, with nearly 200 of them having a continuous recorder. Chemical-quality analyses were made at QW Branch laboratories of samples taken from nearly 2,300 wells in the network, and water-temperature determinations were made periodically at about 870 wells.

The Branch entered the 1947–57 decade with a cooperative program that included 47 agencies representing 42 States, 12 cities located in 6 States, 12 county governments in 7 States, and 3 Water Districts in 3 States. The program was supported by a Federal allotment of about $600,000 matched by a similar contribution from the cooperating parties. An additional amount of nearly $9,000 was contributed by the cooperating parties without Federal matching (Congressional Record, 1947, p. 4,219). The Branch also conducted investigations for several Federal agencies. The total field program was administered in fiscal year 1947 by 36 District offices.

During fiscal year 1947, about 350 investigations (projects) were underway and nearly 200 formal reports were prepared. By fiscal year 1957, work was being done on about 575 projects. Of the reports processed in 1957, 123 were published and 146 released to the "open file" where they were available for public inspection and use. The published reports included 22 Water-Supply Papers, 2 Hydrologic Atlases (maps), 5 Circulars, 37 reports published by cooperating agencies, and 30 papers in scientific journals. About 30 additional reports were released for administrative use by Federal agencies.

The Branch reported that each of the more than 500 projects under investigation during fiscal year 1955 were directed toward a better understanding of one or more of the following: (1) ground-water resources and reservoirs; (2) inland sources of saline waters having a potential for use in saline-water conversion; (3) the hydrology of mining and oil field areas; (4) water loss by water-loving nonbeneficial vegetation; and (5) salt-water encroachment in coastal areas.

The number of full-time personnel in the Branch at the end of the decade was about 2½ times the total at the beginning. The increase would be nearly threefold if the number of part-time people added to the rolls in the latter part of the period were included. As of July 1, 1947, the total of 246 people in the Branch included 155 in professional, 43 in technical subprofessional, and 48 in clerical positions. By mid-1957, there were about 725 employees (105 worked less than full-time), including 396 professional, 214 technical subprofessional, and 115 clerical employees.

HEADQUARTERS ORGANIZATION AND LEADERSHIP

A.N. Sayre, geologist, was chief of the GW Branch throughout the decade, having been appointed in December 1946 following the retirement of O.E. Meinzer who had held that post for 33 years. Sayre, who joined the Branch in 1929, was on special duty with the military forces in Africa during World War II. Upon his return to the Branch in 1945, he had limited supervision over ground-water investigations in States west of the Mississippi River.

A.G. Fiedler, engineer, was assistant chief of the Branch during the decade, having been appointed to that position in July 1942. The first 7 years of Fiedler's career were with the SW Branch, most of them in the Idaho District. He transferred to the GW Branch in 1925 with headquarters at Roswell, N. Mex., for an intensive study of the Roswell artesian basin. He was assisted in this study by S.S. Nye, a geologist. The trial use of the combined talents of an engineer and a geologist (Meinzer's idea) was highly successful. Their findings, now classic, were used as a base for legal controls by which water-conservation measures reestablished and maintained a prosperous agricultural community.

The Branch first established its formal staff sections near the beginning of the decade and became a part of the Division's reorganization of 1948. These sections took over the staff functions formerly organized on a geographical basis. The 1948 organizational chart showed the three sections described below, plus a fourth, the Utilization and Equipment Section, which was never activated.

The Ground Water Geology Section was created in 1946 under V.T. Stringfield who continued in charge until near the end of the decade (April 21, 1957) when the Section was discontinued. He was then placed in charge of the newly formed Division-level Radiohydrology Section.

The Technical Reports Section was under the direction of C.L. McGuinness from the time of its establishment through the balance of the decade. The section was likely established shortly after McGuinness' return from Puerto Rico in March 1946.

The Ground Water Hydraulics Section is believed to have been created on the arrival of W.F. Guyton from the Mississippi District in March 1947. Guyton continued

as the section chief until 1952 when he was reassigned to head the Division's new national studies on water use. R.H. Brown served as acting chief until the reorganization of June 1956.

The manpower and Training Section was organized in 1951 with G.G. Parker as its chief. Under Parker's direction, the highly successful ground-water short courses were developed, and a career-development program was begun (see pt. VI for more details).

In the second reorganization, announced by CHE Paulsen in a June 14, 1956, memorandum, only two of the former sections, the Reports and Training Sections, were carried over into the new structure. Three new sections were established: the Operations Section, the Planning Section, and the Research Section. The Organization and Personnel Directory dated July 1, 1957, shows J.A. Adamson as the chief of the Planning Section, R.R. Bennett as chief of the Research Section, and D.W. Berry as chief of the Training Section.

In 1955, the branch chief designated nine of the senior members of his field organization as part-time project coordinators. The objective of this move was to improve the planning and program execution by the Branch. R.L. Nace recalls (written commun., 1982) that although the effectiveness of the arrangement was limited, it did lead to improvements in planning. The designees are identified later under District activity statements (pt. IV).

R.W. Hart, on the headquarters staff during the entire decade, served not only as chief draftsman on Branch manuscripts being processed for publication, but also visited District offices to train and advise less experienced draftsmen. Another of Hart's responsibilities was to operate a network of observation wells in nearby northern Virginia. Early in the decade he assisted C.F. Jacob, and later M.A. Warren, in laying some of the foundations for the establishment of a uniform national system of reporting observation-well records.

R.H. Brown recalls (written commun., 1987) that those foundations were strengthened in the early 1950's when the Branch established a small unit under P.P. Livingston, headquartered in Austin, Tex., to prepare final copy for the annual publication in Water-Supply Papers of all records of the nationwide networks of observation wells. W.E. Clark succeeded Livingston in 1955 when Livingston retired. In 1955, A.N. Sayre appointed a 10-member Observation Well Committee, chaired by R.H. Brown, to review the entire system of publishing well records. That committee met in mid-1956, and, by the end of the year, its recommendations were being implemented, resulting in significant streamlining of, and greater uniformity in, the system of reporting and publishing well records.

SPECIAL PROJECTS OF BROAD SCOPE

The local investigations undertaken by Branch personnel are covered later. Research, methodology, and instrumentation also are described later in Parts III and V. There are, however, a number of projects of broad scope and significance that warrant special attention.

In fiscal year 1950, in recognition of national interest in ground water, both as an over-developed resource in some areas and as a potential water source in others, the Conservation Foundation sponsored a nationwide survey of the situation and sought assistance from the Survey. H.E. Thomas, one of the senior ground-water hydrologists of the Branch, was granted leave in 1949 to direct the survey and prepare a report. This culminated in the volume, "The Conservation of Ground Water", published by McGraw Hill in 1951 (WRD Circular dated Oct. 1, 1951).

The ground-water program included an increasing number of detailed hydrologic studies of mining and oil-field areas to assist in solving problems of drainage and of general development. Studies of the occurrence and quality of inland sources of saline waters were begun as a base for agencies studying the practicability of saline-water conversion. An atlas-type format was developed for the reporting of certain ground-water studies. Used in conjunction with topographic and geologic information, ground-water studies were effective in locating water supplies in a number of States. A historical paper entitled "The Quantitative Approach to Ground Water" was prepared by J.G. Ferris and A.N. Sayre in 1955. It traced the history and development of the techniques then in use in ground-water appraisal and interpretation and was published in Economic Geology (50th Anniversary Volume, 1905–55, p. 714–747). Under the leadership of T.E. Robinson, quantitative studies were made of the sizable amounts of water consumed by saltcedar and other phreatophytes which resulted in water being lost for beneficial use in the arid western States. Growing interest by industry in liquid-waste disposal through wells into aquifers, and also the practice of pumping ground water for cooling purposes, led to a WRD Circular dated September 4, 1951, that alerted District offices to possibilities of damage to ground-water sources from such practices. G.G. Parker was the first to use formal names to describe important acquifers. He named the Biscayne and Floridan acquifers as a result of his hydrogeologic research in Florida and adjacent States (WSP 1255, 1956) with G.E. Ferguson, S.K. Love, and others.

Quality of Water Branch

The smallest of the three operating segments of the Division during the decade, the QW Branch dates back

to the Reclamation Act of 1902. Originally established as the Division of Hydro-economics under the Survey's Hydrographic Branch (Follansbee, v. I, p. 123) and concerned with both chemical and biological aspects of water, the Branch was given its present name in 1907 (Follansbee, v. I, p. 188). Although its activities subsequent to about 1918 were almost entirely related to studies of the chemical quality of surface and ground waters, the Branch actively broadened its functions into investigations of the physical quality of water just before and during the decade. Measurements of fluvial sediments became a sizeable part of the total Branch activity, particularly during the Missouri River basin program. The Branch was assigned a major role in the collection and evaluation of temperature data in both surface and ground waters, and a program to determine and interpret the radioactivity of natural waters was begun.

The post-World War II search for ever more usable water for industry, agriculture, and public supplies readily revealed that "the local water problem" was frequently one of water quality. Dissolved mineral matter, suspended sediments, and high temperatures occurring naturally or from previous use could, singly or in combination, greatly reduce the usability of water resources. Demands for water-quality data by which water resources could be evaluated with confidence were increasing from both hydrologists engaged in water-resources investigations and public and private water-oriented officials. Radioactive substances in water, both natural and man-induced, caused new concerns in the early 1950's.

The response by the Branch to such data needs resulted in an activity that increased greatly during the decade. W.H. Durum (1978) reported statistics that indicate that the number of water samples analyzed for chemical quality grew from about 17,500 in 1947 to about 60,000 in 1957. Sediment samples analyzed increased from 31,000 to 60,000 during the same period. An annual maximum of 125,000 samples were analyzed in 1951. The number of stream-channel locations at which samples of suspended sediments were collected for analysis increased from less than 70 at the beginning of the decade to more than 200 in fiscal year 1957. By 1953, when the program began, water-temperature readings were being made regularly at more than 300 sites, and at 400 sites by 1956. The total number of stations at which one or more types of data were collected doubled during the 5-year period from 1946 to 1951, then hovered around the 1,000 level until the close of the decade.

The Branch program was conducted at the beginning of the decade by about 90 persons, including 30 chemists, 6 engineers, 1 geologist, and 12 assistants. Chemical analysis of water samples was being made at laboratories at Washington, D.C.; Albuquerque, N. Mex.; Austin, Tex.; Fayetteville, Ark.; Lincoln, Nebr.; Charlottesville, Va.; and Raleigh, N.C.

By 1957, the total number of personnel had grown to more then 300, of which 160 were in professional grades and about 100 in technical-support positions. The Division's official listing of field offices as of July 1, 1957, indicated that new laboratories had been established during the decade at the following locations: Palmer, Alaska; Sacramento, Calif.; Denver, Colo.; Ocala, Fla.; Albany, N.Y.; Columbus, Ohio; Oklahoma City, Okla. (moved from Stillwater in 1954); Portland, Oreg.; Philadelphia, Pa.; Salt Lake City, Utah; and Worland, Wyo. Many of the laboratories were equiped to measure suspended sediment as well as to make chemical analyses. The Worland laboratory was devoted entirely to work in fluvial sediments.

HEADQUARTERS ORGANIZATION AND LEADERSHIP

S.K. Love was Branch chief during the decade, having succeeded W.D. Collins when the latter retired in September 1946. Love had been in charge of the Branch's Washington, D.C., water-quality laboratory. In earlier years he had charge of sediment investigations that the Survey conducted for the Department of Agriculture in Idaho and elsewhere, and of the water-quality segment of the southeast Florida cooperative water-supply study. He told his staff at the Branch Conference in Denver, Colo., in April 1955: "When I reported for work . . . in the late 1920's, . . . the Branch consisted of one office and one laboratory, both located in Washington. Total personnel was about six and total funds for Branch activities was about $20,000 per year."

W.W. Hastings, District chemist for Texas, who also had responsibilities for water-quality programs in Oklahoma, Arkansas, and Louisiana, joined the Branch headquarters staff in April 1948. In 1949, he assumed charge of the Technical Reports Section and was promoted to assistant chief of the Branch in June 1951, a position he held for the balance of the decade. In 1952, W.H. Durum succeeded Hastings as chief of the Technical Reports Section, and remained in that position for the balance of the decade.

W.F. White, Jr., transferred to the branch chief's staff in August 1944 and without further change in headquarters, served as the District chemist for Pennsylvania and later also for Ohio (and concurrently supervised the Washington laboratory activity) until May 1948, when he was designated Regional chemist for the Northeastern States (Maryland to Maine). In June 1951, White became the first chief of the Chemical Quality Section and remained in that position for the rest of the decade (oral commun., 1981). E.W. Lohr, a member of White's staff, had immediate charge of the Washington laboratory. The laboratory, which had been located in a part of the space occupied by the Division and Branch Headquarter's staff

for many years, moved in June 1951 to larger quarters in the old Post Office building, 12th Street and Pennsylvania Avenue, N.W., Washington, D.C. (WRD Bull., Aug. 1951, p. 49). D.E. Weaver was then in charge of the laboratory.

In June 1953, R.B. Vice transferred from the Regional office (Missouri River basin program) of the Branch in Lincoln, Nebr., to become the first chief of the Physical Quality Section. Vice was in charge until April 1957 when he was placed in charge of the newly established Planning Section. The Physical Quality Section was discontinued at that time.

The Headquarters staff as of January 1948 consisted of 17 employees, of which 10 were in professional grades. This included personnel in the Headquarters laboratory. By July 1, 1957, the staff consisted of 11 professional and 11 other employees, not including the laboratory, which was staffed with 8 chemists, plus 5 supporting personnel.

PROJECTS OF NATIONWIDE SIGNIFICANCE

In addition to the Branch accomplishments that will be described in Parts III, IV, and V, a number of achievements of nationwide significance are noteworthy. They include the following:

- A compilation of the chemical characteristics of the water supplies for 1,315 of the larger cities of the United States entitled "Industrial Utility of Public Water Supplies in the United States, 1952" was published as Water-Supply Papers 1299 and 1300 by E.W. Lohr and S.K. Love (Durum, 1978, p. 158);
- The Branch participated in the Department of the Interior's (USDI) saline-water conversion program by giving assistance and advice on specific problems and in studies of the occurrence and chemical quality of saline-water bodies in certain areas;
- A network of sampling stations was maintained on western streams to determine mineral content and thus help to ensure successful continued operation of irrigation projects (Secretary's Ann. Rpt., fiscal year 1955, p. 162);
- Because of impairment of the quality of natural waters by various types of industrial and agricultural pollution, the Branch broadened its studies in 1953 to identify mineral pollutants, including analyses for trace metals and minor constituents in solution (Secretary's Ann. Rpt., fiscal year 1953, p. 271);
- By 1955, water-temperature measurements were included as a regular part of all investigations of chemical water quality. Variations in temperature were found to be important to waterworks, industry, fish culture, sediment transport studies, et cetera (Secretary's Ann. Rpt., fiscal year 1955, p. 163);
- The Branch began studies of background radioactivity of water resources in 1952 with the expectation that the results would be of value both in locating sources of fissionable material and in the appraisal of water resources for public, industrial, and agricultural use (Secretary's Ann. Rpt., fiscal year 1952, p. 244). Durum recalls (written commun., 1981) that these were initially "begun in both the Washington, D.C., and the Denver, Colo., laboratories under the supervision of Frank Barker and L.L. Thatcher, respectively. The principal early development and thrust was through Barker, and Thatcher was mainly responsible for methods research." Durum further states (1978, p. 178) that "radiochemical studies had proceeded sufficiently by 1955 to allow firming up of Branch objectives in this field. One phase of the work was to determine nationwide the distribution and concentration of natural radioactivity in water resources;"
- The Division's search for a better method of tracing the movement of surface and ground waters led to the use of radioactive isotopes during the 1950's because small amounts of these tracers were easily detected and measured. W.A. Beetem used this method in studying the movement of pollutants in the Mohawk River in New York; and
- H.A. Swenson, in his administrative report on "Water Quality and the USGS, 1960," states that the QW Branch published 123 reports during 1947–58, of which 65 were "area reports on contributions to water quality, 24 were annual reports on quality of surface waters, 11 covered the industrial utility of public water supplies, and 8 were on the subject of fluvial sediments or erosion."

Technical Coordination Branch

Known as the Water Utilization Branch until 1948 and then reorganized in May 1956 as the General Hydrology Branch, the TC Branch existed entirely within the Paulsen decade. Although comparatively small as measured by the number of personnel, the Branch played a vital leadership role not only in shaping the Division's new programs but also in formulating its policy decisions during the decade. From the beginning of the decade until his retirement at age 70 on December 31, 1955, R.W. Davenport served not only as the Branch chief but also as acting Division chief during Paulsen's many visits to field installations, meetings with cooperating officials, and conferences of water-related organizations. Davenport had an early career in the field work of the Division and long association with Survey headquarters activities and early interagency events that led to additional program responsibilities for the Division. He was widely respected also because of his mature judgment, which Paulsen sought

frequently. In his memorial for Davenport, W.B. Langbein wrote (*WRD Retirees* newsletter, Feb. 1977, p. 3), "Royal W. Davenport was near, if not the last, of that generation that created the Water Resources Division as we knew it." Upon his retirement, Davenport was succeeded by C.C. McDonald, who remained in that position for the remainder of the decade.

HISTORICAL BACKGROUND

By Walter B. Langbein

In 1948 (Survey Order 173), the old Branch of Water Utilization became the Branch of Technical Coordination. The former name had its origins in 1910 in the work of the WRD on the classification of the Public Domain (Follansbee, v. I, p. 249) and from then on it fulfilled the work (Follansbee, v. 1, p. 443–445) described by its title, "Water Utilization," under the leadership of E.C. LaRue and N.C. Grover until it merged with the Division (Branch) of Enlarged and Stock-Raising Homesteads in 1917. In those early years, "water utilization" embraced the idea of laying out the potentials for water use (see WSP 395, 1916). The Branch was resurrected in 1931 as a post for R.W. Davenport who had completed a tour of duty at the Federal Power Commission, which until 1931 was an "interagency" organization staffed by detailees from three departments—Interior, War (Army), and Agriculture.

Under Davenport, the work of the TC Branch was chiefly comprised of a diverse set of surface-water matters—international boundary with Canada (international gaging stations, backwater and flow depletion studies for the International Joint Commission); relations with the Federal Power Commission (supervision of stream gaging); flood reports; and especially the preparation in the early 1930's of two research reports funded by the Public Works Administration (PWA)—WSP 772 (1936), by W.G. Hoyt and others, on relations between rainfall and runoff, and WSP 771 (1936), by C.S. Jarvis and others, on flood frequency. ("Major" Jarvis, as he was usually called, was a PWA employee hired for this task.) These reports were followed by others on the major floods of 1936 and 1937, which were also funded by PWA.

In 1941, Hoyt obtained an allotment of funds from the USDI for field investigations and reports for the Department's newly launched program of soil and moisture conservation on the vast western acreage under its jurisdiction. Hoyt's interest in the public domain stemmed from his association with the Survey's Conservation Division. These studies, under Davenport's and Hoyt's leadership, set the basis for the work of the new TC Branch. The staff had the responsibility for "technical" objectives of its program. Davenport had responsibility for "coordination" through his rapport with Paulsen. The TC Branch in turn evolved into a broader sphere of work that required new organizational changes. It became the General Hydrology Branch during the last year of the Paulsen decade.

The TC Branch, as conceived by Davenport, had the responsibility to explore and develop ways by which the Division could better adapt to new demands that went beyond the traditional roles of the three operating branches, and to represent the Division in interagency relations on technical matters considering the Division as a whole. Davenport's small but effective staff was composed of hydrologists who were carefully selected for their interest and creative abilities in identifying and placing in useful formats those products of hydrology that were needed but not yet used by the increasingly water-oriented industrial economy and by those attempting to solve land and water problems.

HEADQUARTERS ORGANIZATION AND STAFF

By Walter B. Langbein

At its inception, the senior technical Headquarters staff consisted of W.B. Langbein, W.S. Eisenlohr, G.E. Harbeck, Jr., and A.O. Waananen. Langbein was given considerable latitude to assist and participate in the entire program of the Branch, publishing 14 reports during the decade. Eisenlohr was specially interested and experienced in the preparation of technical reports, and Waananen "ran" the office, taking care of work in connection with the International Boundary (United States and Canada) and the Federal Power Commission as well. Harbeck, a hydraulic engineer trained as a meteorologist during World War II, served in the Research Section where he developed methods for measuring evaporative water losses, and soon achieved an international reputation for his research in this field. Mrs. May Theisen, secretary to Davenport, and Mrs. E. Patton, scientific illustrator, were equally essential to the work of the Branch.

The work at Headquarters was conducted by three sections that had been activated at different times as the program evolved. The Research Section was organized in 1949 with Langbein as section chief, Harbeck as engineer, and Patton as scientific illustrator. Personnel of this section undertook supervision of the Lake Mead sedimentation and water-loss studies, the soil and moisture program, studies of data networks (results presented in a book commissioned by the Conservation Foundation in 1956 and published in 1959, "Water Facts for the Nation's Future," by W.B. Langbein and W.G. Hoyt), and similar operations.

A Technical Reports Section was activated in 1950, comprised of Eisenlohr as chief, Ms. E.W. (Wilson) Coffay as staff engineer, and several editorial clerks and typists. Personnel of this section reviewed and processed the many reports that were produced in Washington and in the field, and prepared the monthly Water Resources Review (which had been prepared by Langbein and Harbeck until about 1950).

A Water Utilization Section was established in 1952 for the particular purpose of inventorying the amounts of water used in various sectors of the national economy and in various regions and States. Personnel of the section also conducted intensive studies of the water used in aluminum, rubber, and other key industries, and water used in major industrial areas (see pt. II, the Federal program.) Under J.B. Graham as section chief, the staff included K.A. MacKichan, O.D. Mussey, E.H. Sieveka, and H.L. Conklin. Graham resigned in 1954 and MacKichan succeeded him in an acting capacity until the section was discontinued in 1955.

In its relations with the field projects, the TC Branch did not operate as a tightly organized unit with well established and continuing District or field offices as did the three operating branches. Rather, it functioned as a unit which directed various projects—namely, Soil and Moisture (S&M) (H.V. Peterson); River Morphology (L.B. Leopold and M.G. Wolman); Water Losses (G.E. Harbeck); Glaciers (M.F. Meier); and Water Utilization (K.A. MacKichan). Each project functioned more or less separately from the others, even though two or more activities at times were being conducted in the same vicinity. Each looked to the Washington, D.C., office for guidance, but each was expected to exercise great freedom to develop the work at hand. It was customary for Washington personnel to spend summers working in the field with project research teams.

SUMMARY OF MAJOR PROJECTS

By Walter B. Langbein

Not falling within the traditional roles of the operating Branches, the projects were considered transitional until they could be absorbed within the operating programs, which, however, did not take place until the succeeding decade. Background information on each is given below.

Soil and Moisture Conservation Program—Studies were begun in 1941 in order to provide hydrologic information and guidance to the land agencies of the Department with respect to water supplies and the abatement of erosion. The most "operational" of all of the TC projects included field investigations for water-resources development in the Public Domain. These are identified in Part III, "Soil and Moisture Conservation Program," and later in Part IV under the specific Western States in which soil and moisture personnel were headquartered.

Lake Mead Sedimentation Survey, 1947–49—Funds were provided by the U.S. Bureau of Reclamation to determine the amount of sediment impounded by the reservoir since its completion in 1935 (see pt. III, Lake Mead sedimentation survey).

Water Loss Project—Studies that showed the importance of evaporative loss in the water balance of Lake Mead were also launched by the Lake Mead Sedimentation Survey. The research involved was mainly to develop practical means for applying a large body of theory for determining the actual loss of water from reservoirs and lakes (see pt. III, water loss projects, Lake Hefner and Lake Mead). Most of this project was funded by the U.S. Bureau of Reclamation and conducted in technical cooperation with the U.S. Navy and the U.S. Weather Bureau.

Water Use Inventories—This project was begun in 1950 to fill a gap in the national water statistics, those of water use that could be compared with those of water supply (see pt. II, the Federal program).

River and Land Morphology—Division personnel had long been measuring river depths, width, slopes, and velocities, but had not examined the geomorphologic relations among these factors. An investigation of the interrelationships was begun when L.B. Leopold joined the Division in 1949 (see pt. III, river and land morphology).

Glaciers—Francois Mathes of the Survey's Geologic Division had been for many years the leader of research on glaciers. His annual reports on glaciers published by the American Geophysical Union were widely read and influential. When Mathes died in 1948, he left a gap in a field ("frozen water") with which the Survey, especially the WRD, needed to maintain contact. With this in mind, the Division in 1956 hired M.F. Meier, then a graduate student, to continue the research. Meier's first Survey assignment was to complete his doctoral dissertation on the Saskatchewan Glacier. His research on the mechanics of glaciers, their alimentation and ablation, became essential to an understanding of their relation to water resources and climate research.

Flood Insurance and Flood Mapping—Soon after the 1951 floods on the Kansas and lower Missouri Rivers, President Harry S Truman submitted a proposal to Congress (82d Cong., 1st sess., 1951) for a national flood-insurance fund. As reported in hearings on the bill, differing points of view were presented by representatives of the Budget Bureau, private insurance companies, and the hydrologic community. The

proposals for flood insurance put forward by the hydrologic community maintained that the rates charged should be in proportion to the hazard so that prospective builders would have a tangible measure of the cost of building in a flood-plain area. The Survey's responsibility was to show that the necessary records and techniques were in fact available (U.S. flood history is well documented). Although the proposal was not acted on by the 82d Congress, there was considerable discussion of flood insurance in the press and in the technical literature. Among the literature was a paper by W.B. Langbein (Flood insurance, Jour. of Land Economics, v. 29, p. 323–330, 1953) that gave the message that the availability of long-term flood records were sufficient to warrant flood insurance as a means of promoting wise use of the floodplain.

A new bill was proposed by the President on May 5, 1952, which, like the first, assigned responsibility for flood insurance to the Reconstruction Finance Corporation (RFC) because it had administered the War Damage Indemnity Program. Several conferences were held between WRD and senior staff members of the RFC, U.S. Army Corps of Engineers, U.S. Weather Bureau, U.S. Coast and Geodetic Survey, U.S. Department of Agriculture, and the Bureau of the Budget.

The first flood insurance bill was finally enacted in 1956 (P.L. 1016, 84th Cong., 2d Sess.) in response to the devastating floods of 1955 in heavily populated areas of New England, Pennsylvania, and California. The Act assigned administration of the program to the Housing and Home Finance Agency, which invited several members of the hydrologic community to discuss the technical problems of flood insurance with personnel of that agency and with representatives of the fire insurance industry. More detailed information is available in a memorandum from the "Work Group on Flood Insurance" to the Insurance Commission, dated February 1, 1957, signed by senior staff of the Corps of Engineers, U.S. Geological Survey, U.S. Coast and Geodetic Survey, and the U.S. Weather Bureau. That memorandum pointed out that the determination of rate structure would be the key item in the success or failure of a flood-insurance scheme (see also statement on January 27, 1956, by W.B. Langbein, Congressional Documents, Hearings on Disaster Insurance, Committee on Banking and Currency). Again, different points of view were not resolved and, by early 1957, the program had not received its initial appropriations.

The Flood Insurance Act of 1956 was nevertheless the incentive for several studies initiated by the Division to demonstrate how hydrologic data and analysis could be applied to appraising the flood potential and risks inherent in occupation of the floodplain. An example of this, although not in print during the Paulsen period, was a study of flood-plain planning conducted in cooperation with the State of Pennsylvania by S.W. Wiitala, K.R. Jetter, and A.T. Sommerville (WSP 1526, 1961).

The program remained in abeyance during the remainder of the Paulsen years. Meanwhile, the Division began publishing its flood data in map (Hydrologic Atlas) form which was adaptable to an insurance program. The first such map was for the Kansas River at Topeka, Kans. (HA-14, 1959), and others soon followed. This mapping program was given greater support by House Document 465, and by the National Flood Insurance Act of 1968 (P.L. 90–448), which at last recognized hydrologic evaluation of flood risk as its basic principle (see also "Flood Studies Led to National Flood Insurance," Civil Engineering, p. 89–94, Feb. 1979).

Program Control Branch

The PC Branch was formally established in November 1951 as a part of the 1948 reorganization of the national headquarters of the Division. The Branch was a staff organization providing coordination and guidance to (1) planning, development, organization, control, and financing of work programs, (2) liaison among local field offices of the three operating branches, and (3) coordination of relations with Federal and State cooperating agencies.

The relatively long period between the creation of the PC Branch "on paper" as a part of the 1948 Division reorganization and its formal activation was largely because of the Congressional limitation on headquarters personnel. Prior to the formal establishment of the Branch, G.E. Ferguson, who was to be its chief, and other members of the administrative staff of the Division chief, had developed and conducted most of the Branch functions following Ferguson's completion of the 1948 organization plan in 1947. The staff of the fully activated Branch, as shown in the Division's personnel listing as of January 1, 1952, included more than 30 persons.

Among the PC Branch officials listed who had or were to have extended careers with the Division were Frank Barrick, Jr., administrative officer, who had joined the Division in June 1948 following earlier employment (1938–43) in the Survey's Division of Accounts, which was followed by service with the Air Corps and a period with Interior's Office of Land Utilization; M.A. Allen, who had joined WRD's administrative staff in 1931, and was in charge of the Adminstrative Services Section (PC) and in equivalent positions during and beyond the decade; C.M. Roberts, a career ground-water geologist, who was a member of the staff from October 1948 until

August 1951; C.W. Morgan, an accounant, who transferred to the Division in January 1949 and had charge of the Fiscal Management Section for the balance of the decade; and K.B. Young, an engineer, who transferred from the SW Branch Headquarters staff in October 1951 to direct the Program Development Section and later (1956) the Planning Section (WRD). While in the Program Development Section, Young prepared what was to be the Division's first manual on program procedures. Despite the fact that it was never formally approved by the then Division chiefs, the manual was extensively used far beyond the end of the decade.

H.A. Swenson, chemist (QW), Lincoln, Nebr., was on detail to the pre-PC staff for special studies from December 1951 to June 1952, and G.D. DeBuchananne, ground-water geologist, transferred from the Tennessee District (GW) to head the Program Coordination Section from June 1952 to July 1955. J.C. Kammerer, ground-water geologist, transferred to the Program Coordination Section in November 1953 and remained until September 1955 when he joined the headquarters staff of the TC Branch. S.K. Jackson, District chief, SW, from Oklahoma, also assisted the Branch while he was on detail during the early 1950's.

The greatest achievement by Branch personnel during its relatively brief existence was the establishment of modern and more effective systems of program analysis and documentation by which field projects were effectively reviewed by the Washington office staff, used in annual budget presentations to Congress, and later placed in proper priority for funding. In earlier years, the CHE had personally directed a single allocation of funds to each Branch chief. Suballocations were carried out within the Branch organizations.

Beginning in 1948, the newly assembled programming staff that later made up a part of the PC Branch began to develop forms by which projects could be described in a fairly uniform manner, to canvass the field offices for information to determine the degree of which water data were needed and used in the economy (for justifying budget requests), and to arrange for "around the table" discussion by representatives of all branches for all new projects proposed by any one Branch (as a base for equitable allocation of funds). The first two steps continued in use during the decade, but the third was so great a change from tradition that it brought a reaction from one or more of the branches. As a result, a memorandum signed by Paulsen established an interbranch committee to assist him in the the allocation of funds. The decade ended before steps were approved that required District offices in the same State to share information about projects that were proposed or underway.

The preparation of effective annual budget estimates required far more program data than had earlier been available. The collection of program statistics thus became a major endeavor of the Branch staff. In 1949, the first relatively detailed field inventory of water records collected and investigations in progress was compiled from District responses to an inquiry. The information was used not only in budget preparation but also in Division administration (WRD Circulars dated July 12, 1948, and June 20, 1949). The statistics were updated annually.

The magnitude and nature of requests for hydrologic data were effective in justifying annual budget presentations. A format for recording such requests was developed (WRD Circular, March 30, 1951). The results were so impressive that the recording period was extended (WRD Circular, May 29, 1951) and quarterly reports were requested (WRD Circular, Aug. 7, 1951). Reports were discontinued by WRD Circular dated July 2, 1952, because "the source and volume of such requests had become established," but were activated once again by WRD Circular dated September 14, 1956.

A special analysis was made early in the decade as to the degree water data were useful to activities beyond those for which they were collected. This was accomplished by questionnaire to District offices. The findings showed that if water data were collected by each Federal, State, and municipal agency and used on a single-purpose basis, the present program would cost nearly three times as much (Estimates of Appropriation, fiscal year 1950, v. 7, pt. 2, p. 223–224; Record Group 57, Budget and Finance Branch Estimates of Appropriation 1926–49, Box 5, National Archives).

Another activity that required considerable effort by the Branch staff was in the development of and assistance to State Councils. This activity is described in Part II.

In June 1956, L.B. Leopold succeeded Ferguson as chief of the Program Control Branch and, in the fall of that year, the Branch itself was discontinued as a part of the reorganization of 1956. These and other changes were described in the Department's press release dated September 27, 1956, and are covered in Part II.

Growth of Interbranch Activities and Organization

It was obvious to some in the Division, even at the beginning of the decade, that its organizational structure of the past was ill-suited for the future. In earlier years, each Branch was able to maintain investigative programs that had relatively little relation to projects conducted by other branches in the same locality. But as the number and scope of investigations increased and as water resources were subjected to more intense investigation, the program and project objectives of the three branches began to merge and sometimes overlap. Questions were

raised of interbranch jurisdiction with no local (field) organizational entity present to decide on the issues.

Competition between operating branches for funds needed to finance the cooperative programs with State agencies was also on the increase. Many State agencies provided local support for projects conducted by the districts of two or even three branches. Rivalries sometimes developed, which reduced the desired degree of liaison and coordination between District offices and some opportunities for coordinated programming. For the most part, interbranch relations remained good and, as shown in District activity statements in Part IV, chiefs of well-established districts were most helpful in arranging local programs to be administered by other branches.

Although the District staffs and budgets of the SW Branch usually were large enough to support an efficient administrative section, the GW and particularly the QW Districts in many States were composed of only a few persons with limited budgets. That these weaknesses in the field organization did not go unnoticed is evident from a statement (WRD Circular dated Nov. 30, 1951) by Paulsen to District officials:

> "You should be aware that the Division is under increasing criticism by investigators of the Interior Department and Bureau of the Budget and others who feel that our intra-State organization is weak, particularly with respect to (1) coordination between Branch activities, (2) Division-wide representation in our relations with other agencies, and (3) economical and efficient 'housekeeping' activities."

Concurrently with these early efforts to define and implement organizational changes to strengthen the Division's ability and efficiency in the pursuit of its program goals, the Director and Assistant Director were making progress toward reshaping the Survey's field organization for somewhat similar reasons. Former Director Nolan recalls (written commun., Nov. 1985) that the pressures for change were largely due to the greatly increased size of all of the Survey units, with corresponding increased space requirements, the growing complexity of operations with attendant need for costly laboratories and equipment, as well as the need for more coordination of what had been (in each Division) several relatively independent units. The moves were triggered by the availability (post-war) of World War II-era facilities. A secondary incentive was to establish more firmly an effective Bureau-level regional organization with more opportunity for interdivisional field liaison while still retaining the traditional Division-level lines of direction from Washington, D.C., headquarters.

The Survey's newly established "field centers" at Denver, Colo., and Menlo Park, Calif., were ready for occupancy in early 1953 and, by memorandum dated December 1, 1952, the Director asked the Division chiefs to begin the steps by which field units would be transferred to these centers as it became feasible to do so. The resulting moves of Division personnel in those States are covered in the appropriate District activity statements.

During 1952 and 1953, a number of senior officials of the Division were invited to comment on the type of field organization best suited to future needs after G.E. Ferguson presented (memorandum dated Jan. 25, 1952) Paulsen with a plan providing for a consolidation of the local District activities of each Branch under the supervision of a Division-level District chief. In a later memorandum (March 10, 1953) to Paulsen, Ferguson stated that "during the past several months, branch chiefs, assistant branch chiefs, and certain key personnel in the field have considered and discussed the need for field reorganization . . ." and presented a number of ways to strengthen field coordination and performance that might meet with the general approval of the Branch chiefs. Most of the recommendations were adopted, as shown in a WRD Circular dated September 24, 1953, which is described in Part VII.

Although technically possible to correct known weaknesses through changes in organizational structure, Paulsen was reluctant to support changes sufficiently drastic to invite loss of morale at the Headquarters and field levels. He chose instead a series of gradual steps that, hopefully, would condition the personnel for such a change at a later date. As it happened, that change was well beyond the end of the decade and his career.

In late summer 1953, Paulsen appointed a special committee to study the organization of the Division. Its members were W.W. Hastings, H.B. Kinnison, and H.E. Thomas. According to Paulsen's letter dated July 27, 1955, to Acting Director Nolan transmitting the Committee's recommendations, the material was used primarily in furnishing information requested by the "Van Pelt Committee" (see pt. VII), which at the time was also reviewing the Survey's organizational structure for the Secretary.

DEVELOPMENT OF THE STATE COUNCILS

One of the first steps toward the integration of certain field activities of the branches was the consolidation of "housekeeping" functions for District offices of different branches that were located in the same building or even in the same city. Credit for the first formal consolidated fiscal and clerical unit apparently should go to those in charge of Branch activities at the Missouri River basin program headquarters in Lincoln, Nebr. P.C. Benedict (QW), D.D. Lewis (SW), and G.H. Taylor (GW)

arranged to have Taylor's administrative staff conduct bookkeeping and clerical services for the Lincoln headquarters of all branches. In 1948, the group was reestablished as the Fiscal and Clerical Section of the Division and placed under the direction of the elected chairman of what was to be the first WRD Council. J.R. McLaughlin, assisted by L.M. Stephens, remained in charge of the section throughout the decade.

Another successful effort in consolidation of field accounting that dates back to 1948 or earlier was in Utah where one group served not only the WRD offices but also those of the Geologic Division. This service was under the supervision of T.S. McIlhenny, who reported to R.R. Wooley, district engineer, TC Branch.

Encouraged by these successful experiences, Paulsen issued a directive (WRD Circular dated May 6, 1949) requesting that Water Resources Councils be established no later than July 1, 1949, in all other States where they "would serve a practical purpose" in setting up and administering local "housekeeping" functions, in integrating program planning, and in coordinating project execution. The chairman and vice-chairman of each Council were to be elected by the District chiefs as council members. (The term "Council" was adopted because of the prevailing public feeling against attempts to "govern by committee.")

The first 2 years of experience with Council performance was reviewed in a WRD Circular dated November 30, 1951, which reported that, although Council activities had in general been satisfactory in States having two or more District offices, more attention should be given to project planning. Council members were urged to attempt to achieve the same degree of "balance" (relative emphasis on component parts of a project or program to provide optimum value) in interbranch programs as existed in intrabranch studies. The Circular also specified a certain format for preparing minutes of meetings and stated that such would be carefully reviewed in the Washington, D.C., office as a means of identifying Councils whose performance needed strengthening.

By February 1952, the Councils were established and active "in almost all areas" (WRD Circular, Feb. 14, 1952) and the prescribed minutes of Council meetings were being carefully reviewed, primarily in the PC Branch. WRD Circular dated July 8, 1952, acknowledged, as an example to other Councils, a commendable approach to achieving better "balance" (between local districts) in program planning that H.M. Stafford had developed under the encouragement of the California Council. The California Council also held a conference in October 1952 that was attended by personnel from all three local districts.

WRD Circular dated January 2, 1953, advised that chairmen need not rotate and might, when so elected, succeed themselves. They were required, however, to be well informed as to the entire program and this experience was not often gained in less than a year of service in a District. Later (WRD Circular dated Sept. 26, 1955) it became necessary to restrict a chairmanship to resident council members available to represent the Division on short notice. Some District chiefs had charge of Branch programs in several States and so were resident members of one council but non-resident members of others.

Toward the end of the decade, when the Division had established field regions called "areas," the council chairmen were asked to send minutes of meetings to the newly appointed "Division hydrologists" (WRD Circular dated Oct. 26, 1956). Soon after (WRD Circular dated Dec. 21, 1956), the Councils were asked to become the point of contact between the Division hydrologists and the local districts in the development of District plans and programs. The Councils continued to be so used until the mid-1960's when local offices in a State were consolidated into a single Division-type District.

The Councils served well as a transition from the strictly Branch-type field organization to the single Division-type District. The effectiveness of individual Councils depended largely on the council membership, especially the chairman. Responsibilities of the District chief to maintain Council objectives were technically voluntary in that they were "not in his job description;" however, the attitude typically ranged from willingness to enthusiasm.

OTHER STEPS TOWARD INTEGRATED FIELD PERFORMANCE

Another early step toward conditioning the branches for integrated performance occurred in April 1950, when Paulsen established a Water Utilization Committee to "promote and assist in the planning and preparation of reports on the water resources of specific areas" (WRD Circular dated April 3, 1950). Membership consisted of W.F. Guyton, GW Branch (Chairman); W.W. Hastings, QW Branch; and G.C. Stevens, SW Branch. The committee was to be under "the general guidance of the TC Branch." Guyton resigned in December 1950 to begin a career as a private consultant. Committee activity also may have been short-lived because, as expressed in the Survey report to the President's Water Policy Commission in mid-1950, leadership in report compilation was best done by designation of individuals (WRD Circular dated June 5, 1950).

In fall 1953, prompted by the scrutiny anticipated from the newly established "Secretary's Survey Committee on USGS" (pt. VII), a new statement of Division objectives was sent to the field (WRD Circular dated Sept. 24, 1953).

It called for "the housing of all of the District offices of the Division for every State, under one roof," preferably at the State capitals or in proximity to the principal cooperating State agency. So that lack of local funds would not be an obstacle to prompt action, a contingency fund was set up to defray moving costs where necessary. The Circular further stated that "the concept of 'Branch ownership' in relation to space is not tenable for the future." Once moved to adjacent space, separate "housekeeping" units were to be consolidated. The statement also called for the joint planning of projects by District chiefs within a State, even though the project was to be accomplished by a single Branch. A single cooperative agreement would preferably be written for each cooperating agency instead of one for each Branch, and the collection of routine water records would be assigned to the field staffs who could perform the task most efficiently, regardless of Branch.

Another portion of the policy statement was intended to dispel fears that successful careers had to be via the supervisory route. It stated that those having sufficiently strong scientific capabilities might have a grade level equal to or even greater than their supervisors. The final provision called for greater emphasis on pure and applied research to achieve a better program balance. These efforts to give better recognition to the Division's most capable scientists and thus to strengthen scientific performance were in keeping with well-established Survey policy that had been the subject of negotiations not only with the Department, but also with the Civil Service Commission (written commun., former Director Nolan, 1985). The Circular was prepared and issued shortly after Director Wrather announced that the Secretary of the Interior, newly appointed after a change in party administration, had set up a committee to investigate the activities of the Survey.

REORGANIZATION OF 1956

The second major reorganization of the Division during the decade was announced internally by Paulsen's memorandum dated June 14, 1956, to District supervisors and staff officials. It was largely the product of L.B. Leopold, who had transferred from the TC Branch to become chief of the PC Branch in June 1956, and R.L. Nace, chief, Idaho District (GW), who had been on detail to the Washington, D.C., office. (Leopold and Nace were being recommended by the Director to become the chief and associate chief, respectively, of the Division upon the retirement of Paulsen at age 70 on April 30, 1957. Their transfer to key administrative posts nearly a year in advance of that date gave Director Nolan a working relationship with the Division that he thought advantageous to his and former Director Wrather's long-standing aspirations to strengthen the WRD by giving more emphasis to basic research and less to "service-type" activities.) The reorganization and the staff changes in top positions were announced by Interior Secretary F.A. Seaton by press release dated September 27, 1956.

Unlike the reorganization of 1948, the new 1956 structure introduced a change in field organization in that it established a new intermediate ("area") level of supervision between the District offices and the Branch chief. It also created, at each of the four area headquarters, a "Division hydrologist" whose responsibilities were defined in detail in Paulsen's memorandum to District and staff officials dated March 21, 1957. Directly responsible to the Division chief, the Division hydrologists were "program officers at their respective field centers." They were to represent the Division in a "line" capacity, essentially on matters of common concern to the branches. Working with the local Branch area chiefs, the Division hydrologists were responsible for developing recommendations for sound effective programs in their area. Figure 2 shows the boundaries of each area.

A second major change brought about by the reorganization of 1956 was the establishment of two assistants to the Division chief, one for programs and development (essentially the functions of the discontinued PC Branch), and the other for operations. Primary features of the organization chart used in release no. 23 (Apr. 4, 1956) for the Interior Department Manual is reproduced as figure 3.

As stated earlier, the initial staff changes under the reorganization were announced through the Interior Department's press release dated September 27, 1956. Leopold and Nace had been designated assistant chiefs of the Division for program and development and for operations, respectively. C.C. McDonald became chief of the newly created General Hydrology (GH) Branch. Frank Barrick, Jr., was named administrative officer. A.M. Piper and G.E. Ferguson were appointed as Division hydrologists for the Pacific Coast area and the Atlantic Coast areas, respectively. The remaining Division hydrologist posts were filled soon after: H.C. Beckman for the Mid-Continent area (July 1957) and S.K. Jackson (Apr. 1957) for the Rocky Mountain area.

The Branch chiefs concurrently were selecting those who were to fill the positions of Branch area chief. As of the end of the decade, the following appointments had been made: for the Atlantic Coast, H.C. Barksdale (GW); for the Mid-Continent, no appointments; for the Pacific Coast, H.B. Kinnison (SW) and H.E. Thomas (GW); for the Rocky Mountain area, F.C. Ames (QW), F.M. Bell (SW), S.W. Lohman (GW), and H.V. Peterson (GH).

The Atlantic Coast headquarters was in a part of the recently rented space in Arlington Towers (renamed

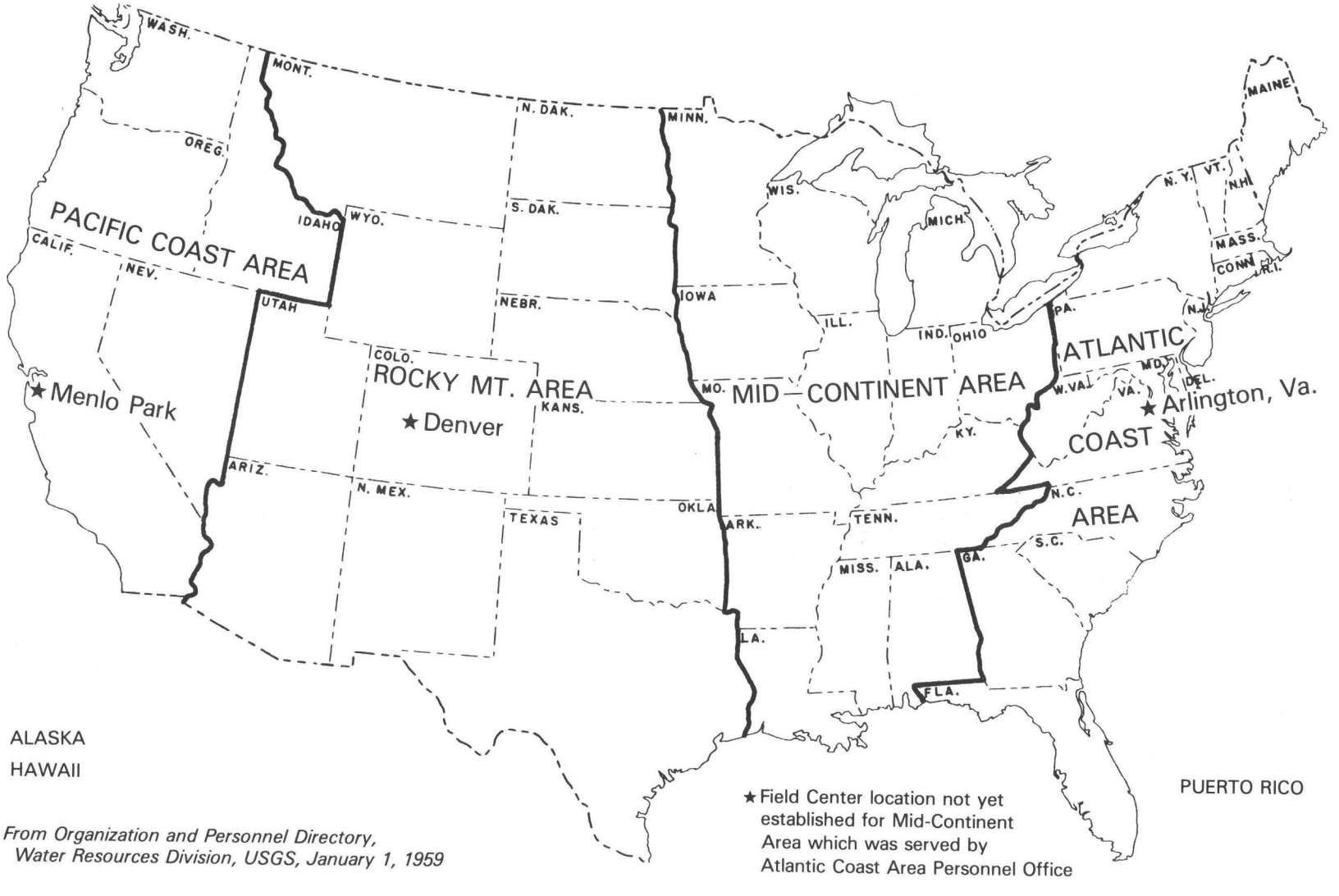
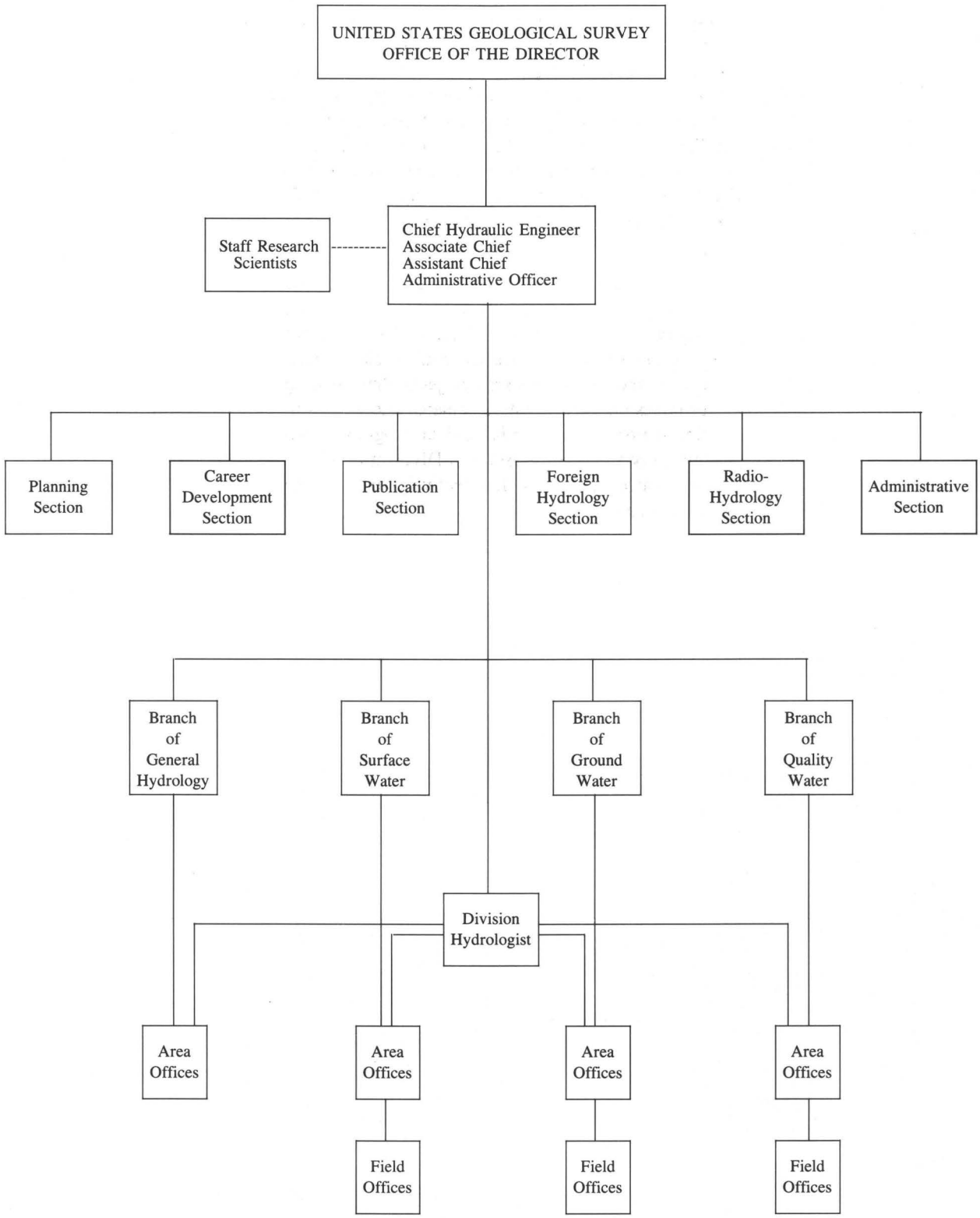


Figure 2. Geographic areas and field center locations, 1956.



(From WRD Organization and Personnel Manual July 1, 1957.)

Figure 3. Plan of organization, 1956.

"River House" in the early 1980's), an apartment complex in Rosslyn, Arlington County, Va. Space for the Pacific Coast and the Rocky Mountain areas headquarters staffs was in the Geological Survey field centers in Menlo Park, Calif., and Denver, Colo., respectively. In the Mid-Continent, Beckman remained at his former headquarters at Rolla, Mo., through the end of the decade. The objectives of the organizational changes were summarized by Director Nolan (from House Hearings on the fiscal year 1958 budget, p. 5) as follows:

> "To meet its responsibilities in the phase of water economy which the Nation is now entering, the Geological Survey, during the 1957 fiscal year, began a reorganization of its water resources program so as to emphasize and develop fundamental and applied research projects, thus assuring progress on those fronts commensurate with continued progress in our basic-data program. Concurrently the Water Resources Division itself was reorganized to enable it effectively to meet the challenge of the future."

PART II—THE NATIONAL PROGRAM, ITS NATURE AND FUNDING

The term "national program" as used in this volume denotes the total nationwide activity of the Division. During the decade, its two primary elements, systematic data collection and project investigations, did not change greatly from earlier years except that growth continued. The data-collection activity is illustrated in table 3. The period of time required to obtain adequate information on a specific type of data at a given location varied from a period of months to many years. The results normally were tabulated in special series of reports that required a minimum of text.

The findings from the project investigations were expressed through reports that typically described the presence or movement of water. Sufficient information also was given about the geologic and physical environment to assist in developing water supplies or in resolving various water problems. Problems included those associated with water supply, flood protection, and pollution. Some projects were research oriented. Water records often provided needed background information for hydrologic investigations, as did geologic reports and maps from the Geologic Division and topographic maps from the Topographic Division (now National Mapping Division).

The composition of the national program was by no means simple, and its method of funding was unique, especially when compared with agencies outside the U.S. Geological Survey. The work of the Division was accomplished under four major programs. The largest, the Federal-State program, commonly referred to as the "co-op" program, was made up of many field projects, each of which was supported by contributions of State or municipal funds nearly always "matched" by equal or slightly lesser amounts of Federal funds appropriated for that specific purpose. During the decade, the cooperative program (local, plus Federal funds) used slightly more than half of the funds available to the Division from all sources.

Next in size was the work conducted for, and with funds provided by, other Federal agencies. Such funds were transferred to the Survey under the authority of the Economy Act (see pt. II, Investigations funded by other Federal agencies). This work comprised about 28 percent of the total program of the Division during the decade.

Third in size was the Federal program, which was supported by the remaining portion (nearly one-half) of the direct appropriation after the Federal funds designated for matching State and municipal funds were allocated to the co-op program. The Federal program, which the Division had relatively wide latitude in shaping, accounted for about one-fifth of the overall activity.

Two other very small increments in the national program were the soil and moisture conservation program and the permittees and licensees of the Federal Power Commission. Permittees were supported by a separate item in the Survey's appropriation bills, and licensees used contributions from the various power companies. Together they accounted for less than 1 percent of the Division's total funds.

Each of the above segments of the national program were in existence prior to, and continued during and beyond, the decade. They did vary in magnitude, depending on budget proposals, congressional appropriations, and funds available from States and municipalities and from other Federal agencies. Some secondary items were eliminated in favor of emerging items of greater priority and some were lost because of changes in budget patterns.

The foregoing description of the elements of the national program, as used in the allocation of funds received, was somewhat different in terminology from that used in annual budget presentations. The budget format was required largely to conform to authorizing legislation. Tables 4 and 5 show a cross-section of the funding from annual budget presentations, one near the beginning and the other near the close of the decade. Note that the long-standing term "gaging streams appropriation" was dropped during the decade. The events leading to the appropriation by Congress for each fiscal year of the decade are summarized in Part II under Annual Budgets and Congressional Appropriations.

THE COOPERATIVE PROGRAM WITH STATES AND MUNICIPALITIES

The cooperative programs with more than 200 State and municipal agencies comprised the largest and strongest segment of the Division's activities, and enjoyed

a sizable growth and stability during the decade. Each program was composed of one or more individual studies or investigations, referred to as "projects." Some projects, such as the collection of streamflow records, continued indefinitely. Others, such as ground-water studies, had a life of perhaps two or more years. Planned jointly, but normally conducted and reported on by the Division, the cost was shared essentially on a 50-50 basis by both parties, Federal and local.

ITS NATURE AND HISTORICAL BACKGROUND

The advantages of such a joint approach to water-resources studies of mutual interest were first demonstrated in California in the late 1890's (Follansbee, v. I, p. 108). These jointly financed programs grew steadily because of strong support from the cooperating States and municipalities; however, the principle of 50-50 cooperation was not specifically defined in the appropriation language until the 1931 fiscal year. Under the new language, a specific appropriation was identified for use in matching State and municipal contributions, but with the specification that the Federal monies could not be used to finance more than 50 percent of the cost of any investigation. Because State and municipal offerings were usually far from firm at the time of the House and Senate hearings, the Congress also indicated at that time that it would consider annual deficiency items in amounts to meet the final offerings.

Contributions by individual States at the beginning and at the end of the decade are shown in table 6. Every State had been participating in the cooperative program for surface-water investigations long before the beginning of the decade. As of August 1953, 43 States were cooperating in the financing of ground-water investigations and 15 in quality-of-water and sediment studies (statement by Paulsen before the Association of Western State

Table 3. Types and numbers of water records collected by U.S. Geological Survey during FY 1950[1]

Type of Record	Direct appropriation[2]		Other funds		Totals	
	Daily	Periodic	Daily	Periodic	Daily	Periodic
Stream records						
Stage	1,312	303	717	76	2,029	379
Water discharge	4,372	988	1,865	169	6,237	1,157
Sediment discharge	44	12	114	30	158	42
Chemical quality	165	884	31	120	196	1,004
Temperature	308	3,413	84	904	392	4,317
Reservoirs, lakes, and ponds						
Water level	367	126	106	22	473	148
Reservoir content	79	44	89	15	168	59
Chemical quality	.....	23	.....	17	.....	40
Temperature	.....	152	.....	10	.....	162
Springs records						
Water level	51	321	1	21	52	342
Chemical quality	.....	80	.....	17	.....	97
Temperature	1	158	.....	17	1	175
Ground water records						
Water level	826	13,099	34	5,611	860	18,710
Well discharge	183	1,520	3	22	186	1,542
Recharge	3	209	.....	.....	3	209
Chemical quality	.....	2,696	.....	460	.....	3,156
Temperature	.....	1,660	.....	213	.....	1,873
Snow measurements						
Depth only	.....	35	.....	2	.....	37
Water content	.....	210	.....	1	.....	211

[1]From FY 1952 Estimates of Appropriations, table 7, p. 72.
[2]Includes Federal program, Federal-State program, and also State and municipal funds.

Table 4. Sources of funds for water-resources investigations for FY 1948[1]

Gaging streams appropriation	1948 Obligations
Cooperative funds	$2,013,543
Noncooperative funds	
Water resources of Alaska	39,804
Federal gaging stations	159,613
Compact requirements	152,918
Water investigations for other Federal agencies	321,117
Ground-water program to meet Federal needs	34,885
Quality-of-water program to meet Federal needs	91,528
Research and development	46,047
Other public service	181,870
Printing of reports (comparative transfer in 1948 and 1949)	75,000
Total direct appropriations or estimates	$3,116,325
State and municipal cooperative offerings	$2,026,909
Funds received from other Federal agencies	
Interior Department	
Bureau of Reclamation	$689,410
Office of Land Utilization	35,222
Office of Indian Affairs	20,126
Geological Survey-Geologic Division	12,273
Fish and Wildlife Service	4,345
Bonneville Power Administration	750
National Park Service	600
National Defense Establishment	
Department of the Army	586,147
Department of the Navy	7,312
Department of State	105,941
Department of Agriculture	
Forest Service	582
Soil Conservation Service	300
Department of Commerce (Weather Bureau)	90
Tennessee Valley Authority	78,184
Atomic Energy Commission	11,733
Federal Security Agency (Public Health Service)	5,825
Public Works Authority (Virgin Islands)	592
Veterans Administration	455
Federal Power Commission	.....
Total funds received from other Federal agencies	$1,559,887
Permittees and licensees of Federal Power Commission	$40,485
Grand total	$6,743,606

[1]Format and dollar amounts taken from FY 1950 Budget Justifications, U.S. Geological Survey, p. 99–100.

Table 5. Sources of funds for water-resources investigations for FY 1957[1]

Water-Resources Investigations	Obligations
Geological Survey appropriation	$8,511,012
States, counties and municipalities:	
Reimbursements, matched	4,106,045
Reimbursements, unmatched	63,586
Direct State payments	963,470
Permittees and licensees of the Federal Power Commission	153,927
Miscellaneous non-Federal sources	41,073
Bureau of Reclamation	1,112,406
Department of Agriculture	337,673
Department of the Army	1,350,410
Department of State	104,787
Atomic Energy Commission	348,529
International Cooperation Administration	435,377
Miscellaneous Federal agencies	402,355
Total	$17,930,650
Soil and moisture conservation: Geological Survey appropriation	$129,466
Grand total	$18,060,116

[1]Taken from FY 1959 Budget Justifications, U.S. Geological Survey, p. 168.

Engineers, Aug. 1953.) Total annual contributions (in $1,000 units and including direct expenditures as shown below) by State and municipal agencies during the decade were as follows:

Fiscal Year	*Amount*	*Fiscal Year*	*Amount*
1948	$2,027	1953	$3,500
1949	2,512	1954	3,706
1950	2,770	1955	5,060
1951	3,100	1956	4,599
1952	3,250	1957	5,070

Thus the cooperative program for fiscal year 1957 in dollars was more than twice that for 1948. In fiscal year 1957, the SW Branch administered about 55 percent, the GW Branch about 37.5 percent, and the QW Branch about 7.5 percent of the program. The major obstacle encountered under the cooperative program during the decade was an attempt by a well-drilling company to eliminate funds for ground-water activities, which is described later in Part II, Annual Budgets and Congressional Appropriations.

THE COOPERATIVE AGREEMENT

The terms of the standard agreement under which the Division conducted cooperative work with State and municipal agencies had historically been brief, simple, informal, free of legalistic language, and relatively stable with respect to time. Its success was likely due to the fact that the negotiating parties, Federal and local, were already acquainted, had mutual respect and trust, and found the format advantageous to both. The agreement forms, previously revised in 1940, were used through fiscal year 1952. There was a common initial sheet and the second page had a separate format for surface-water and ground-water investigations. The surface-water format specified that all operations and records (such records were essentially streamflow data) should be open to the inspection of both parties and also that the original records should be deposited with the Survey. The ground-water format required the prompt release of records and reports to public inspection. Also available were standard forms for use in providing additional funds to an already active program during the year and for continuing a cooperative investigation into a second or later year.

A new agreement form (fig. 4) was developed by the Survey for use beginning with the 1953 fiscal year. It was changed slightly in order to make the cooperative agreements of the Geologic, Topographic, and Water Resources Divisions as nearly similar and consistent as possible. The new format, to be used by all branches of the Division, included some changes that were significant. Although still specifying that the investigations be under the direction of an authorized representative of the Survey, the matter of work supervision and approval of expenditures was deleted. Added were provisions that the investigations in progress be open to inspection by either party and that either party could end the agreement upon 60 days written notice.

Agreements generally covered all investigations to be conducted by a single branch for a particular cooperator. Thus, within the Division, there were two and even three

Table 6. State and municipal funds used in cooperative water-resources investigations at beginning and end of decade

State	1948 FY[1] Appropriated	1957 FY[2] Obligations	State	1948 FY[1] Appropriated	1957 FY[2] Obligations
Alabama	$19,495	$167,800	Nevada	$24,252	$31,595
Arizona	47,448	127,414	New Hampshire	11,239	20,881
Arkansas	27,721	54,079	New Jersey	36,406	132,282
California	109,345	430,141	New Mexico	67,063	193,296
Colorado	58,849	111,786	New York	128,607	263,696
Connecticut	15,750	36,600	North Carolina	42,433	123,079
Delaware	3,797	29,662	North Dakota	26,401	36,418
Florida	90,151	201,362	Ohio	72,268	153,051
Georgia	26,400	104,489	Oklahoma	54,028	116,527
Guam[3]	.....	20,090	Oregon	32,067	70,189
Hawaii[4]	63,100	107,936	Pennsylvania	86,615	175,174
Idaho	41,362	63,026	Rhode Island	4,600	24,742
Illinois	27,833	72,637	Samoa[3]	.....	1,738
Indiana	49,345	152,585	South Carolina	14,373	36,413
Iowa	39,201	60,603	South Dakota	1,989	27,569
Kansas	35,381	91,556	Tennessee	33,718	89,827
Kentucky	28,090	144,745	Texas	158,459	369,883
Louisiana	37,983	166,675	Utah	51,971	114,909
Maine	8,499	12,594	Vermont	7,260	8,560
Maryland	41,727	61,581	Virginia	45,403	70,627
Massachusetts	36,093	49,582	Virgin Islands	.....	.....
Michigan	59,562	92,475	Washington	72,353	129,793
Minnesota	19,458	126,879	West Virginia	14,778	36,220
Mississippi	11,551	61,424	Wisconsin	26,149	50,460
Missouri	23,700	40,061	Wyoming	33,645	65,736
Montana	27,098	57,096			
Nebraska	31,893	81,972	Total	$2,026,909	$5,069,515

[1]FY 1948 values taken from FY 1950 Justifications for Appropriations, U.S. Geological Survey, p. 87–88.
[2]FY 1957 values taken from FY 1959 Estimates of Appropriations, U.S. Geological Survey, p. 119. Fiscal year ended on June 30 of year shown.
[3]Trust Territory.
[4]Territory.

COOPERATIVE AGREEMENT
FOR INVESTIGATION OF WATER RESOURCES

THIS AGREEMENT is entered into as of the _____ day of _____, 19____, by the GEOLOGICAL SURVEY, UNITED STATES DEPARTMENT OF THE INTERIOR, party of the first part, and the _____ _____, party of the second part.

1. The parties hereto agree that subject to the availability of appropriations and in accordance with their respective authorities there shall be maintained in cooperation an investigation of the water resources of _____ .

2. The following amounts shall be contributed to cover all the cost of the necessary field and office work directly related to this investigation, but excluding any general administrative or accounting work in the office of either party and excluding the cost of publication by either party of the results of the investigation:

(a) $ _____ by the party of the first part during the period to _____ of which amount of portion may be held in reserve, for later release if funds permit, in order that the available Federal funds may be distributed proportionately among the cooperating States and municipalities.

(b) $ _____by the party of the second part during the period to _____ .

(c) Additional amounts by each party during the above period or succeeding periods as may be determined by mutual agreement and set forth in an exchange of letters between the parties.

3. Expenses incurred in the performance of this investigation may be paid by either party in conformity with the laws and regulations respectively governing each party, provided that so far as may be mutually agreeable all expenses shall be paid in the first instance by the party of the first part with appropriate reimbursement thereafter by the party of the second part. Each party shall furnish to the other party such statements or reports of expenditures as may be needed to satisfy fiscal requirements.

4. The field and office work pertaining to this investigation shall be under the direction of an authorized representative of the party of the first part.

5. The areas to be investigated and the scope of the investigation shall be determined by mutual agreement between the parties hereto or their authorized representatives. The methods of investigation shall be those usually followed by the party of the first part subject to modification by mutual agreement.

6. During the progress of the work all operations of either party pertaining to this investigation shall be open to the inspection of the other party, and if the work is not being carried on in a mutually satisfactory manner, either party may terminate this agreement upon 60 days written notice to the other party.

7. The records and reports resulting from this investigation shall be released for public inspection as promptly as possible. Both parties shall have the privilege of publishing the reports, provided that the reports published by either party shall contain a statement of the cooperative relations between the parties.

GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

By _____

By _____

Figure 4. Cooperative agreement form in use from FY 1953.

agreements per year for a sizable number of cooperating agencies. These were sent to the headquarters of the appropriate branch and reviewed. If the agreement as proposed was not of the standard type, or if it involved new or unusual types of direct expenditures, the members of the Division's cooperative committee would give it joint consideration. Before final approval by the Director, the proposed agreement might even receive attention by the Bureau-level review committee to assure that any new and unwise feature or condition would not become an unfortunate precedent.

DEVELOPING THE ANNUAL PROGRAMS

Methods used to develop estimates of cooperative offerings as a basis for justifying Federal matching funds (referred to as Federal-State program funds) in the annual appropriation were somewhat similar to those in use before and after the decade. District chiefs, who maintained close contact with State and municipal cooperating officials, submitted initial estimates of offerings in time for the Washington headquarters staff to prepare the preliminary budget estimates, perhaps 15 months in advance of the start of each fiscal year. The estimates varied greatly; at that early period, many cooperating officials could provide no more than amounts requested of legislatures or municipal boards. A second and later estimate was forwarded from the field for use in preparing the Survey's formal estimates to the Bureau of the Budget and revisions to those values were reported through District officials for use in the preparation of the budget justifications to the Congress. In some years, members of the House and Senate Appropriation Subcommittees, aware of the ever increasing refinement, would ask for the latest estimate at the time of the hearings, and would adjust the budgeted Federal matching funds upward if doing so appeared necessary to provide for 50-50 matching.

Following the reorganization of the Washington, D.C., office in April 1948, cooperative proposals were reviewed by a team composed of representatives of each branch (usually the chief or assistant chief) with a chairman from the PC Branch or, later, the chief of the Planning Section. Cooperative projects were identified within each local cooperative program (agreement) and each was reviewed with respect to such factors as objective, degree of national interest, and need for interbranch assistance. The organization of this review function changed slightly during the decade. For example, the 1957 cooperative proposals were sent to the appropriate Branch for review and approval, then on for review by the Division program staff. Once approved by the CHE, the agreements were sent to the Director for formal approval.

Beginning with fiscal year 1949, the districts were asked (by WRD Circular dated June 7, 1948) to execute and forward two new forms with each signed cooperative agreement. One, a fiscal abstract, was to expedite the processing time in Washington and reduce the chance of error in interpreting the sometimes complex terms of agreement. The second gave descriptive and justification data needed in budgeting and planning. The WRD Circular dated June 21, 1948, to the districts soon followed, which defined the policy under which cooperative agreements should be reviewed prior to acceptance. Probably the most comprehensive cooperative policy statement up to that time, the Circular reflected the criticism leveled at the cooperative program during the House hearings a year earlier. Earlier prohibitions were restated, such as the solicition of cooperation and test drilling for water development. It further stated that test-hole drilling to define hydrologic conditions would preferably be done under private contract, and all programs were to have broad public value and sufficiently stable support so as to assure completion of the roject.

Usually the appropriated Federal matching funds were somewhat less than the total of all estimated offerings at the beginning of the fiscal year. To spread the Federal funds equitably among all cooperative projects, including those for which offerings were not yet firm, the Division applied an ''abeyance'' which was used frequently and successfully during the decade. For example, if the appropriated Federal matching funds were sufficient to match only about 95 percent of the most recent estimate of local funds, the field allotments would be prepared with a 5-percent abeyance. That is, for each $1 of local funds contributed, 95 cents of Federal funds would be made available. As the new fiscal year progressed, the local estimates that remained gradually became firm. Although a few estimates of local funds available were larger than the anticipated amounts of Federal funds because of sudden needs for new investigations, more project costs tended to be less than originally estimated and the initial abeyance (as high as 25 percent in 1 year) usually was either eliminated or greatly reduced. Although the abeyance complicated the fiscal procedures somewhat, it was a helpful device because it gave the needed flexibility and was often a means of financing critically needed new projects not included in the earlier estimates. Officials of cooperating agencies generally recognized the need for the abeyance, and did not object to paying slightly more than 50 percent of the cost of the investigations when Federal funds were inadequate. Major cooperators in one or two States, however, applied a similar abeyance on the State side which tended to assure them the exact 50-50 ratio of funding.

Although allocation of funds was made directly from the office of the CHE to the District offices of the three

operating branches, the chief of each of those branches continued to have responsibility for the planning and execution of his program and the reporting of the findings. Many major State cooperating agencies had a separate agreement with two and sometimes all three of the Division's operating branches. Such coordination as was required on cooperative projects across Branch lines was done voluntarily by the District chief and sometimes by the cooperators. No formal coordination mechanism was available at the Washington office. Major issues were settled either by the Branch chiefs or, when desirable, by the CHE.

The administrative and overhead costs of the cooperative program incurred by the Washington office were supported by charges against each of the allotments of Federal funds made to the districts to match State and municipal offerings. These overhead charges usually amounted to about 10 percent of the Federal allotments, or about 5 percent of the total cooperative program. Such "top costs," of course, reduced the amounts that could be used directly for field work. An effort was made by the Survey in the 1948 budget proposals to add $220,000 to the "Other Public Service" item under which Washington office overhead costs for other programs were supported. The $220,000 item was roughly 5 percent of the total (from both sides) cooperative program. Although the item was approved by the Bureau of the Budget, it was disallowed by Congress.

COOPERATOR RELATIONS AND NATIONAL SUPPORT

Relations with cooperators during the decade generally were excellent as can be judged by the rapid growth of the program. Cooperative activities with counties and cities usually were free of problems. At times, however, some of their officials did seek engineering advice from Survey personnel that was outside the scope of the cooperative study and the Survey's authority. This problem was solved usually by the cooperator engaging the services of a private engineering consultant who was experienced in using project findings as a base for decisionmaking. Some States had water-oriented agencies that employed hydrologists who conducted water-resources studies outside the cooperative program but paralleling those of the Geological Survey. An effort was made, through negotiation, to avoid duplication of effort under such dual programs.

One of the features of the Federal-State program that required considerable negotiation with cooperating officials of State agencies was the policy on so called "direct expenditures." Under this arrangement, the cooperator was given credit for other types of support unlike the normal "repay" arrangement wherein the State or municipal cooperator provided his share of funds according to previous agreement. The most common direct expenditure was credit for State employees assigned to the project. Other credits reflected the cost of equipment or utilities furnished, such as electric current in space provided by the cooperator. A few cooperating officials claimed as a proper credit to the State side that portion of their own salaries that they spent on the administration of the cooperative work. Such "evaluated services" sometimes were also applied to others on the cooperator's staff who conducted a variety of tasks associated with the program.

By its nature, work conducted as a direct expenditure credit to the cooperative agreement generally was more difficult for District supervisors to monitor and control than that conducted by their own staffs. For this reason, work conducted under a direct expenditure was not encouraged, particularly during periods when District staffs could be readily enlarged through recruitment to meet program needs. Although the total direct disbursements by State and municipal cooperating officials under the cooperative program increased from $685,000 in fiscal year 1948 to more than $963,000 in fiscal year 1957, the ratio of direct expenditures to total local cooperative funds during that period decreased from about 34 percent to 19 percent.

Division programmers took courage in 1953 from emphasis given by President Dwight D. Eisenhower in his State of the Union message when he called attention to the need for a sound natural-resources program. The President confirmed his views in a message to Congress on July 31 of that year. Among other measures, he advocated land and water conservation programs including "the replenishment of ground-water reserves" and urged "maximum cooperation" with the States and local communities (H. Doc. 221, 83d Cong., 1st Sess.).

The Federal Program

The Federal program (referred to within the Division as the "Non-cooperative program" prior to fiscal year 1951) was composed of those activities that were funded directly by Congressional appropriation to meet objectives not covered under the Federal-State program or in work for other Federal agencies. This included independent research, studies of widespread national value, and work to which the Federal government became specifically committed. The Federal program had its origin in the first Congressional appropriation made specifically for stream gaging in 1894 (Follansbee, v. I, p. 70). Although subsequent annual Federal appropriations grew steadily, so did the amounts of money contributed by the States to augment investigations of greatest interest to them. Thus, the plans for use of Federal funds were influenced in the direction of mutual interest, especially during the 1920's when annual State contributions were larger than the appropriations from Congress.

In fiscal year 1929, when the Congress began appropriating funds specifically to match State and municipal contributions, a small balance of other (non-cooperative) funds remained in the appropriation that were not committed to cooperative work. These became Federal program funds. So much of the Division's attention up to that time had gone into the vigorous cooperative program that this residual, for studies of "a purely Federal character," was referred to in the 1940's as "a remainder for other purposes" (Follansbee, v. IV, p. 4).

Despite the fact that the Federal program did not get the same enthusiastic congressional support that the Federal-State program enjoyed (in which $2 of work could be accomplished with $1 of Federal funds), the importance of adequate funding for the Federal program was well recognized by the Survey and amounts budgeted for it were defended vigorously. The steady and large growth of the Division's overall program, nearly all of which was designed to meet the needs of States, municipalities, and other Federal agencies, did leave unfinanced certain types and areas of investigation that were essential to a balanced national program. For example, research in new methodology and the development of new equipment were required to assure the greater efficiency of all future investigations.

At the beginning of the decade (fiscal year 1948), the Federal program was composd of nine specific items (see table 4). The financial support for the network of Federal gaging stations and for the "compact requirements" (U.S. and Canada) were longstanding. The "other public service" item, also longstanding, included the preparation of reports and compilation of data in response to inquiries outside the scope of the cooperative programs. Newer items, first financed in fiscal year 1947, included support of the Federal observation-well program, regional water-quality laboratories, interstate sediment investigations, water-resources studies in Alaska, water investigations for other Federal agencies, and research and development. The amount appropriated ($1,038,500) was about 40 percent of the entire "gaging streams" appropriation.

By the end of the decade, the appropriation for the Federal program had increased to $2,836 million (fiscal year 1957), an increase of 270 percent over that for fiscal year 1948. It was, however, only about one third of the total Water Resources Investigation (formerly "gaging streams") appropriation. Other new activities that were added during the decade included flood and drought studies, flood-frequency analysis, radioactivity of water resources, and hydrologic studies of mining and oil field areas.

In the budget for fiscal year 1951, the nine items formerly under the Federal program were regrouped under four major items and continued under the same headings for the balance of the decade. The items under the Federal program will be described for the entire decade under the headings and subheadings used first in fiscal year 1951.

STREAM-GAGING ACTIVITY

The item for stream gaging was by far the largest in the Federal program and was administrated by the SW Branch. Its several parts are described below.

Collection of Basic Records

This subitem pertained to a network of Federal base gaging stations that was established long before the beginning of the decade (Follansbee, v. IV, p. 84). These stations, in which the obligations and interest of the Federal Government were paramount, provided data required in the solution of interstate and international problems and in the planning, construction, and operation of Federal water-resources projects (see 1949 fiscal year Justification of Appropriations). By the end of fiscal year 1947, the network consisted of 218 stations, and at the end of the decade the number had increased to 245.

Flood and Drought Studies

Although special reports that documented water levels, streamflows, rainfall, and other pertinent hydrologic data during major floods and droughts had been made by Division personnel for many years, it was not until fiscal year 1951 that funds were appropriated specifically for this activity. These funds provided the means for the SW Branch to train and maintain a group of flood specialists, the activities of which are graphically described in Paulsen's monthly report for December 1955 to the acting Director. Paulsen stated that "the training of a corps of flood specialists during past years as part of the Survey's surface-water investigation 'paid off' this fall and winter. Immediately after the record-breaking flood in the Northeastern States, these specialists began arriving at the flooded areas from all parts of the country to collect data on the flood that will be used for planning, rehabilitation, and basin development for years to come. Again in December these specialists were dispatched to the California-Oregon flood area and are currently making field surveys and calculating floodflows at critical points and preparing a second major flood report within a 4-month period. The speed with which men and equipment, without regard to holidays and normal working hours, were dispatched from other work in widely scattered points and quickly organized into small groups moving from one point of study to another in the face of broken dams, highways, and communication systems is considered

to be an organizational triumph. Also a record is the speed with which the preliminary report on the Northeastern Flood was completed (17 weeks) in order to provide flood facts for the Corps of Engineers and other users."

As shown in table 7, there were 28 major floods during the decade, an average of about three per year. Of these, 24 were covered by flood reports prepared by personnel of the SW Branch. The funds appropriated for such surveys were modest in relation to needs. They varied from $45,000 in 1951 to $60,000 in 1956, with an annual average of about $52,000. Additional funds were received from supplemental appropriations as indicated in table 7, and from the local District offices to the extent that monies could be diverted by rescheduling cooperative and other projects. Such funds also were used for the rehabilitation of flood-damaged gage structures.

The major drought under study and reported on under this subitem occurred in the Southwest beginning in the mid-1940's. Studies began in 1952 and continued during 1953. The report on the California portion, where the drought had eased, was published as WSP 1366 in 1957. District activity statements include numerous other drought studies.

Flood Control and the Slope-Area Measurement

The SW Branch personnel had already attained expertise and experience in flood studies by the beginning of the decade, but the national significance of this work was not fully realized until later. W.B. Langbein, one of the pioneers in the development of modern flood surveys and reporting, contributed, in 1978, the following background statement under the above subject heading:

"The Independence Day celebrations in the southern tier of New York in 1935 were disrupted by severe thunderstorms that raised rivers there to new highs and caused great damage (WSP 773-E, 1936), but the most significant aspect of that event was the first systematic application of the slope-area technique to determine flood discharges that were beyond the scope of the small stream-gaging program of that day. One of the other aspects that made the slope-area technique so important was that this innovation occurred 1 year before the enactment of the Flood Act of 1936 which launched the national program of flood control as a Federal obligation (Follansbee, v. III, p. 62).

"That Act created an enormous demand for information about floods that exceeded by far anything then known. Data were sought on floods of an extraordinary nature, about the intense destructive flood that occurs within a few minutes time and then is gone leaving a devastated valley behind. Data were needed on the extreme rare flood that might endanger the numerous flood-control dams, for it was unacceptable that a dam built for flood protection could be itself a victim of a flood, adding to, rather than subtracting from, the loss of life and property.

"The slope-area technique was the only method available for answering the questions, and indeed an alliance established after the 1936 Act between the USGS and Corps of Engineers, for providing the key data, allowed the flood-control program to move ahead. The key men were Gail Hathaway of the Corps and Carl Paulsen of the Survey."

Evaluation and Compilation of Records

The program began in fiscal year 1951 with a request for a modest amount ($25,000 in 1951 and the same amount in 1952) for "an evaluation" of streamflow records pertaining essentially to rivers in the Columbia River basin. Early work revealed that the format used in summarizing the evaluated records held promise in shortening the search time for the many users of the records. The fiscal year 1952 appropriation provided about $237,000 for a nationwide accelerated effort using the Columbia River basin as a "pilot study." About 12 percent of the nationwide project was completed by the end of 1952. An even heavier work schedule was applied in 1953, using an allotment of $315,000. The rate of progress increased again in 1954, under a $395,000 allocation, and the project was about 45 percent complete at year end. Funding was reduced in 1955 ($340,000) and 1956 ($370,000) and, by the end of the decade, the project was about three-fourths finished with completion scheduled for fiscal year 1958.

As stated in the fiscal year 1955 Justification for Appropriations (p. GS-41), the program involved "reviewing, filling in gaps, and summarizing all available surface-water records in most usable form." The compilation was designed to "save a tremendous amount of time and research" in answering "the thousands of individual requests for streamflow records received each year. For example, a single inquiry has taken the researcher into as many as 50 separate volumes." Use of the compilation reduced the time required to determine flood frequencies to about one-fourth the amount previously required. The results were published during the decade by "parts" (geographic subdivisions of the country, each comprising one or more river basins) in Water-Supply Papers 1301 through 1319 and 1372.

Flood Frequency Analysis

This project, under which the probable frequency of occurrence of floods of various magnitudes was determined from studies of streamflow records of past years,

Table 7. Major floods during 1947–57 decade and coverage by USGS hydrologists[1]

Date		Area	USGS report	Approximate damage[2]	Estimate of current cost of report and rehabilitation
1947	Sept.–Oct.	Florida and North Carolina	None	$59,000,000	$75,000
1948	April	Red River of the North	None	19,000,000	45,000
.....	May–June	Columbia River basin	WSP 1080	102,700,000	[3]250,000
.....	June–July	Arkansas	None	14,500,000	35,000
1949	Jan.	New York-New England	Circ. 155	6,000,000	30,000
.....	May	Trinity River, Texas	None	14,000,000	40,000
.....	June	Upper Potomac River basin, Virginia	None	9,000,000	35,000
1950	Apr.–May	Missouri River basin, North Dakota-South Dakota	WSP 1137A	9,710,000	45,000
.....	Apr.–June	Upper Mississippi River and Lake Superior basin, Minnesota	WSP 1137G	5,000,000	.....
.....	Apr.–July	Red River of the North basin	WSP 1137B	32,990,000	40,000
.....	May–June	Southeastern Nebraska	WSP 1137D	60,000,000	50,000
.....	Oct.–Nov.	California and Oregon	WSP 1137E	10,000,000	70,000
.....	Nov.–Dec.	Central Valley basin, California	WSP 1137F	31,500,000	.....
1951	July	Kansas-Missouri	WSP 1139	870,240,000	[4]225,000
1952	Mar.–Apr.	Missouri River basin	WSP 1260B	179,000,000	[5]125,000
.....	Apr.	Upper Mississippi River	WSP 1260C	30,000,000	50,000
.....	Apr.–June	Utah and Nevada	WSP 1260E	10,000,000	.....
.....	Sept.	Central Texas	WSP 1260A	11,950,000	35,000
1953	Jan.	Western Oregon and northeastern California	WSP 1320D	5,000,000	30,000
.....	Apr.–June	Louisiana and adjacent States	WSP 1320C	34,770,000	.....
.....	May–June	Missouri River basin in Montana	WSP 1320B	8,600,000	.....
.....	June	Northwestern Iowa	WSP 1320A	26,000,000	.....
1954	May–June	Iowa	WSP 1370A	27,970,000	50,000
.....	Sept.	New Jersey to Maine	WSP 1370C	[6]23,600,000	.....
.....	Oct.	Chicago area	WSP 1370B	25,000,000	35,000
1955	Aug.–Oct.	Northeastern States	WSP 1420	457,700,000	[7]310,000
.....	Dec.	California, Oregon, and adjacent States	WSP 1650	190,000,000	[8]410,000
1956	Aug.	Southwestern Pennsylvania and adjacent States	WSP 1530	6,000,000	.....
1957	Jan.–Feb.	Southeastern Kentucky and adjacent States	WSP 1652A	61,000,000	80,000

[1]Adapted from table dated December 30, 1964, prepared by Plans and Operations Section (Wallace Miller, Section Chief), Surface Water Branch. Floods causing damage of less than $5 million not included.

[2]Most reliable damage estimates available from Weather Bureau, Corps of Engineers, Red Cross, and other sources.

[3]Of this, $175,000 actually used—from supplemental appropriation.

[4]Of this, $150,000 actually used—from supplemental appropriation.

[5]Of this, $145,000 actually used—from supplemental appropriation.

[6]Mostly from rain; some wind damage.

[7]Supplemental appropriation of $300,000.

[8]Supplemental appropriation of $330,000 requested initially. Request subsequently withdrawn and scope of work curtailed to stay within the $250,000 available from all sources within WRD in 1956, 1957, and 1958 fiscal years.

was first proposed in the 1954 budget. It was not until fiscal year 1956, however, that funds appropriated were sufficient to allot $30,000 to the analysis. The nationwide project, estimated to require 6 years and cost $500,000, was conducted by SW Branch personnel and was well underway by the end of the decade.

The frequency data were vital to the design of highways, bridges, dams, levees, and other structures exposed to the forces of flood waters. Without it, such structures were subject either to costly overdesign or disastrous underdesign. Frequency data were also valuable to residential, farming, and industrial activities within a floodplain.

SEDIMENT INVESTIGATIONS

Sediment studies, as a specific item under the Federal program, began in fiscal year 1948 when suspended sediments carried by the Rio Grande and its tributaries were measured at 19 locations in New Mexico. This investigation was recommended by six Federal agencies striving for the solution of complex land-water problems in the Rio Grande valley. In 1950, the annual allotments earlier of about $64,000 were increased to $100,000 and supported studies in the Colorado River basin in addition to the Rio Grande. In 1951, under an allocation of about $181,000, the program was divided into two parts, "critical area investigations" and the new "index station" network to provide information on sediment discharges in a few scattered sections of the country. Under the "critical area investigations" part, additional data were collected to meet the requirements of the Colorado River Compact. The funds were increased to $196,000 in 1952 when stations in the Pecos River basin were added to the area studies.

In 1954, the program was again restructured into collection of basic records (CBR) and area investigations. The CBR activity provided for the continuing nationwide collection of sedimentation data, including what had been accomplished under the "index station" network, as well as a part of those stations formerly under area investigations. The sediment investigations were under the jurisdiction of the QW Branch staff and the work was accomplished largely from its District offices with assistance by the SW Branch field personnel who provided much of the water-discharge data. (For information on sediment studies prior to 1947, see Follansbee, v. IV, p. 367.) Funds spent under the CBR in 1954 totalled about $376,000 and an additional $46,000 was spent for area investigations. The CBR funds were reduced to about $238,000 in 1955 because of the curtailment of sediment investigations in the Missouri River, and continued at about that level through the end of the decade. Because of the completion of the reconnaissance work in the Arkansas-White-Red Rivers area and the curtailment of activities in the Missouri River basin, the "area investigations" funds decreased to $5,000 in 1956 and were discontinued at the end of that fiscal year.

CHEMICAL QUALITY STUDIES

The fiscal year 1947 budget justification was the first in which a request was made specifically for funds for studies of chemical water quality, an activity that had long been a growing segment of the cooperative program. Titled "expanded quality of water program," an amount of $25,000 was proposed to establish a new laboratory at Salt Lake City, Utah, for the analysis of water samples primarily from the Great Basin. An allocation of $13,700 was received by the QW Branch for this purpose.

For the 1948 fiscal year, a request was made and funds were received ($33,800) of which $11,300 was to be used to complete the Salt Lake City lab, and the balance was to be used to establish a similar facility in the Pacific Northwest (Portland, Oreg.). The fiscal year 1949 appropriation apparently included the $19,000 requested to help support the two regional labs of the Branch, one at Salt Lake City and the other at Columbus, Ohio, and such support continued in later years.

The 1951 budget requested a "continuation of work" in Alaska and in the Colorado River basin, costs of which were financed earlier under other subheadings of the Federal program. In fiscal year 1952, studies for interstate river compact commissions, a western irrigation water-quality station network, water use, and radioactivity of water resources were added, the last two being portions of interbranch activities. By 1954, the Federal program monies for chemical-quality studies peaked at about $400,000 annually and began a decline that was largely due to a gradual closing out of the QW Branch portion of the Missouri River basin program which had been added to the Federal program. "Area" (interstate compact) studies also were tapering off. The "collection of basic records" heading, introduced into the budget in fiscal year 1954 and a part of earlier work under different subitems, continued through the end of the decade.

The fiscal year 1957 Federal program appropriation carried $300,000 for chemical water-quality studies. Also included was the continuation of GW Branch studies, such as the artificial recharge of ground-water basins and the hydrology of oil-field areas, identification of inland saline-water bodies, and a reconnaissance of water quality in the New York-New England region.

STREAM TEMPERATURE MEASUREMENTS

Many of the field personnel of the SW and QW Branches had been measuring temperatures of stream

waters while collecting other types of data prior to the beginning of the decade. By the late 1940's, the value of stream temperature records was so well recognized that, by WRD Circular dated February 3, 1948, plans were announced to field officers for nationwide coverage. Because water temperature was closely associated with other measurements of water quality, the leadership of this informal program was given to the QW Branch. Most of the measurements, however, were taken by SW stream gagers during their visits to the station. Some of the temperature readings were a part of investigations funded under the Federal program, but the largest portion by far was under the cooperative program.

GROUND-WATER INVESTIGATIONS

First identified as a specific budget item under the Federal program in the 1947 fiscal year, funds were provided to establish and maintain a Federal observation-well program. More specifically, the allotment was "used to collect, compile, and process in annual reports and in the monthly water resources review, comprehensive information on the status of artesian pressures and water levels in selected wells throughout the United States" (1949 fiscal year Budget Justifications, p. GS-76). In 1947, periodic measurements were begun of about 60 wells under an initial allocation of $13,500. Data obtained supplemented data available from observation wells operated under the Federal-State programs. An allotment of $40,000 in 1948 and a similar amount in 1949 permitted an expansion in the Federal network that continued through the decade. By 1957, the allotment had grown to about $125,000. No numerical listings of network size appeared in any of the annual budget justifications subsequent to 1949. It is assumed, therefore, that the funds were used to develop a more accurate and extensive data base from a sizable number of observation wells selected from those wells that had been previously established and operated to meet the needs of individual investigations. The funds permitted installation of better instrumentation for recording water levels, gave assurance of continuity of record after local projects ended, and aided in the analysis and publication of uniform, nationwide water-level data.

In fiscal year 1951, a second activity entitled "area investigations" was added, which included ground-water studies that had been conducted since fiscal year 1947 as a part of the Federal program entitled "Water Resources of Alaska." In addition, studies largely in "trouble spots" of the United States were begun. These included the Columbia River basin, the Central Valley of California, and Central Arizona (1953 fiscal year Budget Justifications, p. GS-71). By the end of the decade, work was underway in these areas. Allocations of funds, which began at a reported amount of $218,000 in 1951, increased to a maximum of $477,000 in 1954 and then decreased to slightly more than $150,000 by the end of the decade.

During the 1952 and 1953 fiscal years, a project referred to as "compilation and evaluation of records" was conducted with a total allocation of about $35,000. It placed, in a form that could be used most expeditiously by those engaged in production activities for the Department of Defense, "a large assortment of ground-water records and related data collected under special World War II projects" (1952 fiscal year Budget Justifications, p. GS-23).

A project entitled "hydrology of mining areas" was begun in 1952 ($25,000) and continued under slightly different terminology during the balance of the decade. The studies were directed toward better techniques for controlling seepage into and flooding of mine workings and for the dewatering of undeveloped areas suitable for mining (1953 fiscal year Budget Justifications, p. GS-72). Areas under study in 1952 were in Arkansas, Michigan, and Minnesota, and, by 1954, additional work was being conducted in Alabama, Tennessee, Pennsylvania, Wisconsin, and Nevada (Annual Report of the Secretary of the Interior, p. 154). In 1954, the project was broadened to include the study of ground-water movement in deep aquifers and its effect on the accumulation of oil and gas. Work was begun in the Big Horn basin in Wyoming. Funding of the project averaged about $50,000 per year during the decade.

In fiscal year 1955, under the budget designation of "hydrogeologic studies," reinvestigations were begun of earlier areal projects, the research potential of which had not been covered because of pressures to get the immediately usable findings into the hands of users. Through restudy, fundamental principles were identified and new techniques developed that were advantageous to future ground-water programs. Much of the work in this new category was already underway under other activity headings. Allocations of funds ranged from an initial $150,000 to the nearly $200,000 requested for fiscal year 1957.

Not all proposals for investigations to be financed under the Federal program were approved. Apparently, with the support of local public officials, $100,000 was included in the preliminary estimates for the 1950 fiscal year for an investigation of the natural hydraulic system of the Mississippi River embayment, a 45,000-square-mile area that included eastern Arkansas, southwestern Kentucky, northern Mississippi, southeastern Missouri, and western Tennessee. An area of heavy pumpage, the withdrawal rate was than being estimated at 20 billion gallons per day. The Bureau of the Budget did not allow the request to go to the Congress. The Senate hearings for fiscal year 1950

revealed (p. 12) that the Chairman inquired about the project and asked Paulsen to prepare a statement describing it (p. 14–17). The Senate Report of the 1950 bill stated that the appropriations subcommittee had given careful consideration to the need for the embayment project, but felt that it could be accomplished under the cooperative program (p. 20).

RADIOACTIVITY OF WATER RESOURCES

Beginning with a small-scale study, Division personnel began to investigate the natural or "background" radioactivity of water resources in 1952 with the expectation that such information might lead to the discovery of new natural sources of fissionable material. Division personnel believed also that such information might be vital to the public health should radioactive materials be accidentally or deliberately introduced into water resources. Preliminary work showed the need for improved techniques for data collection, preservation of field samples en route to the laboratory, and laboratory analysis. In 1954, field tests were made of how radioactive wastes dissipated when introduced into a stream. By 1955, a limited program of systematic field sampling was underway. In 1956, studies of specific terrains were made in five western States and single samples collected in many parts of the country. Studies were begun in 1957 of the uranium and radium content of ground water in several areas of the West (annual reports to the Secretary, 1952 through 1957).

Obligations of funds for studies of radioactivity grew from about $51,000 in fiscal year 1952 to nearly $90,000 by fiscal year 1954, and annual allocations of between $90,000 and $100,000 continued beyond the end of the decade. All operating branches participated in the program under the leadership of the QW Branch.

COMPACT REQUIREMENTS

This item supported a commitment on the part of the Survey, dating back to the first of the interstate compacts (the Colorado River Compact of 1922), to provide sufficient streamflow data so that the compact commissions could determine and maintain an equitable apportionment of water among the signatory States (Follansbee, v. II, p. 99; v. IV, p. 85). At the beginning of the decade, the number of such compacts had grown to six (1949 fiscal year Budget Justifications, p. GS-75). The fiscal year 1948 allocation of funds to maintain equitable apportionment was $162,000. The funds supported the services of the Federal representatives in certain compacts, some of whom were WRD officials. Water-quality data also were collected to meet compact requirements (1951 fiscal year Budget Justifications, p. GS-29). Beginning in 1953, the separate item for compacts was discontinued and nearly all of that activity was placed under the Federal network of gaging stations, a part of the stream-gaging item.

RESEARCH AND DEVELOPMENT

In addition to the Federal program activities that were within the jurisdiction of a single branch, a number were conducted jointly by two or more branches. One of these, "research and development," was first introduced as a budget item in fiscal year 1947 and was granted an allotment of nearly $31,000. It was designed to meet urgent needs for types of research and development that could not be financed under cooperative and other Federal agency projects that normally were geared to the solution of local problems. The individual projects conducted were numerous and many were devoted to the design or improvement of equipment, particularly for use in stream gaging. (This budget item supported much of the research, methodology, and instrumentation described in pt. V.) From fiscal year 1951 on through the balance of the decade, the Federal program activities were presented under four new headings, and research and development lost its identity.

OTHER PUBLIC SERVICE

The "other public service" activity appeared in the annual budgets of the Division prior to the beginning of the decade. The item is described in the fiscal year 1950 Budget Justifications (p. GS-95) as providing services mainly of two types: (1) to satisfy the need for "up-to-the-minute water facts ahead of regular publication" and (2) to accomplish specific minor but valuable tasks "not comprehended by the regular program." The first included the answering of inquiries and the preparation of the Water Resources Review. The second included flood and drought investigations (later to become a separate item) and processing material for publication. The annual allotment to "other public service" ranged between $150,000 and $175,000. As with research and development, its segments were distributed to and justified under the four new items carried under the Federal program beginning with fiscal year 1951, thus losing its budgetary identity.

WATER-USE STUDIES

Water-use studies began in fiscal year 1951 in response to requests by the Munitions Board and the National

Security Resources Board (NSRB) for surveys that would determine the requirements for water in industry, and also to give assurance that, in each critical area of the Nation, there was sufficient water to meet the demands of defense production. Late in 1950, the NSRB gave the Survey a list of 29 highly industrialized areas in the country that were subject to expansion in a defense economy, and asked that the maximum amounts of available water be determined. The NSRB also provided a list of defense products and requested that studies be made of the water requirements to produce each (1953 fiscal year Budget Justifications).

Collection and publication of water-use data were underway prior to the specific requests made by the NSRB. Demands were so heavy for copies of the publication "Estimated Water Use in the United States, 1950" by K.A. MacKichan (USGS Circular 115, 1951) that plans were announced (WRD Circular dated June 26, 1953) that the Circular would be updated at 5-year intervals. In accordance with this plan, the national water-use data estimates were revised as of 1955 and published as USGS Circular 398 in 1957. A summary of earlier water-use estimates is given on page 1 of that Circular.

In the process of collecting and compiling records of water use, officials of some industrial plants in water-critical areas demanded that the data remain confidential. This was resolved satisfactorily by publishing water-use totals for the area instead of by individual user (WRD Circular dated Oct. 23, 1950).

More detailed investigations of water resources of local areas existed prior to the NSRB requests and might have stimulated the Board's interest in the need for better knowledge of water supply in critical localities. For example, the water supply of the Houston gulf coast region was studied in cooperation with the Texas Board of Water Engineers, and used data compiled through 1949 (Texas Board of Water Engineers Bull. 5101, Jan. 1951).

By the end of the decade, the Division had completed appraisals of the water-resources potential of about half of the critical areas designated by the NSRB, the number of which had, by that time, grown to more than 50 (1957 fiscal year Budget Justifications, p. GS-59). Reports concerning 10 of the areas were published in Water-Supply Paper 1499 (1961). Others were published as USGS Circulars and by State cooperating agencies as parts of their own publication series. Most of the investigations in the critical areas were delegated to the District offices, and will be covered later (pt. IV) in the descriptions of District activities. It is estimated that nearly $600,000 of Federal program funds were obligated for these studies from 1951 to the end of the decade.

Field investigations of the water requirements for the manufacture of the specific products identified as critical by the NSRB are documented in WSP 1330, parts of which were published separately by specific product manufactured. Although published as WSP's after the close of the decade, those publications that cover surveys made during the decade include "Water Requirements of the Pulp and Paper Industry" (O.D. Mussey, WSP 1330-A, 1955); "The Carbon-Black Industry" (H.L. Conklin, WSP 1330-B, 1956); "The Aluminum Industry" (H.L. Conklin, WSP 1330-C, 1956); "The Rayon- and Acetate-Fiber Industry" (O.D. Mussey, WSP 1330-D, 1957); "The Copper Industry" (O.D. Mussey, WSP 1330-E, 1961); and "The Petroleum Refining Industry" (L.E. Otts, WSP 1330-G, 1963). (Other products for which water requirements were investigated and reported on just after the close of the decade include "Styrene, Butadiene, and Synthetic-Rubber Industries" (C.N. Durfor, WSP 1330-F, 1963) and "Iron and Steel Industries" (F.B. Walling and L.E. Otts, WSP 1330-H, 1967)).

In WSP 1330-A, Mussey states that the report was prepared under the direction of J.B. Graham, Chief of Water Utilization Section, TC Branch. He also acknowledges the contribution of E.H. Sieveka "who planned the scope of the reports on the use of water in industry . . . ." One of the significant findings by the investigators was the varying amounts of water used by different manufacturers within the same industry and during the same operation.

In 1954, at the request of the President's Council of Economic Advisors, the Division furnished estimates of the quantities of water available for use in each of the river basin areas shown on the U.S. Water Resources Development Map printed in spring 1954. The Council needed the data for the preparation of another map that portrayed the extent of coverage of water use studies (WRD Memos, Oct. 11, 1954, and Nov. 2, 1954).

During the decade, water-use specialists at Division headquarters maintained a close and mutually advantageous liaison with W.L. Picton of the Business and Defense Services Administration (BDSA) of the U.S. Department of Commerce. Picton's summary of information on water use in the United States, 1900–1975, published by BDSA in January 1956, was widely studied, particularly its forecast of future water use.

Permittees and Licensees of the Federal Power Commission

This small but separate item in the Survey's annual budget dates back to the Federal Water Power Act of 1920 under which the Federal Power Commission was created. The Act "gave the Commission authority to make investigations and collect data on the utilization of water resources and the waterpower industry. In short, the

Commission at that time had authority to license waterpower plants and to conduct water-resources studies. . . .'' (Langbein, WRD Bulletin, Oct.–Dec. 1975, p. 6). Under the Commission's regulations, the records were to be collected under the supervision of the Geological Survey at the expense of the licensee. The arrangements under which this was accomplished for each waterpower site ''varied widely according to circumstances, from little participation by the Survey where the licensee or permittee could perform the work satisfactorily, to complete performance by the Survey . . . .'' (Follansbee, v. II, p. 97).

''Power sites subject to the provisions of the Act were those located on boundary waters, navigable streams, or public land adjacent to streams having sufficient fall for power. . . .'' (Follansbee, v. II, p. 95). In 1947, that part of the Survey's supervisory role under the Act that applied to sites situated on public lands was in most instances transferred from the SW Branch to the Conservation Division.

Investigations Funded by Other Federal Agencies

The Survey has conducted water-resources studies at the request of and with reimbursement from other Federal agencies since the early 1900's. These studies were authorized under the Economy Act of June 10, 1872, under which a Federal agency could request another such agency to provide services of any kind when it was in the interest of the Government and also to reimburse the servicing agency for the cost thereof (U.S. Code, 1970 Ed., Titles 27–31, p. 8,404). For example, work for what is now the U.S. Bureau of Reclamation began in 1902 when the Secretary of the Interior directed the Survey to study streamflows to meet Federal commitments under the new Reclamation Act while the Reclamation Service was being organized. In the same year, the Indian Service hired the Survey to gage streams in the Uinta Reservation in Utah. In 1915, the Survey entered into a cooperative agreement with the U.S. Army Corps of Engineers to establish and operate gaging stations on streams tributary to the Ohio River. A year later, several gaging stations were established in western national parks in cooperation with the National Park Service (Follansbee, v. I).

In later years, the number of Federal agencies for which the Survey conducted studies varied appreciably from year to year. For example, an average of about 18 agencies sought the Survey's assistance during 1938–47. In 1942 during World War II, the number increased to 25 agencies; in 1947, only 12 agencies are listed (USDI Appropriations Bill, 1948, p. 838). The size of the ''other Federal agency'' program as measured by dollars received also differed from year to year. In fiscal year 1947, funds totaled nearly $1.5 million, which was about one quarter of the Division's total program. By 1957, the amount, as shown in the House hearings for fiscal year 1959 (p. 356), exceeded $4 million, still about one quarter of the overall program.

The activities under this heading are not the same as those conducted under that portion of the ''gaging streams'' budget item entitled ''Water Investigations for Other Federal Agencies'' that appears in table 4 for fiscal year 1948. The latter covers investigations needed by another Federal agency, findings (or data) of which would have such broad value that they were more equitably financed through an appropriation made directly to the Geological Survey. Also covered were data-collection programs that were initially requested from the Division and funded by the other agency, but which grew with time to have such wide usage that future support through appropriations to the Survey was justified. In the late 1940's, for example, sizable amounts were transferred from the budgets of both the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation to the Survey's budget for continued operation of stream-gaging networks.

The specific projects conducted at the request of and paid for by other Federal agencies are referred to in many of the District activity statements in Part IV. For this reason, only general reference need be made to the Survey's relations with the agencies requesting and funding the largest of the programs. The annual transfer of funds from some agencies differed little in amount from year to year. For other agencies, the change was appreciable. Some programs, such as the stream gaging conducted for the U.S. Army Corps of Engineers, were comparatively stable because of the long-range nature of the activity. Projects for other agencies, such as the Atomic Energy Commission, were of shorter duration.

Of the other USDI agencies, the Division's program with the U.S. Bureau of Reclamation was by far the largest, especially that portion under the Missouri River basin program which is described later (pt. III) under regional programs. Transferred funds totalled more than $800,000 in fiscal year 1947 and more than $1.1 million in fiscal year 1957. The program for the Office of Indian Affairs also grew substantially during the latter part of the decade because of ground-water studies in the Navajo Reservation in Arizona. The Office of Land Utilization, Bonneville Power Administration, National Park Service, and Fish and Wildlife Service all requested substantial studies from the Division during all or portions of the decade.

The operation of that portion of the sizable nationwide network of gaging stations, funded by the U.S. Army Corps of Engineers and beginning with the 1947–48 funds

transfer, continued during the balance of the decade in a reasonably stable pattern. Specific work for the Corps is described in many District activity statements. One interstate project is noteworthy: in early 1949, H.E. Thomas studied the ground waters of eight western States for the Corps, the findings of which were of optimum value to its engineers.

The Atomic Energy Commission (AEC) sought the assistance of the Survey's water-resources personnel as early as the late 1940's, primarily in the Northwest and the Northeast. The geologic and hydrologic information was used by the AEC in site selection for reactors and testing facilities, and for the storage of radioactive waste by-products. As stated in the Division's report to the Director for August 1955, the site-selection studies also included those for AEC's new headquarters building in the vicinity of Washington, D.C. After the selection of the new site near Germantown, Md., a geologic reconnaissance was conducted and assistance given toward developing producing water wells. C.V. Theis served as the Division coordinator of the numerous field personnel conducting studies for the AEC.

Division personnel working on projects at the request of the so-called "sensitive agencies," such as the AEC and the military establishment, had been subjected to security investigation and clearance for several years before the beginning of the decade. Clearance permitted them to visit restricted areas and to collect confidential data needed for current projects. V.T. Stringfield was the Division security officer for a period which is believed to have included all of the decade. The AEC projects for which clearance was needed are identified in the District activity statements.

The program of sediment investigations in cooperation with the U.S. Department of Agriculture's (USDA) Soil Conservation Service from the late 1920's to the early 1940's had about ended as of the beginning of the decade (Follansbee, v. III, p. 81 and 89; v. IV, p. 78). Cooperation with the USDA was anticipated by the Division after the passage of the Hope-Aiken Watershed Protection and Flood Prevention Act (P.L. 566, 1954). That Act, administered by USDA, made reference to a role by the Geological Survey as well, but the cooperation apparently did not materialize to the degree expected (memorandum to districts, May 14, 1954). The Division then agreed to assist in the collection of data specified by the Soil Conservation Service and, at the end of the decade, the annual transfer of funds was more than $300,000.

Funding from the Department of State was largely for services and expenses of Division personnel on foreign detail. This activity is covered under the section on the foreign-assistance program.

Annual Budgets and Congressional Appropriations

The task of preparing the annual budgetary documents began at least 18 months before the start of the fiscal year on July 1 (fiscal year 1953, for example, ended on June 30, 1953). Congressional appropriations (funds) that were needed by the Division were expressed through the Survey's budgetary documents, beginning with the "preliminary estimates." The "budget estimates," a more comprehensive and formal presentation, followed once the USDI had allocated its initial "ceiling" that was established by the Bureau of the Budget. Following the Bureau of the Budget hearings and the issuance of revised (and usually reduced) allowances, the "budget justifications" were prepared for Congressional scrutiny and action. Hearings by the Subcommittee on Interior and Insular Affairs of the House Appropriations Committee were usually more thorough than, and in most cases preceded, those of the Senate. Monies actually appropriated usually identified the amount to be used by the Division; however, in 1 or 2 years, the Director had to make allocations of the Survey's appropriations based on his judgment as to Congressional intent.

The task of determining the proper level of annual appropriations for the Division (and perhaps for the entire Survey) was not a simple one. It required a measurement of the Nation's need for hydrologic data, but few yardsticks were available. One indicator that undoubtedly was used by the Bureau of the Budget and the Congressional committees was the willingness of the States, municipalities, and other Federal agencies to contribute to the support of the program. Another was the increasingly critical relation between water requirements and water availability.

Although the Democratic and Republican parties were each in control of the Executive Branch and the Congress at different times during the decade, general support for the Survey's water-resources program proved to be essentially nonpartisan. Other factors, such as government versus private enterprise, relative priorities between military and nonmilitary expenditures, and the desire for government retrenchment, did affect appropriations. But the events and forces influencing each of the annual appropriations were quite different and are best described chronologically. Specific sources are not given for many of the dollar values and other facts appearing in this chronology because they are too numerous and are all available from various program documents stored in the National Archives and Records Service. These materials are in "containers 4 (1955–57), 5 (1931–49), and 6 (1950–54), Interior Department, Geological Survey, Accession Number 61A-50, Record Group 57," and are labeled "Budget Files from the Water Resources Division."

1948 Fiscal Year

The decade covered by this volume began on the same day (July 1, 1947) that 1948 fiscal year funds became

available for use. The problems encountered prior to July 1 in securing such funds, however, were sufficiently unique as to warrant a somewhat detailed description. In conformance with Departmental and Bureau of the Budget allowances, the Survey's fiscal year 1948 budget justification to Congress carried an amount of $3,750,000 in its "gaging streams" item through which the Division received practically all of its direct appropriation. Of this total, $2,220,000 was to be available only for matching Federal and State offerings for cooperative work. The above amounts were appreciably larger than the $2,588,672 (gaging streams) and $1,710,000 (matching co-op) that had been available for the 1947 fiscal year. The budgeted increases were in recognition of larger offerings from cooperating State and municipal agencies, and reflected the inflation prevalent at the time.

At the hearings on February 3, 1947, before the House subcommittee that had jurisdiction over the USDI appropriations, Lee Rogers, President of Layne Western Company of Minnesota, aided by a resolution from the Minnesota Well Drillers Association dated January 1947, complained through his local Congressman about the Survey's cooperative ground-water program. Rogers claimed that certain of the Division's cooperative projects with the State Geologist of North Dakota, in which State-owned test-drilling equipment was used in ground-water studies for municipalities, was an infringement on private enterprise. (Additional information is given in pt. VII).

Division officials had been advised earlier of Rogers' claims, but they did not anticipate that the situation would become an issue at the hearings. Director Wrather and CHE Paulsen referred many of the critical questions to Assistant GW Branch Chief Fiedler. However, the difficulty of convincing subcommittee members as to the need for a Federal investigation (including operation of a State-owned test drilling rig) of the ground-water resources of municipalities was a difficult task in the brief time available at the hearings. Despite voluminous data submitted to the subcommittee that showed the nature and use of the Survey's ground-water activities, the Interior Appropriations bill that was brought to the House floor on April 25 had language added to the "gaging streams" item that specifically prohibited cooperative and non-cooperative ground-water activities.

During the debate on the House floor, several Congressmen spoke in behalf of the need for the Survey's ground-water investigations and supported an amendment by Congressman Mahon of Texas that would have removed the restriction. Congressman Jones of Ohio, Chairman of the subcommittee for USDI appropriations, defended the prohibitive language. Jones called attention to the great debt incurred by the Federal Government during the recent war years and the huge postwar surpluses of funds held by many States, and he then asked why it was unfair "to require that instead of the States paying 50 percent of the cost, they shall pay it all?" The House voted 92 to 152 against Mahon's amendment and for the elimination of the ground-water activities.

The news of the House action traveled quickly and widely, and brought rapid response from officials of the many agencies and water-resources organizations who were familiar with the Survey's ground-water program and its value to the Nation. When the "gaging streams" item came up at the Senate hearings on the fiscal year 1948 Interior Appropriations Bill on May 9, the retention of the ground-water activities was vigorously supported by eight or nine witnesses (including several Senators) and by more than 40 written statements. Although Rogers, armed with the Minnesota Well Drillers Association resolution, alone represented the opposition, he was given full opportunity to introduce and be questioned on his primary assertion that ground-water development for municipal water supplies could best be done by private well drillers, cooperating when necessary with State water agencies, without any Federal participant such as the Geological Survey.

The dilemma of the Survey and its supporters was that they had to prove that the Federal participation in ground-water development, management, and conservation was essential, and that private industry, States, and municipalities would be unable to attain the required technological and scientific progress without it. This defense called for points of judgment that required the experience of knowledgeable and highly respected third parties. Fortunately for the Survey, some of them were present at the hearings.

Witnesses at the hearings giving testimony in support of the Survey reminded the Senate subcommittee members repeatedly that ground-water problems frequently were interstate in nature, that ground-water hydrology was a complex science, and that professional experience gained in one State was often advantageously applied in another. Clifford H. Stone, Director of the Colorado Conservation Board, stated that the need was not just to find ground water for some city, but rather "to remove the mystery about water." He added that it could be advantageous to some to keep it a mystery. The need for broad scientific ground-water investigations and the Survey's established competence in the field was the substance of many introduced statements. The U.S. Chamber of Commerce was among those entities recommending removal of the House action prohibiting ground-water investigations by the Survey. Testimony in support of the restoration was also given by several witnesses at the Senate hearings on the U.S. Bureau of Reclamation appropriations bill for 1948.

Impressed by the extent and nature of this support, the Senate struck out the prohibiting language imposed by the

House and restored funds in the amount of $845,000 for ground-water investigations, of which $650,000 was for cooperation with States and municipalities. The House and Senate conferees accepted the Senate action. As enacted, the Bill carried a total of $2,625 million for "gaging streams."

By April 1948, the House and Senate had each approved in the First Deficiency Bill, 1948, an additional amount of $485,000 ($635,000 had been requested) for matching State and municipal offerings, which enabled the Survey to provide about 96 cents of Federal funds to "match" each $1 of cooperative funds. An amount of $175,000 was also received on June 25, in the Second Deficiency Act, 1948, for use in the Columbia River basin: $95,000 for a flood report and $80,000 for repair of flood-damaged or destroyed gaging structures. The supplemental appropriation, having been made directly to the Office of the Secretary, did not appear in the Division's appropriations documents.

Because it was built largely upon a series of restrictive clauses, the language of the "gaging streams" item was a carefully heeded statement. For the 1948 fiscal year, it carried the following language:

> "Gaging streams: For gaging streams and determining the water supply of the United States, its Territories and possessions, investigating underground currents and artesian wells and methods of utilizing the water resources, $2,625,000, of which not to exceed $10,000 may be expended for acquiring lands at gaging stations, and not to exceed $265,000 may be expended for personal services in the District of Columbia: *Provided*, That no part of this appropriation shall be expended in cooperation with States or municipalities except upon the basis of the State or municipality bearing all of the expense incident thereto, in excess of such an amount as is necessary for the Geological Survey to perform its share of general water resource investigations, such share of the Geological Survey in no case exceeding 50 per centum of the cost of the investigation: *Provided further*, That $1,586,500 of this amount shall be available only for such cooperation with States or municipalities: *Provided further*, That no part of the funds appropriated in this paragraph shall be used for the payment, directly or indirectly, for the drilling of water wells for the purpose of supplying water for domestic use: *Provided further*, That not to exceed $10,000 of this appropriation shall be available for payment of the compensation and expenses of the person appointed by the President pursuant to the Act of April 19, 1945 (P.L. 34), Seventy-ninth Congress, to participate as the representative of the United States in the negotiation of a compact between the States of Colorado and Kansas relative to the division of the waters of the Arkansas River and its tributaries: *Provided further*, That notwithstanding the provisions of any other law to the contrary, the President is authorized to appoint a retired officer of the Army as such representative without prejudice to his status as a retired Army officer who shall receive such compensation and expense in addition to his retired pay; (*43 U.S.C. 31,36b; 44 U.S.C. 260; Interior Department Appropriations Act of 1948*)." The last two provisions, not sought by the Survey, were inserted by Congress as a new item in fiscal year 1948.

1949 Fiscal Year

The Survey's fiscal year 1949 budget justifications included the amount of $3,434,800 for the "gaging streams" item and a statement that at least $2,400,000 of this amount would be needed to match the anticipated offerings by States and municipalities for cooperative programs. At the House subcommittee hearings on March 3, 1948, there appeared to be some retention of the attitude of a year earlier that the Survey's ground-water studies for municipalities were an infringement on private enterprise. Congressman Curtis of Nebraska and Congressman Davis of Tennessee appeared in support of the "gaging streams" item. The final appropriation (P.L. 841, 80th Cong.) carried $3,496,700 for "gaging streams," of which $2,361,000 was available for cooperation with States and municipalities.

The terms of the appropriation bill gave a much needed increase in the earlier ceiling on expenditures for personal services in the District of Columbia. The Division's allocated share of the limitation, when imposed 21 years earlier, was equal to about 14 percent of its total expenditures at the time. By fiscal year 1948, the total program had grown much faster than the District of Columbia salary ceiling ($265,000), which was only about 4 percent of the total program funds. With Senate support, the salary ceiling was raised to $350,000, the amount requested in the budget justifications.

A 24-page description of the activities of the Division and the use of its data and hydrologic appraisals on the economy was prepared under the leadership of A.M. Piper and was used in the preparation of fiscal year 1948 and later budgets. The report was dated May 10, 1948, and was reproduced for field use as well.

1950 Fiscal Year

Congress appropriated to the Survey all of the funds requested ($2,940,000) to match the expected offerings

of States and municipalities for the cooperative program during fiscal year 1950, but support for the Federal program was weaker. The requested amount of $1,258,000 for the Federal program was cut by $198,000 by the House. Director Wrather made a plea for full restoration of funds for this and several other items, citing a statement from the report of the Natural Resources Task Force of the Hoover Commission that recommended "the immediate expansion of the programs of the basic data collection agencies . . . to keep pace with development programs." A number of Senators who were not on the Appropriations Committee sent statements in support of the restoration. The Senate restored $125,000 of the House reduction and the conferees agreed to this figure. Later in the year, an additional $15,000 was appropriated toward pay increases.

Congressman Kirwan of Ohio replaced Congressman Jensen of Iowa as Chairman of the Interior Subcommittee on Appropriations beginning with the fiscal year 1950 budget hearings. Mr. Jensen was water conscious from an agricultural viewpoint and a particular advocate of holding the water at or near the source, but Mr. Kirwan represented an industrial area where the available water was recycled extensively. He knew firsthand the manner in which the Survey's water-resources studies helped the economy and thus was an advocate of maintaining adequate program levels.

Prior to 1950, cooperative work conducted on a reimbursable basis for States and municipalities was financed temporarily through a working fund that was appropriated annually. In 1950, the House established a revolving (continuing) fund for this purpose.

A special effort was made in the fiscal year 1950 budget justifications to illustrate the extent to which water data collected specifically for one purpose eventually was used in other activities. The percentages of the Division program that had potential use for each of 11 data-dependent activities were calculated. For example, 40 percent of the program supplied data useful for irrigation activities, 35 percent for municipal water-supply activities, 25 percent for pollution abatement activities, et cetera. The sum of the percentages, totaling 295 percent, indicated that, if the data were collected independently for each activity and were not readily available for other types of uses, the cost would theoretically be nearly three times the existing level. This, for the first time, provided a statistical measure to the value of the Survey's national water-data program.

The Division reported, in keeping with the Director's interpretation, that all of its requested appropriations for 1950, as well as those received in 1948 and 1949, were appropriately identified as to research and development. This request to Interior's agencies by Bureau of the Budget examiners reflected a continuing interest by Congress in Federal outlays for research. A similar response was made earlier to the President's Scientific Research Board.

As a result of presentations by the Director and also by a research group who were advising the U.S. Civil Service Commission, the traditional "printing and binding" item was eliminated from the Survey's 1950 budget. The Division, which had received an allocation of $75,000 as its share of the liquidated item plus the authority to use its operating funds as well, was able to have a large number of its backlog of unpublished manuscripts printed.

1951 Fiscal Year

The format for the fiscal year 1951 budget presentation differed greatly from earlier annual estimates because of instructions from Congress to reduce the number of individual appropriation items and also to make presentations conform to the new "performance type" of budget. This new format, recommended by the Hoover Commission, was an attempt to show more clearly the full cost of the work to be conducted with funds from several sources. The separate and historic "gaging streams" item was eliminated. All Survey appropriations were covered under a new item entitled "Surveys, Investigations, and Research" (SIR). Funds for the Division were identified in two of the seven subitems: The primary one, "Water Resources Investigations" (WRI), was essentially the old "gaging stream" item; the other was "Soil and Moisture Conservation: Geological Survey Appropriations," which was closely related to the Department's S&M program.

Under the new budget format, the allowances granted by the House, the Senate, and the joint conference committee did not always clearly identify the specific amounts in the WRI subitem. In such instances, the amounts were established by the Director from his interpretation of congressional intent.

The budget pattern within the WRI subitem was also changed. The "Cooperative program" became the "Federal-State program." The "Non-cooperative program" (a term that carried a negative connotation) was changed to the "Federal program." The Federal program was further subdivided into four parts: stream gaging, sediment investigations, chemical-quality investigations, and ground-water investigations. All were identified in the budget justifications to Congress.

In May 1949, the Survey sent preliminary estimates (that is, what the Director felt could be used effectively to meet program goals) through the Department to the Bureau of the Budget, which included $10,650,000 for water-resources investigations. In July 1949, the Department advised the Survey of its "ceiling", that is, the maximum amount to be used in its budget request ("budget estimates") to the Bureau of the Budget. (This ceiling was an allocation by the Bureau.) The Department also advised that the Bureau of the Budget would be receptive to

''over-ceiling'' estimates if they were held to a minimum and were comprised of items that had lower priority than the regular estimates but were considered too urgent to be postponed.

The Survey's ''within the ceiling'' estimate to the Bureau of the Budget included $5,599,000 for water-resources investigations and $40,000 for soil and moisture conservation. Its accompanying over-ceiling presentation included an additional $5,150,000 for water-resources investigations, nearly 70 percent of which was to be applied to a major expansion of the stream-gaging station network. Following its hearings on the Survey budget items, the Bureau of the Budget approved the amount of $5,300,000 for water-resources investigations and $40,000 for soil and moisture conservation as segments of the Survey's item in the Federal budget for fiscal year 1951.

Particular interest was shown (once again) by Chairman Kirwan during the House hearings January 16, 1950, on the current water-supply problem for New York City. After Paulsen explained that it was a case of increasing water consumption overtaking development of additional sources, the Chairman asked for a listing of other cities where the supply and demand relationships might be critical. The Division quickly provided a summary entitled ''Areas of Critical Water Supplies'' that was inserted in the record of hearings. On July 31, the list was released to the press by the Secretary of the Interior. A few days later, Paulsen was publicly criticized on at least one local radio station in Chicago, Ill., for having included the Chicago area on the list. The fact that the press release accurately stated that the water within the Cambrian sandstone was overpumped and that yields were declining gave little consolation to the critics. Chicago officials, in seeking industry for the area, cited the presence of Lake Michigan as assurance of abundant water. The reaction had a short life and the Survey's relations with the city and the area were not adversely affected.

Mr. Kirwan, recently back from Europe where the stream waters were relatively free of sediment, urged the Survey to expand its studies to include the causes of sedimentation. This request was supported by Congressman Jackson of Washington and Congressman Fenton of Pennsylvania. Former Chairman Jensen criticized the small size of the S&M program and urged more extensive investigations of how to lessen the erosion of topsoil from agricultural lands.

The House approved $5,200,000, nearly the full amount budgeted, for water-resources investigations. Recent developments, such as the New York City water shortage and other inadequacies of water supply, had demonstrated a need to procure more basic water data. The Senate approved the House allowance and added an additional $253,000 from a supplemental budget estimate to provide stream-gaging funds for the upper Colorado, the Arkansas, and the Pecos River Compacts that had recently been approved by Congress. The House and Senate conferees accepted the Senate's allowance for the Survey's item but made no mention of subitems. The public law by which the appropriations were enacted gave no further details except to state that ''$3,100,000 shall be available only for cooperation with States and municipalities for water-resources investigations.''

In May 1951, however, the unobligated portion of the Division's 1951 funds was reduced because of the Nation's financial burdens that came with the commitment of the U.S. Armed Forces to the Korean conflict on June 30, 1950. In accordance with the General Appropriations Act, 1951, $175,000 was withdrawn from the Federal program as a part of a general ''nondefense'' item reduction. An additional $68,000 from the Federal program and $32,000 from the Federal-State program were taken to meet the needs of the defense industries. Despite the reductions, the Division's available WRI funds ($5,178,000) were still considerably larger than the $4,125,000 appropriated for fiscal year 1950.

1952 Fiscal Year

Although President Truman set a fiscal year 1952 Government-wide budget ceiling that would provide for no program increases except under exceptional circumstances, the Bureau of the Budget advised that it did allow for ''some increase in the soil and moisture program'' and ''expansion of the resource basic data program of the Geological Survey.'' The Survey responded in April 1950 with a preliminary estimate for the SIR of $40 million, double that of its budget estimate for fiscal year 1951. This included $10,600,000 for WRI, a 45 percent increase, and $250,000 for S&M, a sixfold increase.

These amounts were scaled down, first in the allowances by the Bureau of the Budget and later in December 1950 by the President's directive to reduce all nonmilitary expenditures. The commitment by the Nation to the Korean conflict was proving to be more serious and enduring than thought earlier in the year. The U.S. Budget carried an amount of $22,900,000 for the Survey's SIR item, of which $6,015,000 was for water-resources investigations (including $3,300,000 for cooperation) and $41,000 was for S&M. In his budget message to Congress, President Truman stated that ''because of their importance to planning for defense projects, increases are recommended for topographic mapping and water-resources investigations.''

During the House hearings on February 23, 1951, the subcommittee members present—Chairman Kirwan (Ohio), former Chairman Jensen (Iowa), and Congressman Norrell (Pa.)—appeared even stronger in their

support of the Survey's programs than they were a year before. Mr. Jensen was again critical of the small amount budgeted for soil and moisture conservation.

At the end of the session, Mr. Norrell asked that a statement of Dr. Wrather's "distinctions, in addition to the technical qualifications and training that he has, go in the record so that the general public may know the caliber of the official that we have at the head of the Geological Survey." Jensen added his commendation saying in part that "because of my high regard for you, Dr. Wrather, and your fine administrative staff, I believe that it is fair to say that you have the most able and efficient agency in Government today." Chairman Kirwan stated that "I am grateful also to be sitting across the table from you—as a pupil—and learning . . . ." The tributes continued, Mr. Norrell saying, ". . . I have been on this committee a long time and it [the Survey] is one agency that I have never found withholding information from us . . . ." (On the way back to the office, the author recalls the always modest Director saying that he was so embarrassed that he wished he could have disappeared.) The strains and discouragements stemming from the complaints brought against the Survey's ground-water activities at the House Subcommittee hearings only 4 years earlier were now only a matter of history.

The subcommittee members again expressed their regard for the Survey and its program on April 23 when the Interior Appropriations Bill was presented to the full House. Chairman Kirwan stated: "I think if there is one agency in the Department of the Interior that everybody has complete confidence in, it is the Geological Survey. The Committee has approved their budget estimate of $22,900,000, which amounts to an increase of $4,018,000 above the amount they had for the current year."

When the House continued discussion of the bill on May 1, Congressman Davis of Georgia offered an amendment that would reduce the SIR item by $1 million. He called attention to the recent rapid growth in the program and said that such spending by civilian agencies should be reduced in deference to the need for vastly increased spending for defense purposes. In discussing Survey activities that might be reduced, he suggested that no increase be allowed for water-resources investigations, that there were "many agencies, Federal, State, as well as private, constantly doing work of this nature." (The remarks by Congressman Davis eventually came to the attention of Garland Peyton who headed the Department of Mines, Mining, and Geology of the State of Georgia's Division of Conservation and who was a long-time cooperating official with the Survey. By letter dated August 30, 1951, to Congressman Davis, Captain Peyton discussed the unique role of the U.S. Geological Survey, among other agencies, in assisting Georgia in water conservation and development, stating that "I am left with the conviction that had you been more fully informed concerning the value and scope of the work of the U.S. Geological Survey in Georgia, in cooperation with the Georgia Geological Survey, your remarks would have been less critical of that agency and very likely you would not have even offered the amendment to cut the appropriation in that amount.") Although Chairman Kirwan and Congressman Jensen gave spirited objections, the amendment passed by a vote of 66 to 64. Allowances for other Interior items were similarly reduced. The bill was passed by the House on May 2.

When he appeared before the Senate subcommittee on May 8, Interior Secretary Chapman was critical of the sizable reduction to a Departmental budget request that was already below the 1951 appropriation. He stated that, if not restored, the $1 million reduction in the SIR item would result in a $500,000 cut in mapping, and the remainder of the reduction would be divided between water-resources investigations and geological and mineral resources surveys, and made a plea for full restoration. The Senate, however, made a further reduction in the SIR item on July 12, allowing $21,300,000 and, by amendment, provided that funds not to exceed $13,455,000 be made available for personal services. The bill, as enacted, carried these amounts.

The Survey's 1952 SIR item stood up well, however, in comparison with severe cuts in many other civilian activities because of the rapid escalation of expenditures for the military. SIR funding was nearly 13 percent above the amount available for 1951. The $21,300,000 was distributed by Survey Budget Officer J.L. Ramsey and his Budget Committee members largely by prorating the total increase allowed in proportion to the increases requested by subitem. The Division received, for the WRI subitem, a total of $5,629,000, an increase of 9 percent over that received for 1951. Of that, $3,300,000 was for the Federal-State program. The S&M subitem remained at $41,000.

The Senate added an amendment to the 1952 bill requiring that purchases of supplies, materials, equipment, lands, and structures be no greater in the fourth quarter of each fiscal year than the quarterly averages of such purchases for the first three quarters. Although the amendment was deleted by the conferees, their report carried the admonition that "excessive last-quarter purchases [are to] be prevented so that accumulated last-quarter balances revert to the Treasury." The Director determined that this restriction was intended to apply to all Survey funds regardless of source. The Division could no longer hold many of its equipment purchases until late in the year out of concern that the encumbered funds might be needed to cope with unforeseen and unbudgeted events as the year progressed.

The severity and magnitude of the July 1951 floods in Kansas and Missouri resulted in the passage on

September 30 of Public Law 875, 81st Congress, that authorized the appropriation, not to exceed $15 million, for alleviation and suffering from such major disasters. P.L. 875 also provided for the replacement of damaged facilities owned by the United States Government. In the supplemental budget estimate that followed, an item of $195,000 was included for the Division, of which $120,000 was for a flood study and report and $75,000 for the rehabilitation of 63 flood-damaged gage structures and instruments. The item was reduced to $150,000 by the Senate and enacted on November 1, 1951, in that amount.

1953 Fiscal Year

The Survey's preliminary estimates for fiscal year 1953, prepared in March 1951, included amounts for water-resources investigations that were of the same level as justified in the preliminary estimates for the previous year. These were consistent with the estimates of cost of the first year of the accelerated program of water-resources investigations envisioned in H.R. 1673 and set down on page 81 of House Document 706. The $10,600,000 requested would have expanded the Federal program to about 2½ times its 1952 level. The Federal-State program request was increased to $3,500,000 and S&M from $41,000 to $250,000.

The Survey also included in its preliminary estimate a proposed draft of a bill in which Congress would authorize the Secretary to enter into a lease-purchase agreement to provide a building ". . . in Montgomery County, Md., necessary to provide space for the eastern field center activities of the Geological Survey . . . ." The accompanying justification stated, however, that the facility was to be used for all of the Survey's personnel in the Washington area, then 1,835 persons dispersed in 15 buildings. Forwarded with the preliminary estimates was an impressive State-by-State summary of recent requests for water data for use in the current mobilization effort.

The final fiscal year 1953 estimates to the Bureau of the Budget were based on a Survey ceiling set by the USDI and allocated by the Director to subitems, which allowed $6,400,000 for WRI, of which $3,500,000 was for cooperative work. The S&M activity remained at $41,000, unchanged from the previous several years. New language in the administrative provisions would more clearly allow the funds to be used in payment of salaries and expenses of Survey personnel engaged as Federal representatives on interstate and international compacts.

The 1953 justification to Congress carried $6,375,000 for WRI, including $3,500,000 for the cooperative segment. S&M was increased to $44,000. The total SIR item was $29,055,000. At the House hearings on January 21, 1952, Director Wrather reported that "the Survey's programs have been reoriented and directed almost wholly toward defense requirements . . . ." The questioning reflected the national concerns about growing international tensions.

The House Appropriations Committee allowed the requested amounts in its report to the full House when the SIR item was considered on March 26 and 27. On March 27, Congressman Colmer of Mississippi offered an amendment that would reduce the SIR item to $25,362,685, which he stated was the amount appropriated the year prior. His objective was to help balance the budget. Two other members spoke in support of the amendment and despite Congressman Kirwan's objections, it was passed. The Survey and the U.S. Bureau of Mines were, however, specifically exempted from another amendment that was passed, which placed restrictions on the filling of most vacancies during 1953 and was intended to reduce the number of Federal employees by attrition.

Restoration of the House cut was urged by both Interior Secretary Chapman and Director Wrather at the Senate subcommittee hearings on April 25 at which the SIR item was considered. Senate action, however, reduced the item still further to $25,301,000 and recommended a distribution that provided $5,987,000 for the WRI subitem and $43,700 for S&M.

The House and Senate conferees agreed on the House allowance of $25,362,685 for SIR and specified in its July 3 report an increase of $200,000 over the Senate recommendation for WRI. The 1953 appropriation, approved on July 9, 1952, as Public Law 470, provided $2,687,000 for the Federal program (about 10 percent more than the previous year) and $3,500,000 for the Federal-State program (a 6 percent increase). P.L. 470 also carried new language that clarified the use of funds for Federal representatives or compacts.

Although not specified by Congress under the 1953 appropriations language, the Director ordered that the limitation on fourth quarter equipment purchases be continued. Later, by its Bulletin No. 53-22 dated July 17, 1953, the Bureau of the Budget, in a further step to control excessive buying late in each fiscal year, set up a reporting requirement to identify cases where year-end obligations exceeded the level not only of the earlier quarters but of preceding months in the fourth quarter as well.

One other adjustment in the 1953 appropriation process was small in dollar magnitude, but it established a procedure that the District chiefs found difficult. An amount of $31,000 was transferred from the WRI subitem to the General Services Administration's (GSA) 1953 budget. This represented the current rental costs for office and other types of space used by the Division at 30 locations

in 19 States. Despite an earlier protest by the Survey that was forwarded to the Bureau of the Budget, GSA was given authority over the procurement and administration of all rental space of all Federal agencies.

Considerable time and effort was expended by the Division during 1953 on the development of annual financial planning so that expenditures could be subject to better scrutiny and control. As part of a Bureau-wide project, these plans were developed under the close scrutiny of Assistant Director Nolan. These plans were essential because of the growing number of restrictions on the use of funds and the now complex pattern of charges against each subitem to support the various administrative and service functions operating at both Bureau and Division level.

1954 Fiscal Year

The Division proposed in May 1952 that a $500,000 emergency fund be added to the 1954 and later appropriation bills for the rehabilitation and replacement of flood-damaged gaging facilities, with the stipulation that monies remain available until spent. In previous years, such work was largely delayed until deficiency funds became available. The request was not approved.

The amount of $10,600,000 for WRI was again requested from the USDI in the 1954 preliminary estimates, as was $250,000 for the S&M subitem. The USDI asked the Survey to prepare also a supplemental preliminary estimate under which it would investigate the quantity and quality of irrigation waters with the objective of assuring sustained irrigation and food supply in the West. This activity, supported by the National Reclamation Association, was to be part of a larger effort conducted to a great extent under the purview of the Department of Agriculture. The Division responded with a request for $250,000.

In discussions with Division officials in April 1952 regarding its preliminary estimates, Director Wrather and Assistant Director Nolan expressed concern about the extent to which the Division's program was being diverted to short-term studies of local areas in which water supplies were critical with respect to demand. They felt that more of the effort should be applied tc research-type projects that would enhance the knowledge of hydrology. Another point of concern was that, over the previous several years, fewer of the Division's reports were being published. Many were remaining in "open-file" status or being published by the State cooperating agencies. Director Wrather stated that the Government Printing Office promised faster service if the Survey would set up and conform to specific report schedules which could be given priority in printing. The criticism was heeded in the Division and publication efforts were strengthened. Talent that had been applied to short-term efforts in water-critical areas (so-called "putting out fires") was gradually adjusted to provide a greater expansion of research.

Under ceilings set by the Department in July 1952, the budget estimates were prepared in the amounts of $31,070,000 for SIR, of which $6,500,000 was for WRI and $45,000 for S&M. At the hearing on September 26, 1952, Bureau of the Budget examiners announced that they planned to visit the Survey and develop a greater familiarity with its various programs. The visit benefited both sides in the years that followed.

The budget justifications for 1954 carried $31,070,000 for SIR, the same as the ceiling set by the Department. The WRI subitem had been increased to $6,960,000, of which $3,700,000 was for cooperative work. The S&M subitem was increased to $100,000.

The House Committee on April 23, 1953, reported the SIR item out in the amount of $27,750,000, a reduction of $3,320,000 that was to be applied to the topographic surveys and mapping subitem which had grown greatly in recent years because of the need for military mapping. The 1954 estimate for topographic surveys and mapping in the U.S. Budget was $14,950,000, which was more than double the size of either the WRI or the geologic and mineral resources subitems. The House subcommittee learned during the hearings that military mapping priorities had been reevaluated downward.

The Senate allowed $26,380,000 for SIR but the conferees agreed to the House allowance of $27,750,000. They also agreed to the House allowance of $3,700,000 for cooperative water studies instead of the $3,600,000 set by the Senate. The Bill was enacted on July 31, 1953. The WRI subitem of $6,960,000 that was carried in the U.S. Budget was enacted in that amount.

The Bureau of the Budget, apparently dubious about the Division's ability to match the appropriated $3,700,000 of Federal-State program funds, impounded $100,000 with the understanding that it would be released if needed. This was part of a Government-wide effort to reduce expenditures. The impoundment resulted in a deficiency in Federal-State funds in the amount of $123,000 that was met by applying an abeyance of 2 percent and by using $33,000 of Federal program funds. The Director did not request release of the impoundment, likely because of the anticipated year-end surpluses in other Bureau subitems. This placed the base for Federal matching funds for 1955 at an unrealistically low level of $3,600,000.

An additional $150,000 was also impounded from the Federal program. Throughout the year, the Bureau of the Budget's search for unneeded funds from the Federal establishment resulted in tighter internal budgetary controls than ever before.

The control over expenditures made directly by cooperative officials within the cooperative programs was

continued. On January 13, 1954, the Division asked the Bureau for an increase in the ceiling for direct expenditures from $1 million to $1,050,000. Such expenditures by cooperating officials at the State and municipal levels normally were as requested or approved by the local District chief.

1955 Fiscal Year

The 1955 U.S. Budget was the first planned and prepared under President Dwight D. Eisenhower's administration. The USDI segment was under Secretary McKay's direction. The usual preliminary estimates were not requested, but the Director provided the Department with the Survey's program recommendations in July 1953 so that the Secretary would have better information on which to allocate the forthcoming allowance from the Bureau of the Budget. The recommendations were for a SIR item of $31,800,000 within which WRI was allotted $7,550,000 and S&M $150,000; $4,370,000 was to be used as Federal cooperative matching funds.

In August 1953, the Survey received a ceiling of $28 million with which to prepare its formal budget estimates that included activities under the Survey's portion of the Missouri River basin program that were to be transferred from the U.S. Bureau of Reclamation to the Survey. The WRI subitem was $7,200,000, of which $3,400,000 was for the Federal program (including $400,000 for Missouri River basin activities) and $3,800,000 for Federal matching funds (an amount equal to the current estimate of 1955 offerings). The S&M activity was allotted $75,000.

At the Bureau of the Budget hearings on October 1, 1953, Chief Examiner Dodd reported that agency requests were being screened carefully on the basis of questions such as "Is it necessary? Can it wait? Can it be done by parties other than the Federal Government?" Deficiency items were not contemplated.

The U.S. Budget carried $27,335,000 for SIR, of which $7,025,000 was for WRI and $100,000 for S&M. The WRI subitem, as shown in the budget justifications, consisted of $3,225,000 for the Federal program and $3,800,000 for the Federal-State program.

At the House Hearings on February 2, 1954, Felix R. Wormser, the new Assistant Secretary for Mineral Resources, spoke of his distress in finding the Survey in so many scattered locations in the Washington, D.C., area. Director Wrather summarized progress on the rehabilitation of space at the Denver Federal Center and the new space at Menlo Park, Calif., both near completion and financed by a $900,000 capital outlay item carried in the previous three annual budgets. Wrather stated that further work toward a Washington building must await passage of lease-purchase legislation. At the suggestion of Chairman Jensen at the 1954 hearings, the Survey had prepared such a bill but Congress did not pass it. Wormser and Wrather reported that the team headed by Dr. Robert van Pelt who were appointed to investigate the activities of the Survey had been at work about 2½ months (see pt. VII).

The House reduced the SIR item to $25,362,685, the level of the 1953 program. The reduction included $1,475,000 for the Missouri River basin studies. A strong statement was added in support of a new building for the Survey and proposed a continued expenditure of up to $75,000 of the 1954 funds for capital outlay items, necessary plans, and specifications.

The Senate allowed an SIR item of $25,860,000. The House-Senate conferees agreed on a compromise figure of $25,735,000 and also agreed to allow the House language regarding funds for planning the new building. The bill was enacted on July 1, 1954.

The Bureau allocation of the $25,735,000 SIR item provided $6,530,000 for WRI and $100,000 for S&M. Because the provision for Federal matching funds (Federal-State program) had remained unchanged in the language at $3,800,000, all of the reduction had to be taken by the Federal program, which, at $2,730,000, was about 10 percent below the level of the previous year.

The 1955 budget was developed, presented, reviewed, and enacted with little attention to national defense or security (the fighting in Korea had ended in July 1953). Final appropriations apparently reflected a desire for greater frugality in government, and some of the agencies of the USDI were cut back to near the level of the 1953 appropriations.

The Survey's appropriation language relative to cooperation was changed in 1955 in a manner that removed one more opportunity for flexibility in the year-end use of Division funds. Prior to 1955, the terms regarding expenditure of cooperative funds were: "*Provided*, that the share of the Geological Survey in any topographic mapping or water-resources investigations carried on in cooperation with any State or municipality shall not exceed 50 per centum of the cost thereof." The language was continued as above in the U.S. Budget for 1955. The new terms first appeared in the House Bill as follows: "*Provided*, that no part of this appropriation shall be used to pay more than one-half the cost of any topographic mapping or water-resources investigations carried on in cooperation with any State or municipality."

The Division's interpretation of the new language, according to Paulsen's memorandum dated April 25, 1955, to District supervisors, was that it required "a balance between Federal and State funds for each year." Previously, in cooperation with certain States and municipalities whose fiscal years began earlier or later than the

Federal fiscal year or whose funds did not lapse at year end, District personnel had found it advantageous to carry small amounts of local monies into the new Federal year. This could no longer be done.

1956 Fiscal Year

In June 1954, the Survey presented a preliminary estimate to the Department with the SIR item totaling $30,061,000, of which $7,075,000 was for WRI and $150,000 for S&M. The WRI subitem was comprised of $4 million for the Federal-State program and $3,075,000 for the Federal program. The increase for the Federal program was to be applied largely to new studies of water-land relations. Later in June, a supplemental preliminary estimate was sent to the Department that raised the SIR item to $30,876,000. The increase of $815,000 was for Survey-wide studies that would provide a base for the detailed planning and design of the Colorado River storage project. The President had recently asked Congress to approve the project and to authorize construction of the Echo Park and Glen Canyon Dams. The WRI segment in the amount of $325,000 for the Federal program would have involved all of the branches.

Early in August, the Director announced that the Department had allowed a ceiling of $26 million for the SIR item, of which WRI was allocated $6,530,000 and S&M $100,000. An over-ceiling request was authorized for $200,000 for the Federal-State program, for a total of $4 million. No provision was made for studies relating to the Colorado River storage project. The 1956 program, still early in the budget cycle, was already at the level of the past 2 years. The Division had earlier hoped that its program would have stronger support under President Eisenhower's administration on the basis of his statement in the announcement of his new Cabinet Committee on Water Resources: "I have become convinced that before very long, America will almost unanimously look upon water as its single greatest resource."

The Budget Bureau hearings were held on October 7. The Bureau allowed the Survey an SIR item of $26,285,000, slightly more than its earlier ceiling allowance. The WRI subitem was $6,700,000, including $4 million for the Federal-State program.

At the House hearings on January 31, 1955, after Secretary McKay gave a brief general statement on the USDI budget, Chairman Kirwan made a strong introductory statement to the effect that more of the Federal budget should be devoted to the Nation's water needs. Specifically, he said that ". . . what is needed far more than $100 billion for roads is $50 billion for water." Congressman Jensen's following statement supported Chairman Kirwan's and included a well-expressed comment on the placing of culverts under highways to avoid erosion and soil loss. The Secretary followed with remarks that indicated that he, too, was water-conscious. Assistant Director Nolan accompanied Director Wrather to the hearings and took an active part in answering questions. Plans for a new Survey building were reported as being deferred pending studies of the dispersal of new buildings in the area and completion of other proposed agency buildings. The House passed the Interior Bill leaving the SIR item unchanged from the $26,285,000 in the U.S. Budget.

At the Senate hearings on March 4, a resolution and two letters from cooperating officials were introduced, each supporting adequate funding for cooperative water-resources studies. Chairman Hayden asked if budgeted funds were adequate and learned that they were $700,000 less than the estimated matching State and municipal offerings. The Senate passed the SIR item with the $700,000 added, a total of $26,985,000.

In the House-Senate Conference, only half of the deficiency for complete matching was allowed, and the $350,000 increase for cooperation gave a final SIR item of $26,635,000. The bill was enacted on June 16, 1955, as Public Law 78.

In August 1955, heavy rainfall from two hurricanes caused flooding in the Northeast. Runoff in many places exceeded all previously known records of stage and discharge. The resulting damage to life and property probably exceeded any similar disaster in U.S. history up to that time. Additional funds ($245,000) were requested for flood surveys and for rehabilitation of damaged gage structures at Bureau of the Budget hearings on January 23, 1956, and that amount was included in the Second Supplemental Appropriations Bill, 1956. (No evidence could be found that the funds were ever received. The work was likely accomplished using regular funds.) The bill also included funds to meet increased costs of the pay raise enacted June 28, 1955, as Public Law 94.

The Division also sought funds for a survey and report and for rehabilitation of damaged gaging facilities in California, Oregon, and adjacent States as a result of the floods of December 1955 and January 1956 that caused great physical damage and loss of life. A request for $330,000 was included in a Departmental supplemental estimate, but was withdrawn by the Survey in March 1956 before it reached the Congress.

1957 Fiscal Year

The formats for the Survey's preliminary estimates were identified by Acting Director Nolan at a meeting on February 23, 1955. Having the strong support of Assistant Secretary Wormser for an increased program because of new mineral and water legislation, Nolan asked that each

Division present its increases under new subitems so that they could be better identified. He further suggested that, for the Water Resources Division, the subitems be studies of water requirements and waste disposal for industrial users of atomic energy; methods by which existing data could be extended into ungaged areas; research on methods of increasing available water supply, such as studies of phreatophytes and saline water; and studies on the movement of water in both surface streams and aquifers.

Nolan, a strong advocate of more basic research in water-resources programs, said that his specific suggestions had been influenced by talks with C.V. Theis and R.L. Nace. At that time, Theis was a staff scientist coordinating the Division's cooperative investigations with the Atomic Energy Commission and also its Federal program activities relative to radioactivity of water resources. His headquarters was at Albuquerque, N. Mex. Nace was District geologist for ground water in Idaho.

In the limited time available, a number of research-oriented individuals, including Theis, Nace, and A.M. Piper, worked with the PC Branch staff to prepare a preliminary estimate that met the Acting Director's approval and which was incorporated in the preliminary estimate in May. It was a good exercise for the Division. The participants did not fully agree on the specific proposals, or on their relative priorities or the type of organization within the Division under which they could best be carried out if funded. But the effort generated many new ideas, and the discussion of their relative priorities, strengths, weaknesses, and alternatives strengthened the Division's competence for future planning and programming. It was agreed that such planning should be on a continuing basis rather than in sessions scheduled just to meet budgeting target dates.

The preliminary estimates for 1957, forwarded to the Department in May 1955, showed $34,660,000 for SIR that included one new and two existing subitems for water resources. The WRI subitem was in the amount of $7,700,000 and the $1 million increase over 1956 was entirely for additional Federal matching funds. The S&M subitem showed an increase of $50,000 over 1956, for a total of $150,000.

A new WRI subitem of $1,750,000 was for "new responsibilities in hydrology," which was related to changes in national water policy and technological advances and was composed of two parts. One part covered proposed programs arising from technological, industrial, and agricultural progress and was composed of nuclear-energy waste disposal, salvage of saline waters, past and future water shortages, an expanded national highway program, saltwater encroachment, land subsidence, and deterioration of stream channels. The second part was in response to "The Watershed Protection and Flood Prevention Act of 1954 (P.L. 566)" designed "to preserve and protect the Nation's land and water resources." The President's order had specified that the Geological Survey should assist and cooperate with the U.S. Department of Agriculture in carrying out this Act with respect to the collection and interpretation of basic data and in the analysis of the effects of the projects initiated under the Act. Of the $775,000 requested, $275,000 was for the WRD. The balance was for topographic mapping of watershed development areas. A similar item had been suggested by Dodd of the Bureau of the Budget during a conference with CHE Paulsen in November 1954.

The 1957 estimates, forwarded to the Bureau of the Budget in September 1955, showed a total of $31,615,000 for SIR and included $7,910,000 for WRI, $130,000 for S&M, and $890,000 for "new responsibilities in hydrology." The presentation for the last subitem, although rewritten, proposed projects similar to those covered in the preliminary estimates. The WRI subitem included $5,070,000 for Federal matching funds.

The Bureau of the Budget allowed $31,602,000 for SIR, including $8,513,000 for WRI, and $130,000 for S&M. Of the total for WRI, $5,070,000 was for the Federal-State program, $2,836,000 for the Federal program, and $607,000 for "new responsibilities in hydrology." Under the reduced amount for the "new responsibilities," now a part of the WRI subitem, it was specified in the justification that only a start on some of the planned projects would be possible in 1957.

The Division's reaction to the Bureau of the Budget's allowances was expressed by Paulsen in his memorandum dated December 8, 1955, to the Branch chiefs. He wrote that "it is gratifying to see the recognition of our program needs by the Budget Bureau . . . Assuming that the funds requested are appropriated and including the State matching funds, the Division will have over a $1½ million increase in its program . . . However, as you are quite aware, there is the problem of staffing . . . (1) to draw out the special talent required to perform the new research, and (2) to replace that talent with individuals qualified to perform our ever-expanding regular work in the cooperative program."

Support for an adequate Federal-State program under the WRI subitem was strengthened by the policy of the then administration as expressed in President Eisenhower's budget message to Congress in January 1956. Eisenhower wrote: "The recommendations in this budget will result in further advances toward our broad goal of a steadily growing program for resource development through the cooperative efforts of States, local communities, private citizens, and the Federal government."

The House passed the appropriation bill on February 21, 1956, giving the Survey the amounts

recommended in the U.S. Budget. Acting Director Nolan represented the Survey at the hearings on January 17. (Dr. Wrather's retirement was announced, with a commendation for his services, by Congressman Kirwan as the House was considering the USDI Bill on Feb. 21.)

The Senate likewise agreed to the budgeted figures for the Survey's program, stating in its Committee report that it had been assured that the recommended amount for cooperative water investigations "is sufficient to match the State contribution to this very important program." On June 13, 1956, the Bill was enacted as P.L. 573.

1958 Fiscal Year

The 1958 budget was the last prepared under Paulsen's direction. One of his initial efforts in its preparation was to recommend to the Director, by memorandum dated April 19, 1956, that a fifth activity be added to the Federal program segment of WRI that would support many of the existing and planned activities of the General Hydrology Branch. That branch, an "orphan" so far as being identified in the budget structure, had been supported indirectly from other items and from the S&M subactivity. Paulsen suggested the new activity be called "general hydrologic investigations."

The preliminary estimates, transmitted to the Department on May 7, showed a total for SIR of $48,645,000, which was well in excess of the ceilings that had been established the previous year. The greatly increased WRI subitem of $13,700,000 included a Federal program activity into which last year's "new responsibilities in hydrology" had been placed with a new title of "water resources policy recommendations and other new responsibilities" and a $5,264,000 cost. The Federal-State program was increased slightly to $5,300,000. The S&M subitem was set at $250,000, nearly double that appropriated in 1957.

Following Departmental review of preliminary estimates, the Survey was authorized to submit to the Bureau of the Budget in September an SIR program reduced to $38,415,000, including $11,530,000 for WRI. Of this, $5,730,000 was for the Federal program in which modest increases were given to the recurring subactivities and $2,615,000 allotted for the "new responsibilities" item. Federal matching funds were established at $5,800,000. The S&M activity was lowered to $190,000.

Following hearings on September 27, 1956, the Bureau of the Budget allowed an SIR item of $39,190,000 for the U.S. Budget. Of this, the WRI subitem of $11,410,000 was composed of $5,800,000 for the Federal-State program and $5,610,000 for the Federal program.

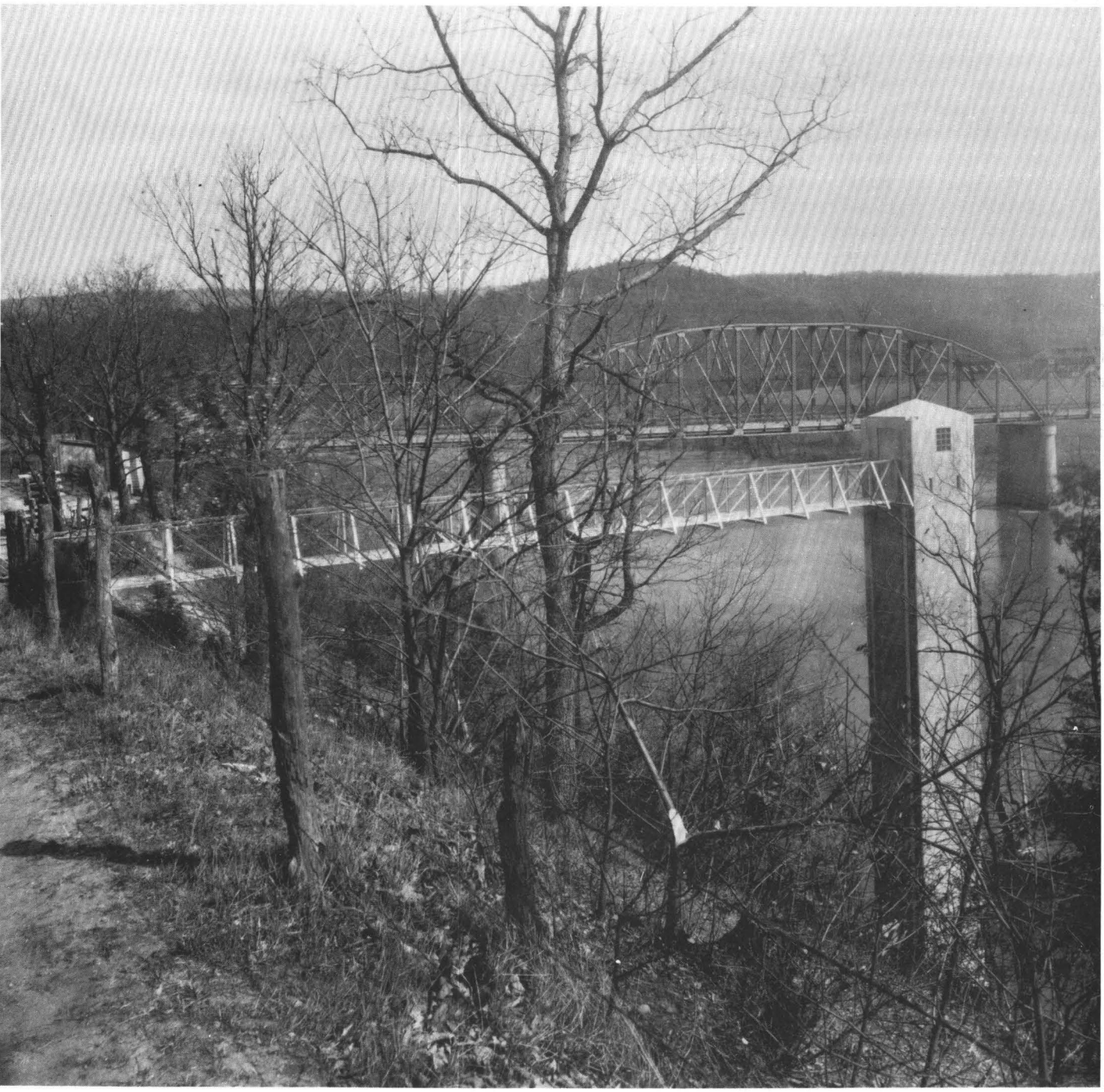
At the House hearings on January 22, 1957, the new Secretary of Interior, Fred A. Seaton, mentioned "the tremendous demand for water in our cities, in our industries." Nolan, now Director following Wrather's retirement earlier in January, stated that "the largest single item of increase is for additional activities by the Water Resources Division," and spoke of the emergence of the need for ". . . a new kind of work, based on but differing from the measurement program—that is a need for interpretive studies that draw out from existing records the information that is most significant and place it in its most useful form." He described the research planned, which was "another significant part of the increase."

Chairman Kirwan mentioned that the President and the Secretary of the Interior were now "flying over the Nation. . . to see critical water shortages" and asked Director Nolan to insert in the record "some of the research activities you have carried on relative to water." The requested statement described the variety of interpretive work and research that had been conducted by the Survey within the past decade, and suggested additional activities not yet funded.

There was no indication in the record of the hearings that Paulsen was present or that his coming retirement was mentioned. Nolan responded personally to all questions on the SIR item and showed a remarkable familiarity with the details of the WRD program.

The House allowed $36 million for SIR, the amount prepared by its Appropriations Committee whose report stated that this appeared to provide the maximum expansion that could be effectively achieved because of difficulties in recruiting qualified personnel. About one-third of the increase was to go toward an increase in retirement costs.

The Senate's report recommended $37,750,000 for SIR and stated that none of the reduction was to be applied to the WRI subitem. The Bill, as enacted on July 1, 1957, appropriated $36 million for SIR. An amount of $10,085,000 was allocated to WRI, $5,800,000 of which was for the Federal-State program and $4,285,000 for the Federal program. That part of the increase that could be applied to program expansion permitted the initiation of several new research and interpretive type projects. The S&M subitem received $160,000.



U.S. Geological Survey gaging station Potomac River at Paw Paw, W. Va. The tallest USGS gaging station, it is still active today (period of record continuous since October 1938).

Part III—Regional, Interstate, and Foreign Programs

During the decade, Division personnel conducted numerous investigations of areas that included more than a single State, such as studies of widespread floods, ground-water basins that crossed State lines, or large river systems. These investigations were conducted largely through interdistrict participation, and many are described later in the District activity statements. The following regional and interstate activities are given separate attention for several reasons: the interstate activities in the Delaware River basin and establishment of the office of the Delaware River Master, which continues to this day (1990); the Missouri River basin development program, because of its great magnitude and relatively long life; the S&M program, because of its continuing nature; and the river and land morphology and reservoir surveys, because the activities were essentially outside the scope of the District programs of the three operating branches.

Interstate Activities in the Delaware River Basin

By Francis T. Schaefer

As described by Follansbee in the preceding volume, the Interstate Commission on the Delaware River Basin (INCODEL), which had been created in 1936 for the primary purpose of reducing pollution in the waters of the Delaware, continued its actions to improve water quality through better treatment facilities. It also was working to develop a compact that would be acceptable to the States and the Federal Government and which would be the foundation for the establishment of a Delaware River Basin Commission.

Cooperation between INCODEL and WRD continued to expand and diversify during the decade. Streamflow records and results of ground-water studies collected by the WRD staff in cooperation with Delaware River basin States, were used regularly and, in 1949, WRD's QW District personnel were asked to participate in research being conducted for INCODEL by personnel at Lehigh University on a continuous water-quality-monitoring device. N.H. Beamer (oral commun., Feb. 1990) recalls that the QW District also provided data for and served as advisor in INCODEL's efforts to lower acid conditions in lakes in the Pocono Mountains by spreading lime during periods of ice cover. Division personnel were invited to place exhibits at and otherwise participate in INCODEL meetings. Cooperative ties were further strengthened by the fact that many of the Division's primary State cooperating officials were also officials of INCODEL.

During the decade, the Supreme Court of the United States, as a result of action brought by the State of New Jersey to enjoin diversions from the Delaware River by the State of New York and the city of New York, with the States of Pennsylvania and Delaware as intervenors, entered the Amended Decree of June 7, 1954. This Decree provided for the establishment of a River Master to "administer the provisions of the decree relating to yields, diversions, and releases. . .; to conserve the waters in the river, its tributaries and in any reservoirs maintained in the Delaware River watershed by the city of New York or any which may hereafter be developed by any of the other parties hereto. . . ." Also, "subject to the concurrence of the Director of the U.S. Geological Survey, the Chief Hydraulic Engineer of the U.S. Geological Survey, or such other engineer of the U.S. Geological Survey as shall at any time be designated by the Chief Hydraulic Engineer, is hereby designated as River Master." The River Master was directed to report not less frequently than annually with copies to the governors and the mayor [of New York City].

On July 14, 1954, Director Wrather notified the governors and the mayor [of New York City] that Carl G. Paulsen, CHE, had been designated as River Master, and that he was convening a meeting of the above parties in Washington on July 22 to plan the operations of the River Master's office. Paulsen continued to serve in this capacity through the remainder of the decade. In March 1955, W.V. Iorns transferred from Tulsa, Okla., to headquarters at Milford, Pa., to assist Paulsen in the River Master activity. Iorns remained at Milford during the balance of the decade.

Missouri River Basin Program: Background, Budget, and Noteworthy Aspects

By Hugh H. Hudson

BACKGROUND

The Missouri River basin (MRB) development program was authorized by the Flood Control Act of 1944 for the development and management of the water resources of the basin by the USDI and the U.S. Army Corps of Engineers (Corps). The USDI, with the U.S. Bureau of Reclamation as its lead agency, was assigned responsibility for irrigation and "associated development in the headwater areas of the 'irrigation' states." The Corps was authorized to construct flood control and navigation works along the Missouri River mainstem.

The plan for the MRB development program was precedent-setting in its comprehensive, multiple-purpose objectives. The plan was designed to provide flood control, irrigation, power generation, and improvement of navigation on the lower Missouri River. The plan envisioned more than 100 dams, 150 irrigation projects involving 5,000,000 acres, 30 or more powerplants, improved water supplies for at least 19 communities, hundreds of miles of flood-control levees and dikes, and more than 700 miles of channelization for navigation.

Anticipating passage of legislation authorizing the MRB development program, the Division prepared a "Water Plan for Missouri River Basin" that was endorsed by Interior Secretary Harold L. Ickes. The plan was forwarded to the Congress, and published in 1944 as an appendix to Senate Document 191.

In the "Water Plan for Missouri River Basin," each Branch of the Division staked out its proposed initial contribution. SW Branch personnel were to construct and operate 129 (later reduced to 125) new gaging stations. The QW Branch proposed operating 10 daily chemical-quality stations (increasing to 15 the following year), and daily, or more frequent, sediment stations at 24 sites. Personnel of the WU Branch were to study precipitation-runoff relations, climatic oscillation, and the effects of man's activities on streamflow. The GW Branch laid out an extensive program of areal investigations, each based on data collection and analyses requiring several years duration and culminating in one or more reports for each area.

LAUNCHING THE PROGRAM

The SW Branch task was large, but may have been one of the easiest to get underway. Its organization was in place when the program began because there was a District or Subdistrict office in each basin State. There was no misunderstanding of its role, and its mode of operations was well-established. By the end of 1946, the first funded year of the program, virtually all of the new stations required for the Department's immediate needs were in operation, as well as an additional 15 mainstem stations that had been requested by the Corps.

The QW Branch's MRB work began under the most severe handicaps because it had operated no systematic program in the basin for nearly 40 years, and its entire staff, nationwide, numbered only 42 in early 1946. Yet, by the end of 1946, the Branch regional office and the chemical-quality and sediment laboratory in Lincoln, Nebr., were in operation. Satellite offices, which included laboratories for conducting sediment-concentration and particle-size analysis, were also operating or were soon to open in Norton, Kans.; Worland, Wyo.; Dickinson, N. Dak.; and Rapid City, S. Dak.

The GW Branch, at the beginning of the MRB development program, was well established in the lower basin, but had little presence in the upper basin. By early 1946, however, a regional office also had been established by the Branch in Lincoln, Nebr. A District-level office established at Bismarck, N. Dak., later moved to Huron, S. Dak. Project offices soon followed in other locations in the upper basin, including Riverton, Wyo., and Billings and Terry, Mont. As described later, funds were also alloted to existing District offices in several other States. But then, almost as soon as the MRB ground-water studies got underway, a misunderstanding occurred with the U.S. Bureau of Reclamation over the role of the GW Branch in the MRB program. The Bureau of Reclamation wanted only limited ground-water studies at project sites; the objective of the GW Branch staff was of complete studies that would produce reports that not only met Survey standards, but would serve planners and administrators well beyond the immediate needs of the MRB development program (the QW Branch staff shared this same philosophy). The Branch held to its objective and the various studies were published largely in the Water-Supply Paper series.

The WU Branch also established its MRB headquarters in Lincoln in 1946. Its field staff in Billings, Mont., was small, and primarily conducted studies in range-soil-moisture problems for the U.S. Bureau of Land Management. The Branch maintained a modest but active role in the MRB program through 1953, then closed its Lincoln office when funding for its work ceased.

THE MRB PROGRAM BUDGET

The MRB budget provided some novel and unsettling experiences for the Division because of its fluctuations

and the manner in which it was legislated and administered. The Geological Survey's funds for participation in the program, like that of other USDI bureaus, were contained in the Bureau of Reclamation's annual appropriation and were identified for transfer to the Survey. Because the funds were first appropriated to Reclamation, some officials of that agency felt that the appropriation process itself conveyed a proprietary right over the money and that priority for ground-water studies should be given to sites identified by the Bureau. As stated earlier, the GW Branch staff maintained that its use of Federal funds carried an obligation to serve a larger audience with more comprehensive reports on the ground-water resources of areas affected by the MRB program.

After the MRB budget for the WRD rose to its all-time high in 1951, it dropped to a near record low in 1955. Many of the MRB staff were reassigned, including most of those assigned to ground-water studies, and the disagreement between philosophies of personnel of the GW Branch and the Bureau of Reclamation was thus indirectly quelled. The budget crash severely hurt the SW Branch, but more so the QW Branch that had built a basin-wide field organization largely on MRB work. And it was this budget crunch that caused the termination of WU Branch participation.

MRB budget allocations to each Branch for fiscal years 1946 through 1957 are listed below.

Fiscal year	SW	QW	GW	WU	Total[1]
1946.....	$206,200	$98,000	$100,000	$50,000	$454,200
1947.....	176,300	109,700	114,300	16,100	416,400
1948.....	141,600	151,000	135,600	21,200	449,400
1949.....	170,000	187,000	180,000	38,000	575,000
1950.....	330,300	305,200	283,500	20,000	939,000
1951.....	410,000	422,000	416,000	36,000	1,284,000
1952.....	311,000	311,000	306,000	25,000	953,000
1953.....	304,600	303,000	303,000	25,000	935,600
1954.....	161,700	157,200	153,000	0	471,900
1955.....	137,200	139,100	95,700	0	372,000
1956.....	212,100	206,600	153,930	3,175	575,805
1957.....	239,180	194,310	166,685	3,165	603,340

[1]Not including Director's Office assessment.

NOTEWORTHY ASPECTS

The MRB program greatly enriched the base of water-resources information of the basin. The years of stream-flow, chemical-quality, and sediment records and reports on ground water generated by the program, particularly during the prosperous 1940's and early 1950's, have proven to be very valuable to subsequent water-resources investigations.

The MRB program brought about a rapid maturing of the Division organization between 1946 and 1957 because the program offered experiences and new relationships between branches that contributed to the organizational improvements that came later. Water-quality studies that were reintroduced in the basin were a factor in the emergence of water-quality support from a laboratory setting to full-participation water-resources studies. The program also provided opportunities to strengthen the reports policies of the Division when the issue was a specific assignment versus complete studies designed to accommodate the future needs of a larger audience.

One of the most enduring features of the program was the opportunity for new "hands-on" experience that increased the knowledge of the younger engineers, chemists, and geologists of the Division, which prepared them for future leadership of the Division. Space does not permit listing those whose contributions to the MRB program led to their selection as District and Branch chiefs, assistant and associate Division chiefs, and supervisors of Division research programs. The following persons, however, are those whose contributions to the program in its early, and at times difficult, years must be acknowledged: H.C. Beckman, USGS representative, USDI, Missouri Basin Field Committee and WRD coordinator for the MRB program, 1945–57; P.C. Benedict, regional supervisor of MRB water-quality activities, 1946–57; G.H. Taylor, regional supervisor of MRB ground-water studies, 1946–57; and R.E. Oltman, WU Branch representative in Lincoln, Nebr., 1946–48, and later chief of special reports, SW Branch, Lincoln, 1949–1955.

DIVISION-LEVEL ADMINISTRATION

H.C. Beckman probably had a greater variety of high-level administrative responsibilities during the decade than any official in the Division outside of the Washington office. At the beginning of the decade, he carried the title of regional engineer for the Mississippi River basin, SW Branch, with headquarters at Rolla, Mo.

About 1949, Beckman was reassigned as coordinator of the Survey's activities under the Missouri River basin (MRB) program. He coordinated interbranch activities as a representative of the CHE; MRB activities among the SW districts as a representative of the chief, SW Branch; and interdivisional activities under the MRB program for the Director. He attended meetings of the USDI Field Committee for the MRB program, also as a representative of the Director.

Such responsibilities included the annual task of recommending allocations of funds received from the Bureau of Reclamation, first among the Divisions of the Survey, then among the four Branches of the WRD, and finally among the participating districts of the SW Branch. Although competition for funds was great and recipients were often far from satisfied with their allotments, Beckman's integrity and fairness were valued.

In July 1957, Beckman was selected as the Division Hydrologist for the newly-created Mid-Continent Area under the Division's 1956 plan of reorganization. He maintained his headquarters at Rolla, Mo., for the entire decade in space adjacent to that used by the SW Branch District staff.

P.C. Benedict, G.H. Taylor, and R.E. Oltman worked closely with Beckman in shaping the Division's MRB program. Each vied for what he thought was his branch's fair share of the annual appropriation for MRB work. But despite this friendly rivalry, the four worked together exceedingly well, and Benedict and Taylor, especially, developed very close interbranch working relations among their staffs. Oltman conducted pioneering studies of river hydraulics and sediment transport, working closely with Benedict, the Nebraska SW Branch's District chief, and their staffs.

General descriptions of the various activities of the GW, QW, and WU branches, conducted as part of the MRB program, are given on the following pages. Detailed activities of these three branches, as well as the SW branch, are described in the summaries for each State.

GROUND WATER BRANCH

By Ray Bentall, Charles F. Keech, and Herbert A. Waite

The segment of the Missouri River basin program assigned to the GW Branch continued to be directed from the Regional headquarters located in the Rudge-Guenzel building (now called "The Atrium") in downtown Lincoln, Nebr. G.H. Taylor, who had been designated regional engineer (GW) in 1946, served in that capacity throughout the decade. His MBR program headquarters staff grew to a maximum of 17 people in 1953, but was reduced to about half that size by the end of the period. Taylor conducted the MRB program directly through newly established District offices in Billings, Mont., and Bismarck, N. Dak. (the latter was relocated to Huron, S. Dak., in 1952), and indirectly through previously established District offices in Cheyenne, Wyo.; Lincoln, Nebr.; Denver, Colo.; and Lawrence, Kans. The Billings and Bismarck (Huron) offices were funded wholly from the MRB program; the other District offices were funded from the Federal-State cooperative program and supplemented by the MRB program.

Taylor's principal assistants at the beginning of the decade included G.A. Waring, H.F. Hayworth, and F.A. Swenson, but each transferred from the headquarters staff in 1948. Ray Bentall, who had been with the Nebraska District since 1945, transferred to the Regional staff in 1949, and served as second in charge through the balance of the decade. For various lengths of time during the decade, the Region maintained one- or two-man offices at nine locations in Nebraska: Ainsworth, Loup City, St. Paul, Fullerton, Grand Island, Holdrege, Edgar, McCook, and Superior. These offices were supervised from the Nebraska District.

At Taylor's insistence, each test hole and each water well inventoried or used for observation of water-level changes were assigned a number based on location within the U.S. Bureau of Land Management land surveys. This inventory system, or modification of it, was adopted also by several districts outside the basin because it made retrieval of data easier.

In 1949, a hydrologic laboratory was established under the MRB program to make permeability, specific yield, and other tests of earth materials sent to the laboratory from the field offices. A.I. Johnson set up and operated the laboratory with the help of one or two assistants. He reestablished the laboratory in Denver, Colo., in 1954 to give nationwide service. In addition to providing testing services, the laboratory staff maintained and devised field equipment to rent to project chiefs. Laboratory staff were available also to operate the rented equipment and ensure that the samples collected were suitable for testing.

Even though the Bureau of Reclamation and other Federal agencies generally requested activities such as well inventory, water-level measurements, construction of water-table contour maps, and test drilling, Taylor required that all projects be described in formal geohydrologic reports. Virtually all of these reports were released first in mimeographed form for other agency use and for review purposes within the Branch. Later, they were published as U.S. Geological Survey Water-Supply Papers, Circulars, or Hydrologic Atlases (maps), or were turned over to local State cooperating officials for publication. Taylor's staff included several typists and draftsmen to reproduce manuscripts for review purposes and for publication. (*Ed. note*: O.M. Hackett, in his review of the manuscript, noted that Bentall has modestly failed to mention his own substantial contribution as editor and reviewer of most of the project reports published from the Missouri River basin program.)

A significant part of Taylor's time was occupied by meetings with regional staff members of the U.S. Bureau of Reclamation and other Federal agencies involved in the MRB program, as well as by visits to field offices at many locations in the basin. On his visits to field offices, Taylor asked his personnel to present a thorough account of their findings to date, and generally gave valuable advice and direction for further activities. On several of his trips around the basin, Taylor was accompanied by one or two members of the WRD Washington, D.C., office staff. In 1953, Taylor suffered a severe heart attack that limited subsequent visits to the field.

During the heyday of the MRB program, Taylor had all MRB staff assemble in Lincoln for an annual conference. He also had J.G. Ferris come to Lincoln to instruct selected MRB personnel in aquifer testing techniques and interpretation of test data. Moreover, he required all professional staff members to take advantage of the ground-water short courses. Such training was highly rewarding in that many of those attending later headed districts or regions or occupied important positions at the national headquarters of the Division.

QUALITY OF WATER BRANCH

By Russell H. Langford

That part of the Missouri River basin program assigned to the QW Branch was conducted under the general direction of the regional engineer (entitled district engineer until 1945) whose headquarters remained in the Rudge-Geunzel building in Lincoln, Nebr., throughout the decade. The staff of the regional office in Lincoln was involved in investigations throughout the 10-State Missouri River basin area and in parts of the States of Minnesota, Iowa, and Missouri outside the basin itself. The regional headquarters staff grew rapidly at the beginning of the decade, increasing from about 10 persons in 1947 to 38 in 1952. The number then declined somewhat.

Immediate supervision of some projects and routine data collection conducted in those parts of the basin outside Nebraska were provided by field supervisors located in Ft. Collins, Colo.; Minneapolis, Minn.; St. Louis, Mo.; Billings, Mont.; Dickinson, N. Dak.; Rapid City, S. Dak.; and Riverton and Worland, Wyo. These area offices and field headquarters were established in the early 1950's and continued into 1956. Their activities will be described in some detail under the States in which they were located.

''Dynamic'' is the word that best describes the QW Branch regional office at Lincoln, Nebr., and its suboffices. Members of the staff believed that they were not only plowing new ground in the Missouri River basin, but that they also were leading the rest of the Branch, nationwide, in many aspects of the water-quality science. Joint projects with their counterparts in the GW Branch resulted in developing scientists who planned the collection of field data, conducted the chemical analyses, interpreted the resultant data, and prepared the water-quality parts of many published reports on ground-water resources. Experts in sediment transport were developed on the regional staff as a result of complex field investigations of bed-load and suspended-load transport of sediments in alluvial channels. These investigations were underway during the decade at the Middle Loup River near Dunning, Nebr., and the Niobrara River near Cody, Nebr. New approaches to the compositing of daily river-water samples for chemical analysis were developed by the staff which resulted in composite samples that reflected the changes in water discharge during the composite period. This, coupled with calculation of annual discharge-weighted concentrations of dissolved constituents, resulted in chemical-quality records that more adequately reflected the water quality of ''impounded water''—an important consideration for agencies, such as the Bureau of Reclamation, that were planning reservoir impoundments throughout the basin.

Scientists in the chemical-quality laboratory at Lincoln undertook the preparation of a loose-leaf laboratory manual (no modern manual existed in the Branch at the time). The results of this pioneering effort were later published in 1960 as WSP 1454 by F.H. Rainwater and L.L. Thatcher. But most important was the attitude and philosophy of P.C. Benedict, who directed the office and who imparted an esprit de corps to, and instilled a breadth of scope in, the staff. Benedict believed, for example, that the agency that collected the water data was in the best position to interpret the data. He instilled this philosophy in his staff.

This philosophy and attitude can, in large measure, be defined by a listing of the variety of technical reports, unpublished as well as published, that were prepared by the staff. But they can also be defined by an action taken by the staff at the time Benedict was leaving Lincoln in 1957 to become the chief of the research section of the QW Branch in Washington, D.C. At the party given him at this time, the staff presented him with an honorary Ph.D. ''degree'' appropriately scribed on parchment. The wording of the ''degree,'' Doctor of Hydrogeochemico-sedimentology, issued by the fictitious ''Lincoln Institute of Alchemy and Hydrosyndromology,'' is illustrative of the respect for Benedict and the recognition of his leadership.

Benedict, like Taylor, fostered training for members of his staff, including course work at local universities, attendance at ground-water and water-quality short courses, and, on occasion, interbranch details. Such training, coupled with the investigative approach to water studies culminating in published reports, provided the staff with the solid technical foundation needed for later, more responsible positions in the Geological Survey, in other water agencies at Federal and State level, and in the private sector.

P.C. Benedict, district engineer until 1945 and regional engineer thereafter, was in charge throughout the decade, having transferred from Iowa City, Iowa, to establish the Lincoln headquarters in 1946. The chemical quality and sediment laboratories were major segments of the headquarters office. Durum (Open-File Report 78–432,

p. 45–46) states that the chemical-quality laboratory was supervised directly by Benedict (until 1951), H.A. Swenson (1951–52), F.H. Rainwater (1952–54), and R.H. Langford (1954 on), and that the sediment laboratory was under J.E. Adams (1949–51) and J.C. Mundorff (1952 on). D.M. Culbertson was in charge of the area office established in 1956 in Lincoln. Other senior members of the staff during sizable portions of the decade not referrred to under writeups for individual States include C.R. Collier, J.G. Connor, W.H. Durum, S.G. Heidel, C.O. Johnson, L.R. Kister, R.F. Kreiss, R.P. Orth, L.R. Petri, R.B. Vice, and J.W. Wark. Ms. Irene Paulsen had a lead role in the fulfillment of secretarial functions during the decade.

Work in Nebraska was conducted largely by the regional office staff in Lincoln, but also in part by personnel stationed at Curtis and Grand Island beginning in 1952. In 1956, an area office, composed of a portion of the regional staff, was established in Lincoln to further expedite the work in Nebraska.

TECHNICAL COORDINATION BRANCH

In 1948, R.E. Oltman, who had represented the Water Utilization Branch (later renamed Technical Coordination Branch) in Lincoln since 1946, transferred to the SW Branch to head a special reports unit in the District. He was assisted by H.J. Tracy. In 1950 or 1951, this unit was upgraded and its personnel conducted interpretive surface-water studies for the entire Missouri River basin. Oltman was then designated staff engineer and headed a field unit of the Special Reports and Investigations Section in the Washington headquarters. Tracy transferred to Atlanta, Ga., in 1952, and Oltman joined the Branch staff in Washington in 1955.

Soil and Moisture Conservation Program

By Walter B. Langbein and Richard F. Hadley

As stated in Part I, "Technical Coordination Branch," the Soil and Moisture Conservation (S&M) program was organized in 1941 to serve the land agencies of the USDI in the administration of the vast public domain and Indian lands of the West. The U.S. Geological Survey's participation was arranged largely by W.G. Hoyt, one of the earlier officials of WRD, later with the Conservation Division, and on detail to the Department. Funding was through a small (for example, $41,000 annually in 1952–53) but separate item in the Survey's appropriation. Direct transfers from the Department's land-oriented agencies were made for specialized work. Because the wide range of required skills crossed the jurisdictional boundaries of the Division's operating branches, the program was assigned to the WU Branch which became the TC Branch in 1943.

The program was divided into four main parts: (1) Water supplies, chiefly well-site prospects and stock-tank surveys. About 550 reports were prepared for the land agencies during the Paulsen years. These were mainly in the form of administrative reports transmitted over the Director's signature to the bureaus concerned. Ultimately, these spot or ad hoc reports led to comprehensive studies of range-water supplies in a State or range district (for example, WSP 1475, parts L, N, and P, all published in 1963); (2) evaluation of land-use practices to arrest erosion and to promote forage. The hydrologic effects of various measures adopted to correct, abuse, or improve forage yield were usually uncertain. The evaluations were made to sort out those that were effective; (3) hydrologic data. Data on the western range was sparse and not included in the regular programs of the WRD, most of which were directed toward irrigation and flood control. Innovative methods were applied under the S&M program. Small stock-water reservoirs, for example, were used to collect information on water runoff and sediment. Interpretive reports included Circular 256 (1953), Circular 110 (1956), WSP 1475–A (1959), and WSP 1531 (parts A and B, 1961); and (4) research on erosion, soil moisture, runoff, and water chemistry. Numerous papers were prepared for the scientific journals, and references to the program, expressed in the words of its senior leaders, is provided in Open-file Report 79–987, "Investigations by the U.S. Geological Survey of Soil and Moisture Conservation on Public Domain Lands, 1941–1964," by H.V. Peterson and K.R. Melin (published posthumously in 1979).

The program was under the direction of H.V. Peterson from its origin through the end of the decade. The staff was headquartered in Los Angeles, Calif., where Peterson had resided prior to the beginning of his employment by the Branch in 1941. In 1947, K.R. Melin transferred to Billings, Mont., to open a field office for activities primarily in the Missouri River basin.

In 1949, by which time the program had expanded and a more centralized location was needed, the Los Angeles office closed and the headquarters moved to Salt Lake City, Utah. Peterson, C.T. Snyder, and R.B. Bennett made the move to Salt Lake City and others on the staff (a total of seven as of January 1949) either transferred to other Survey offices or left the Survey.

In June 1954, the program headquarters again moved, this time to the Federal Center in Denver, Colo. Snyder remained in Salt Lake City, which was retained as a field office. F.W. Kennon continued his work from the Albuquerque, N. Mex., field office through 1957. The Billings, Mont., field office closed in October 1954, and the personnel moved to the Denver Federal Center.

With the establishment of the field office in Billings in 1947 under the supervision of Melin, and with the appointment in 1948 of three geologists, R.F. Hadley, N.J. King, and C.T. Snyder, erosion studies on public lands were greatly expanded. These studies included both interpretation of erosional history and the evaluation of land-treatment practices and erosion-control structures.

In the Wind River basin of central Wyoming, a study of the erosional history of Fivemile Creek on the Wind River Indian Reservation and the Riverton Irrigation project were initiated in 1948 by Hadley and Snyder. Similar studies were conducted in 1948–49 on Whitewater Draw near Douglas, Ariz. The Fivemile Creek studies in Wyoming were part of a larger program to collect data on upland sources of sediment and sediment-yield rates on tributaries to the Wind and Bighorn Rivers. King collected sediment data at Moneta, Wyo., at Fifteenmile Creek in the Bighorn basin, and at Muskrat Creek near Riverton, Wyo.

Several studies were initiated during 1948–50 that used small livestock reservoirs as gaging stations to measure runoff and sediment yield from upland drainage basins that were typical of public lands throughout the West. The geomorphic characteristics of the basins, together with soils and rock type, were mapped in the field and correlated with hydrologic data to develop regression relations and improve the transfer value of the studies. Also during the 1940's, W.B. Langbein, C.F. Hains, and R.C. Culler established staff gages on several stock-water reservoirs in Arizona and in 1950 reported on their rates of sedimentation, seepage loss, evaporation, and runoff.

In 1950, King and M.M. Mace used six small basins and reservoirs on the San Rafael Swell in east-central Utah to obtain data on sediment yield that was typical of the San Rafael basin. Hains, D.M. Van Sickle, and Peterson completed a similar study using small reservoirs in the Little Colorado River basin of Arizona and New Mexico. During 1950–54, Culler, Hadley, and S.A. Schumm conducted a study of sediment-source areas and hydrologic characteristics of small reservoirs in the Cheyenne River basin of eastern Wyoming and adjacent areas in South Dakota and Nebraska in cooperation with the Bureau of Reclamation.

Two other studies were initiated by the S&M program staff that used small reservoirs as gaging stations to evaluate the effects of land treatment on hydrology. In northwestern New Mexico, 13 small reservoirs were constructed by the Bureau of Land Management to control erosion on Cornfield Wash. Culler and Kennon began observations on the operation of these reservoirs in 1951. At Badger Wash near Grand Junction in western Colorado, an interagency pilot study was begun in 1953 on 17 small drainage basins to determine the effects of grazing on runoff, sediment yield, and plant cover. The study was designed to continue for 20 years and G.C. Lusby was in charge of all field operations.

Investigations for ground water supplies for livestock use continued to expand, and included both the examination of individual well sites and areal reconnaissance studies of grazing districts and Indian reservations. In 1948, Hains, Van Sickle, and W. Ryals spent several months completing a reconnaissance of ground-water resources in northeastern Elko County, Nev., for the Bureau of Land Management. This was the first of many areal studies pertaining to livestock water conducted by S&M program personnel. In 1950, King and Snyder initiated a ground-water study in the Massacre Lake area of northwestern Nevada and northeastern California, in the Susanville, Calif., Bureau of Land Management district. Similar studies were conducted in the Arizona Strip area, north of the Colorado River in Arizona, in western Utah grazing districts, and the Ely, Nev., grazing district under the field direction of Snyder.

Individual well-site examinations conducted at the request of the Bureaus of Land Management and Indian Affairs were completed at 550 sites during 1947–57. Most of these investigations were to locate water for individual livestock grazing allotments established on the public lands.

Several studies of the effectiveness of rangeland water spreaders were conducted by personnel of the S&M program. The objective of these studies was to determine the effects on runoff, sediment yields, soil moisture, and forage production of the diversion of floodflows for the irrigation of hay meadows. The studies were located in the Willow Creek basin near Fort Peck, Mont. (1947–57); Alzada water spreader near Alzada, Mont.; the Little Robber water spreader near Baggs, Wyo.; and the Box Creek water spreader near Douglas, Wyo. (1956–57). In addition, several other water-spreading systems were evaluated by R.F. Miller, I.S. McQueen, and F.A. Branson. Peterson continued in charge of all S&M activities through the decade and was assisted by the following staff members not identified earlier: G.C. Lusby (from 1954); I.S. McQueen (from 1956); R.F. Miller (from 1955); Mrs. D.J. Proctor (from 1955); and B.H. Rolf (1952–56).

River and Land Morphology

By Walter B. Langbein

The Division's S&M program involved the arid regions where land erosion was a pervasive problem and probably the most severe on those lands in public-domain States. Most of the productive valleys of the arid regions were incised by deep, continuous gullies, and the tributary lands

were affected by sheet erosion. It was with this set of problems in mind that the Division in 1948 asked L.B. Leopold, a hydrologist with many years of experience in the Southwest, to undertake that kind of research.

From 1950 through the Paulsen years, Leopold and his co-workers (M.G. Wolman and J.P. Miller among others) produced a great number of research papers on the erosion and channel problems of the Southwest. These papers (identified by number in table 8) included surveys of vegetation and vegetal changes (table 8, no.1), climate, and climatic change. In 1951, Leopold showed (table 8, no. 2) that, even though there was no trend in annual rainfall, changes in different intensity groups were such as to exacerbate the gully-erosion problem. In a 1951 report (table 8, no. 3) with C.T. Snyder (of the S&M program staff), Leopold worked out the historical sequence of alluvial fills in New Mexico, while another paper (table 8, no. 4) in 1954 with Miller did the same for alluvial fills in Wyoming. A 1953 paper (table 8, no. 5) dealt with the downstream increase in mean velocity of rivers and another 1953 paper with the mechanics of meanders. Leopold and Miller in 1956 explained (table 8, no. 6) how stream orders of ephemeral streams in arid and semiarid regions were related to measured hydraulic properties.

These studies of river hydraulics and river form that began in the arid region led to a survey of rivers in general under the heading of "The Hydraulic Geometry of Stream Channels and Some Physiographic Implications" (USGS PP 252, Leopold and Thomas Maddock, Jr., 1953, 57 p.). This report was widely discussed and accepted (it won the Kirk Bryan award of the Geological Society of America). Further research showed how discharge and slope determined whether a channel pattern was straight, meandered, or braided (table 8, no. 7). Wolman and Leopold examined the formation of river flood plains (table 8, no. 8) concluding that overbank deposition is only a small part of the material that makes up the flood plain. A study by Wolman and Eiler (table 8, no. 9) of the erosion and deposition caused by the August 1955 flood in Connecticut showed that the area affected permanently by the flood was small relative to the total area flooded.

Table 8. Selected list of publications, river and land morphology

1. Leopold, L.B., 1951, Vegetation of southwestern watersheds in the nineteenth century: Geographical Review, v. XL1, no. 2, p. 295–316.
2. _____1951, Rainfall frequency: An aspect of climatic variation: American Geophysical Union Transactions, v. 32, no. 3, p. 347–357.
3. Leopold, L.B., and Snyder, C.T., 1951, Alluvial fills near Gallup, New Mexico: U.S. Geological Survey Water-Supply Paper 1110-A, 19 p.
4. Leopold, L.B., and Miller, J.P., 1954, A post-glacial chronology for some alluvial valleys in Wyoming: U.S. Geological Survey Water-Supply Paper 1261, 99 p.
5. Leopold, L.B., 1953, Downstream change of velocity in rivers: American Journal of Science, v. 251, p. 606–624.
6. Leopold, L.B., and Miller, J.P., 1956, Ephemeral streams: Hydraulic factors and their relation to the drainage net: U.S. Geological Survey Professional Paper 282–A, 38 p.
7. Leopold, L.B., and Wolman, M.G., 1957, River channel patterns: Braided, meandering, and straight: U.S. Geological Survey Professional Paper 282–B, 51 p.
8. Wolman, M.G., and Leopold, L.B., 1957, River flood plains: Some observations on their formation: U.S. Geological Survey Professional Paper 282–C, p. 87–107.
9. Wolman, M.G., and Eiler, J.P., 1958, Reconnaissance study of erosion and deposition produced by the flood of August 1955 in Connecticut: American Geophysical Union Transactions, v. 39, no. 1, p. 1–14.

Lake Mead Sedimentation Survey

By Walter B. Langbein

Hoover Dam, on the lower Colorado River, was closed in 1935, and the impounded water in Lake Mead reached operating levels within 3 years. It remains the largest storage reservoir in the United States, containing about 30 million acre-feet, a volume equal to 2-year's flow of the river. The reservoir had been in the planning stage for several years during which its merits relative to alternatives were vigorously debated. The Division's role in this issue is documented in WSP's 395 (1916) and 556 (1925). As a multi-purpose project that promised economics of large scale and of combination (irrigation, flood control, hydropower, and water supply), Lake Mead embodied the notion of "wise use," but there were soon anxieties as to the future of the reservoir.

Sedimentation of the reservoir that would in time impair, if not destroy, its usefulness was one of the uncertainties of its design. It was estimated that the lower Colorado River carried about 90,000 acre-feet of sediment per year which, if fully trapped by the reservoir, would fill the reservoir to its spillway in 3 centuries. Was this estimate sound? The critical nature of sedimentation, as a dominant threat to the sustained usefulness of this major project, caused the Soil Erosion Service of the USDI (which became the Soil Conservation Service of the Department of Agriculture in 1935) to arrange for an aerial survey of the reservoir bed as a base for future surveys when the lake began to fill (Brown, C.B., 1941, Mapping Lake Mead, Geographical Review, v. 31, p. 385–405).

The early discovery (Hoyt and Grover) that a large part of the sediment moved as a density or turbidity current through the length of the reservoir raised questions about the distribution of the sediment, namely, how much was in the delta? And, how much was deposited in the deep "dead storage" space? Further, the discharge of dissolved salts from the reservoir was greater than the inflow. To what extent was this due to solution processes in the reservoir? What was the effect of evaporation on salt concentration? How much water was lost by evaporation? Earth tremors had become frequent also since the reservoir was impounded. Had the weight of the water caused down warping in the region? Resolution of these basic questions was delayed by World War II, but was taken up as soon as possible afterward.

At the recommendation of its Washington, D.C.-based hydrology and sediment specialists, M. Dubrow and V.A. Koelzer, and of C.P. Vetter, engineer-in-charge of its river control activities at Boulder City, Nev., the Bureau of Reclamation asked the U.S. Geological Survey to conduct a comprehensive sedimentation survey of Lake Mead. The funding was arranged by Vetter out of open-ended costs of dredging below Hoover Dam from "Colorado River Front" monies.

Because of the size and extent of Lake Mead (over 100 square miles in area and 500 feet in depth), oceanographic methods were needed and so collaboration was sought with the U.S. Department of the Navy, working through W.O. Smith's contacts. Several planning meetings were held in 1947 with key naval officers, including Roger Revelle who was then with the Office of Naval Research. The USGS was the prime contractor, with participation by the Navy Bureau of Ships, the Coast Survey, and the Geologic and Topographic Divisions of the Survey. A three-man directorate was established to give guidance and to provide some coordination on the job: Smith of the WRD (reporting to R.W. Davenport, chief of the TC Branch), Vetter of the Bureau of Reclamation, and G.B. Cummings, in charge of sonar design, Bureau of Ships, U.S. Navy. The floating crafts included a 38-foot converted picket boat, a 21- by 105-foot barge, and several small motor craft for topographic, geologic, and limnologic work. There were at different times possibly as many as 50 specialists involved. Cooperation was harmonious despite diverse backgrounds, agency affiliations, and scientific objectives. The general accommodation led to further work between the Bureau, the Survey, and the Navy, such as the water-loss study that followed.

The field work began in 1947 and was completed substantially by 1949. The results were reported initially as USGS Circular 346 (H.E. Thomas, 1954) and later in Professional Paper 295 (1960) by Smith, Vetter, and Cummings. The sedimentation survey was conducted using sonar soundings with sextant fixes based on a horizontal control net established by the Topographic Division. The survey showed that about 100,000 acre-feet of sediment was deposited in the reservoir annually, compared with the 90,000 acre-feet estimated during the design of the reservoir. Bank storage was found to add 12 percent to the active usable capacity of the reservoir. Although the amount of dissolved solids discharged from the reservoir exceeded the amount in the inflow, the quality of water of the outflow was improved for downstream uses because of the greater stability in concentration of effluent water.

The rate and distribution of the sediment showed that a century would pass before the sediment would reach the level of the lowest outlet gate and more than 4 centuries before the reservoir would be filled to the level of the permanent spillway. Precise leveling around the region revealed also that the reservoir was associated with a basin-like down warping of 160 millimeters between 1935 and 1950.

Sediment as a water problem was increasingly recognized during the Paulsen years when reservoir construction was reaching its height, especially in the western States and including the Missouri River basin. But the interests in sediment-related problems were much narrower than those investigated in the comprehensive Lake Mead survey. The sediment question centered on rates of deposition and volume weights, and the needed reservoir surveys were made at intervals by the constructing agencies themselves. WRD reservoir sediment surveys were otherwise limited to reservoirs on the Public Domain under the S&M program. The comprehensive type of reservoir inquiry came again into prominence with the "environmental" movement after the mid-1960's. The WRD interest in sedimentation dealt with the measurement of suspended sediment in transport in rivers, in measuring the total load in order to obtain data on the probable useful life of reservoirs that were then widely proposed, and with the measurement of transport as an aspect of the water quality—that is, as part of the pollution load of rivers.

Water Loss Projects—Lake Hefner and Lake Mead

By Walter B. Langbein

The Lake Mead sedimentation survey called attention to evaporation from the surface of that reservoir, the largest unmeasured single water loss in the Colorado River system. Further, the collaboration with oceanographers on the Lake Mead project introduced the Survey to literature and to the methods used to estimate ocean evaporation (the first was by Halley in 1715). O.G. Suttom, H.U. Sverdrup, C.W. Thornthwaite, and others had conducted good theoretical work on the mass-transfer theory. Moreover, the energy budget, being rigorously correct

in principle, had the potential to become practical through the development of a simple radiation integrator by N.W. Cummings, a private researcher. Also, at the time, the Navy Electronic Laboratory had developed practical field instruments for the measurement of atmospheric properties with sufficient accuracy for the determination of wind, temperature, and humidity gradients. Although these instruments had been developed for a different purpose, they appeared to be adaptable to the determination of water loss by mass-transfer methods. Thus, there was a body of theory and instrumentation ready to be used to determine evaporation. As with the sedimentation survey, the Bureau of Reclamation provided the funds. The research was assigned to G.E. Harbeck, a hydraulic engineer of the TC Branch who had been trained as a meteorologist during World War II and who had been working on evaporation aspects of the S&M program. Harbeck worked closely with personnel of the Navy Electronics Laboratory (NEL) at San Diego.

The problem was to assess lake evaporation as determined by theory against that determined by an accurate water balance. As it was obvious that the object of the inquiry, Lake Mead, would not meet these conditions, Harbeck began his work with a survey of many possible sites (Circular 103, 1951). This survey showed that Lake Hefner, an offstream water-supply reservoir near Oklahoma City, Okla., best met the necessary conditions. (This lake had been included in the search at the suggestion of Hollister Johnson who had recently completed a study of Oklahoma's water resources entitled "Oklahoma Water" in 1945.) After an initial detail at San Diego (April 1951–52), Harbeck led a cooperative team composed of scientists from the NEL (Lloyd Anderson, J.J. Marciano, and E.R. Anderson, under R.D. Russell), the U.S. Weather Bureau (Max Kohler), and the U.S. Geological Survey (Mrs. E.W. Coffay, G.E. Koberg, F.W. Kennon, O.E. Leppanen, and Margaret Culbertson), all under the financial sponsorship of the Bureau of Reclamation through C.P. Vetter of the Office of River Control at Boulder City, Nev.

The Lake Hefner investigation (April 1950 through August 1951) became the classic piece of evaporation research. (F.W. Kennon was the resident engineer in charge for water budget control who reported to Harbeck.) It provided a set of accurate and concurrent hydrological, meteorological, and limnological data. The results showed the energy-budget method to be a practical field technique for the determination of evaporation for periods of a week or longer. A quasi-empirical mass-transfer equation was also derived that gave good results. The results were first published in Circular 229 (1952) and republished in Professional Papers 269 and 270 (1954). PP 269 contained descriptive and analytical material and PP 270 the base data.

With the results of Lake Hefner in hand, evaporation from Lake Mead was determined by energy-budget and mass-transfer methods. The same cooperative arrangements at Lake Hefner were continued successfully at Lake Mead. Personnel were generally the same, with H.O. Wires being given responsibility for the operation and maintenance of equipment at Lake Mead, as well as for making the necessary thermal surveys of the lake. Observations were begun in March 1952 and continued through September 1953, and results were reported in Professional Paper 298 (1958). For the water year 1953, evaporation from Lake Mead was found to be 875,000 acre-feet, a volume equal to about 10 percent of the inflow to the lake during that dry year. A system of skeletal observations was established and continued during subsequent years so that annual evaporation loss from the reservoir could be reported on a regular basis in the annual reports on the Colorado River.

The evaporation studies begun at Lake Hefner continued at other localities. Studies were made at two high altitude lakes in the Colorado Rockies to define the effect of altitude on evaporation.

In 1954–55, Harbeck examined the effect of recirculated condensing water on the evaporation and thermal structure of a Texas reservoir. Water was withdrawn from the lake, used for cooling, and returned to the lake practically undiminished in quantity but considerably increased in temperature and therefore subject to increased evaporation. The energy-budget method was used to measure evaporation from the lake, and it was possible to compute the effect on evaporation and on the thermal structure of the lake that resulted from the addition of heat from the powerplant. The work showed that the added heat increased evaporation by about 8 inches. The techniques developed proved to be of great practical value in determining water loss at powerplants during the energy crisis of the 1970's.

Harbeck also conducted a study of the effects of salinity on evaporation as a prelude to the measurement of evaporation from Salton Sea in California. The "Paulsen years" saw evaporation measurements become a practical tool of the Division that was widely applied in subsequent years.

Foreign Assistance Program

Although a sizable number of the Survey's professional personnel had foreign assignments that were often in cooperation with our military forces during and immediately following World War II (Follansbee, v. IV, p. 234–237), there were relatively few assignments during the first half of the decade, and most were only a few months in duration. Exceptions were the multi-year

investigations by G.C. Taylor, Jr., in Chile in calendar years 1946–47 and H.F. Hayworth's work in Greece in 1948–49. By 1951, long-term assistance had begun in India and Iran, and in Libya, Afghanistan, and Egypt in 1952. The major effort of the decade, in terms of the number of Survey personnel engaged concurrently in a single country, began in Pakistan late in 1953. The foreign program expanded rapidly beginning in 1952. Assignments were lengthened and the number of detailees increased from less than 5 in 1950–51 to more than 25 in 1955–57 (T.E. Eakin, USGS Adm. Report, 1960, p. 12).

In the early stages of the program, foreign assignees typically received the technical and sometimes the administrative support of their parent Branch. Some short foreign assignments were handled largely by a District office, such as the Florida District (GW) in assisting the U.S. Air Force in the search for ground-water supplies for its installations in the Bahamas.

The GW Branch, having provided about 80 percent of the foreign assignees, had by far the largest task of technical support. Nearly all of the others came from the SW Branch. The QW Branch had a minor role in the program.

By the mid-1950's, the Division's Headquarters and District offices were receiving a considerable number of foreign visitors. They included foreign scientists supported by grants from the State Department, the Foreign Operations Administration, and the United Nations; distinguished visitors representing their governments; and foreign scientists and students traveling or studying in the USA on private funds. The Division coordinated its foreign hydrology activities with the Bureau through the Survey's Foreign Activities Committee, of which T.E. Eakin was the WRD member (written commun., Aug. 23, 1954, Director to Division chiefs).

The growth of the foreign work, and especially the emergence of large and continuing programs in several countries that required the integration of effort by several hydrologic disciplines, made it ever more desirable to place the activity under a new organizational unit reporting directly to the chief of the Division. The Foreign Hydrology Section was established, and its first chief, T.E. Eakin, was formally appointed on April 7, 1957, only a few weeks before the end of the decade. Quite appropriately, Mr. Eakin's background was in the GW Branch. He also had experience with foreign assignments, having made appraisals of ground-water resources in Iran (1952–52) and Jamaica (1954). The personnel list as of July 1, 1957, shows a headquarters staff of five full-time employees. The Section had responsibility for 17 Division detailees located in 11 countries as of that date.

The following summary of the technical assistance provided during the decade by the Division's foreign detailees in each country is largely a condensation of material taken from Professional Paper 911, "Historical Review of the International Water-Resources Program of the U.S. Geological Survey, 1940–70" (1976). It's author, G.C. Taylor, Jr., succeeded T.E. Eakin as chief of the Foreign Hydrology Section in 1962 after having served on numerous foreign assignments.

Afghanistan—Under the sponsorship of the U.S. Technical Cooperation Administration (USTCA), L.J. Snell arrived in Afghanistan in June 1952 and spent the next 3½ years directing a data-collection program and training local hydrologists to meet the needs for water management and further development by the Helmand Valley Authority. I.A. Heckmiller, who arrived in June 1954 to assist Snell, continued as project leader after the departure of Snell in January 1956.

Bahama Islands—In 1953, at the request of the U.S. Air Force, ground-water hydrologists, primarily from the Miami, Fla., Subdistrict office, began studies of fresh ground water at locations in the Bahama Islands that could be used for water supplies for military installations. The most promising of the freshwater lenses revealed by these investigations on the islands of Grand Bahama, Eleuthera, San Salvador, Mayaguana, and Grand Turk during 1953–55 were further investigated through test drilling. Participants included N.D. Hoy, Howard Klein, M.C. Schroeder, and C.B. Sherwood.

Brazil—In spring 1953, G.A. Rynearson and E.W. Reed analyzed the degree to which dewatering and drainage would be a problem in the surface mining of phosphate deposits at Olinda, near Recife, Brazil. The study was made at the request of Brazil's National Department of Mineral Production.

Chile—From May 1946 to January 1948, G.C. Taylor, Jr., surveyed and appraised the ground-water resources of 26 valleys and basins in northern Chile. Survey assistance was at the request of the Chilean Development Corporation. In spring 1950, P.H. Jones determined from a detailed field examination of the Rio Elqui Valley and adjacent areas in northern Chile that the ground-water resources had great potential for development. He also made a brief reconnaissance of the Huachipato-Talcahuano area in central Chile as a part of a search for a water supply for a steel mill in response to a request by the Chilean Corporation de Fomento de la Producion (CORFO). In May 1955, R.J. Dingman began investigations that continued beyond the end of the decade as part of a country-wide geologic, minerals, and ground-water study program that was requested by several Chilean agencies and financed by grant funds from the U.S. Agency for Internal Development (USAID). By the end of 1956, Dingman had completed investigations in three localities assigned high priority by the CORFO.

Egypt—In the mid-1950's, Survey hydrogeologists conducted a 3-year ground-water survey of critical areas of Egypt as a part of the program of assistance by the U.S. Foreign Operations Administration. P.E. LaMoreaux, on a visit to Egypt from September to November 1953, made initial plans as to the nature and duration of the study. C.R. Murray, project chief, arrived in Cairo in November 1953, followed by W.W. Doyel (March 1954) and R.L. Cushman (April 1954). Terminated in 1956, the project did not attain all of the initial goals but specific accomplishments were numerous and of lasting value. The project also provided training for local hydrologists in quantitative ground-water hydrology.

Greece—In February 1948, H.F. Hayworth began a 2-year period of supervision of the use of 25 drilling rigs in the construction of water-supply wells for towns and villages on both the mainland and the islands of Greece. His assistance was provided under the American Mission for Aid to Greece.

Guyana—G.F. Worts, Jr., spent from February until April 1957 conducting a reconnaissance of coastal ground-water conditions in Guyana. The study was made at the request of the Government of Guyana to the U.S. International Cooperation Agency (USICA).

Haiti—From September 1948 to March 1949, G.C. Taylor, Jr., studied the feasibility of extending ground-water development for irrigation and other purposes in certain of the arid lowlands of Haiti. The study, requested by the Institute of Inter-American Affairs, was a part of the postwar technical and economic assistance program to Haiti.

India—As a part of a massive program of economic and technical aid to the government of India (GOI) since the early 1950's, the Geological Survey provided hydrogeologic advisors first in 1950 and then continuously between 1951 and the end of the decade. G.C. Taylor, Jr., who had completed an assignment in Thailand, was asked by the Geological Survey of India (GSI) to be the first such advisor. Taylor, during June and July 1950, visited selected areas in India and designed a long-term assistance program. Once the program was formally established, he returned to India in January 1951 and continued the work until he was reassigned to the Survey's domestic program in August 1955. During his stay, he concentrated his efforts in training GSI hydrogeologists, not only at GSI Headquarters in Calcutta but also in his supervision of field parties in various parts of India. During April and May 1952, F.A. Swenson, serving as a member of a USTCA-GOI team, inspected and evaluated drilling sites for production wells in 22 areas of India. From 1953 to 1956, A.A. Garrett completed the first phases of the drilling for a new project that called for 350 exploratory wells in 15 widely scattered "soft-rock" regions. P.H. Jones succeeded Taylor, arriving in July 1955. During his 2-year stay, he, too, concentrated on training and on the objectives of the overall exploratory drilling project.

Iran—T.E. Eakin conducted an appraisal of Iran's water resources between November 1951 and January 1952 as a part of the U.S. bilateral aid program. J.W. Lang followed, making a more detailed examination of local ground-water problems at 25 localities between April and October 1952. Although the reports of his findings on the large development potential of Iran's ground-water resources aroused local interest, no further investigations were made until after the end of the decade. In November 1953, K.R. Jetter arrived in Iran to spend nearly 3 years assisting in the development of a nationwide program of surface-water investigations. He was replaced by J.A. Baumgartner in July 1956. Baumgartner remained in Iran until his death in 1959.

Jamaica—During the mid-1950's, several WRD hydrologists participated in investigations sponsored by the United Nations. During November 1953, C.H. Hardison and T.E. Eakin prepared plans for reconnaissances for water-resources investigational programs and for the training of Jamaican personnel to conduct them. Hardison concentrated on surface-water requirements and Eakin on ground-water resources. C.C. Yonker arrived in Jamaica in February 1954 and, during the following 12 months, selected the specific sites for 25 stream-gaging stations, saw to the construction of these stations, and trained assigned personnel in the operation of the network. G.C. Prescott was in Jamaica from May 1956 to May 1957 to investigate the ground waters of the Clarendon plain in the southern part of the island and to train Jamaicans in investigative techniques.

Japan—Through the Military Geology Branch of the Survey, a number of ground-water and surface-water specialists of the Division conducted water-supply appraisals of outer Japanese islands for the U.S. military forces during World War II; a water-resources inventory of Japan proper was made later for the U.S. occupation forces. Although such activities ended in June 1946 (Follansbee, v. IV, p. 234), M.L. Brashears spent January through March 1951 in Japan evaluating ground-water problems and outlining needs for ground-water investigations for the Supreme Commander, Allied Forces.

Kuwait—The initial technical assistance by the Survey to Kuwait was during October and November 1947, when S.L. Schoff determined from a review of available data that the possibilities for finding substantial quantities of fresh ground water were generally very poor. The Kuwait government paid the costs of the study.

Libya—Survey hydrologists began in 1952 a study of the ground-water resources of Libya that continued until 1964. The project was at the request of the USTCA under an agreement with the government of Libya. The project was broad in coverage and included exploratory well drilling, areal studies, training of Libyan counterparts, and advisory services to Libyan government officials. It began with the short-term assignment of R.C. Baker, who spent April to October 1952 assembling data on the Al Jifara of Tripolitania. G.B. Maxey, who succeeded Baker, remained from November 1952 to July 1954. Maxey began a typical ground-water investigation largely in the same area. H.A. Whitcomb, who arrived in June 1954, continued the work and guided an exploratory drilling program. Before his departure in June 1956, Whitcomb completed a general reconnaissance of the ground-water resources of the Fezzan region in southwestern Libya. Soon after his arrival in July 1955, D.J. Cederstrom assumed responsibility for the Survey technical support of the Tripolitania study. Before his departure in July 1957, Cederstrom also conducted a comprehensive investigation of the Tarabulus area.

Nicaragua—In September 1956, at the request of USICA, S.L. Schoff conducted a 19-day evaluation of the results of exploratory drilling at an agricultural experimental farm near Managua.

Pakistan—Under an agreement between the Government of West Pakistan and a predecessor of USAID, the Geological Survey began in December 1953 its technical support of a major water-resources investigation that lasted 13 years and that required about 62 man-years of effort. The initial phases, accomplished largely during the decade, provided data needed for improved irrigation, salinity control, and land reclamation in the Punjab region. The project personnel, with their periods of assignment, were as follows: G.A. LaRocque, project chief and ground-water hydrologist, December 1953 to April 1957; F.D. Bertelson, soil scientist, January 1954 to April 1957; R.C. Baker, ground-water geologist, October 1954 to September 1956; R.E. Miller, geophysicist, July 1955 to April 1957; C.C. Yonker, surface-water hydrologist, June 1955 to April 1957; R.T. Kiser, chemist, July 1955 to April 1957; R.P. Borncamp, ground-water engineer, February 1956 to April 1957; and R.L. Cushman, ground-water engineer, January to April 1957. (Personnel with their period of service shown as ending April 1957 continued beyond the decade covered in this history.)

Panama—G.C. Taylor, Jr., during April and May 1949, conducted a reconnaissance of ground-water conditions in selected rangeland areas in the northern part of the Azuero peninsula of Panama. This study was accomplished as a part of a cooperative program between U.S. Department of Agriculture and the Panamanian government.

Peru—In February 1955, as a part of the USAID programs, S.L. Schoff and a Peruvian engineer began a 4-year appraisal of ground-water resources of critical areas throughout the arid coastal region of Peru. One of their first activities was a 3-month study of the ground-water potential of the Rio Rimac basin relative to water-supply requirements for Lima. In September 1955, they started an intermittent 3-year comprehensive study of the Lambayeque valley in northern Peru.

Philippines—C.R. Murray arrived in the Philippines in January 1957 to serve as ground-water consultant to USICA officials in Manila and as advisor to a newly established ground-water organization in the Philippine Government. His assignment continued for more than 4 years. Between February and June 1957, F.M. Veatch assisted USICA and the Philippine Government in the design of a long-range program of surface-water investigations and in the training of local personnel in the establishment and operation of such a program.

Portugal—At the request of the U.S. Air Force, G.F. Worts, Jr., spent April and May 1950 seeking a solution to the problem of providing a more reliable source of water supply for the Lagens Air Force Base on Terceira Island in the Azores, Portugal.

Saudi Arabia—Geological Survey assistance to Saudi Arabia in the investigation of its ground-water resources began with G.F. Brown's detailed study of several aquifers in the Nejd region of central Saudi Arabia from January 1945 through August 1946. This was part of a technical support program by the U.S. Agriculture Mission. Brown also directed a Survey team on a geographic and geologic mapping project of the Arabian Peninsula during the early and mid-1950's and thereafter continued to serve the Saudi Arabia Government as water-resources advisor. D.F. Dougherty was assigned to Saudi Arabia from March 1952 to March 1953 to conduct a study of ephemeral streams and also to determine potential for surface-water storage and ground-water recharge near Riyadh.

Sudan—In spring 1955, H.A. Waite conducted a 3-month reconnaissance of the general hydrogeologic features of Sudan. He was accompanied by representatives of the Geological Survey of Sudan, the agency that requested the study through the USTCA.

Thailand—During his brief visit to Thailand in June 1954, T.E. Eakin made recommendations to officials of that government and to a predecessor USAID group in Bangkok on the need for ground-water studies in northeastern Thailand. From October through December 1954,

P.E. LaMoreaux and five Thai geologists and engineers completed studies of the ground-water resources of the Khorat plateau in northeastern Thailand.

Turkey—Under an agreement between the Government of Turkey and USICA officials in Ankara, K.N. Phillips arrived there in April 1957 for a 3-month review of the existing streamflow investigative program. His findings led to a long-term technical assistance program by the Survey.

PART IV—DISTRICT ACTIVITIES

HEADINGS AND ARRANGEMENT

This section, by far the largest in Volume V, describes within each State the accomplishments of each of the Branches through its District and Subdistrict offices, largely in cooperation with State and municipal agencies and with funding from other Federal agencies. Although many District offices were responsible for programs for their Branch in more than one State, the activities are described separately under each State. The jurisdictional boundary of each multi-State district is given under the State in which the District headquarters was located; the activity statement for each satellite State shows the location of the supervising District headquarters. Because the multi-State district patterns varied widely among the Branches, it was not feasible to group the States geographically. With the cross references just described, the alphabetical arrangement of the States is the most expeditious for those who look for historical facts from this volume. The use of the State as the primary heading and the Branch as secondary, a reversal of the format of previous volumes, is justified in the preface. The omission of a Branch statement indicates that apparently there was no specific program within that State during the decade.

PREPARATION OF MANUSCRIPTS—PROBLEMS AND ALTERNATIVES

The author originally planned to prepare District activity summaries from program statistics and project descriptions known to have once existed at both national and District headquarters. A search resulted in the recovery of only a segment of such information. Some of it was found in the National Archives and in the Division files. The remainder had either been destroyed or sent to the regional record centers where efforts to locate and copy or abstract it at the widely dispersed sites would have been unduly costly in time and travel. (This type of problem was fortunately unknown to author Robert Follansbee whose Volumes II through IV were prepared promptly enough so that he could rely on the current personnel of the District offices who still recalled the comparatively recent program events and could use supporting data in local files.)

The other alternative, to attempt to locate the most knowledgeable living members of the District staffs and prevail upon them to document their recollections of events as far back as 37 years, seemed to be equally formidable. The individuals involved were essentially all retired and were widely scattered geographically. Locating them and asking for their assistance would have been impractical except for one fortunate circumstance: An organization of retirees of the Division (''WRD Retirees'') had been established in 1973 with a membership that, by the early 1980's, included nearly all of the prospective writers. Moreover, the author of Volume V was also then editor of the quarterly *WRD Retirees* newsletter and, as such, maintained a close association with the membership.

SELECTING AND LOCATING WRITERS

Starting with the districts in the western coastal States and proceeding, usually by north-south tiers of States from west to east, the retirees were identified from personnel records and their addresses were usually found in the ''WRD Retirees'' directory. Their response to inquiries by phone was immediately encouraging. Those few who declined usually did so because of their health or that of their spouse. The most knowledgeable were, of course, those who had been District chiefs during all or a part of the decade. If they were deceased or burdened by health problems, a substitute was chosen from the District personnel schedule for the decade (see below). In a few instances, one of the then junior staff members was selected as the writer because he was among the few survivors. Shortly after telephone arrangements were made, a packet of background material was sent to the writer. The contents of a typical packet are described below.

BACKGROUND MATERIAL FOR WRITERS

The packet of material mailed to writers generally included the following items:

1. A schedule of personnel showing names and grades of each career employee at the District headquarters and

at each Subdistrict location for each year of the decade. The schedule also indicated the individual in charge and, for key personnel, the District transferred from or destination of departees, as well as the address and changes of address of District offices. Largely using the annual WRD Organization and Personnel Directories and personnel "card files," these schedules were compiled, which comprised the most vital segment of the packets.

2. A narrative statement of personnel deployment. The statement was based on the above schedule and other information sources were prepared by the author as a guide for each writer. It was suggested that the writer feel free to use all or reshape pertinent portions to fit his manuscript.

3. The local (State) page or pages from the WRD Organization and Personnel Directory as of January 1, 1956, that lists personnel for the particular District. The writers were advised that the Directory would be reproduced as an appendix in Volume V and thus carry a full listing of personnel as of that date.

4. State segments of an unpublished compilation of statements in which District chiefs described their 1949 programs in response to a WRD Circular dated July 15, 1947.

5. Copies of reports by District chiefs giving the number of locations at which each type of water data was being collected in mid-1951 and also describing and giving planned completion dates for project-type investigations. These reports were found in the U.S. Archives and had been prepared in response to a WRD Circular dated June 11, 1951.

6. State segments of USGS Circular 114, prepared in 1950 by C.L. McGuinness. The segments summarized water problems, steps taken or planned by public officials to alleviate them, and the additional hydrologic data and knowledge needed for such steps.

7. Pertinent pages from Follansbee's Volume IV giving a historical summary of District activities in the State during the previous decade. This was to be used as a basis for describing the 1947–57 programs.

8. A copy of the fiscal year 1958 Consolidated Work Plan (CWP) for the State. Although this 1958 record of projects and data collection was completed after the end of the decade and in a period of rapid growth, this CWP was the first statistical report on the entire WRD program with a standard format. Credit should be given WRD program specialists H.G. Thomasson, J.L. Hatchett, and others for holding these CWP's in Division files despite critical space shortages.

9. Copy of portions of 1962 (first) editions of map-index-style WRD publications entitled "Water Resources Investigations in (State)." These indicies gave publication lists extending back through the 1947–57 decade.

10. A two-page set of guidelines for writers. These guidelines were meant to encourage a reasonable degree of similarity in length, coverage, and format.

11. A sample activity statement. The example was one of the better, already written activity statements from a District program of a somewhat similar size within the same Branch.

A Tribute to Volunteer Effort

From 1982 to early 1985, more than 160 different persons had written, participated in writing, assisted the writer or writers, or reviewed the more than 140 manuscripts required to describe the activities of each Branch in each State. Of these 140 manuscripts, less than half were written by the District chiefs or those in charge during all or part of the decade. This ratio varied greatly among branches. Only about 30 percent of the manuscripts for SW activities were prepared by former chiefs, as compared with 75 percent for GW manuscripts. The SW districts were generally established much earlier, and this fact accounts for the greater age of its district engineers during the decade. Most of the remaining statements were written by surviving senior members of the District staffs, a few by junior staff members, and the remainder by the author of Volume V. A few of the participants had resigned from the U.S. Geological Survey many years ago. Several were still on the active roles of the Division.

The time spent by the individual writers did, of course, vary widely, ranging from a few hours for manuscript reviewers to the equivalent of several months for those who, like retiree Miss M.E. Woods of the New York District (SW), must have spent the equivalent of several months in researching and documenting the many program events and finally condensing them to meet space limits. If each of the estimated 160 participants spent an average of only 3 days writing the manuscript, recording recollections, and reviewing prepared statements, the total contribution in time would be equivalent to that of one Division employee working more than 2 years. The author knows of no previous effort of this magnitude by U.S. Geological Survey retirees on behalf of their former agency.

The cooperation of present-day District chiefs and their staffs should also be acknowledged. Many of the writers sought historical information from District files, but a search usually revealed that records for the period had

been destroyed or sent to regional records centers. A number of the larger State agencies that were cooperators during the decade published summaries of cooperative programs with the Geological Survey in their annual reports. These summaries yielded helpful information. In one instance, Hugh Shamberger, former State engineer, kindly wrote the statement of SW activities in Nevada.

The manuscripts vary widely in length, arrangement, and style as was anticipated. Writers were asked to hold manuscripts to a length equivalent to 1½ to 3 single-spaced pages depending on program magnitude. This was exceeded in many cases and approved for publication because of the significance and variety of program elements. In other cases, the writer either was asked to condense the manuscript or the author prepared a condensation. The writers' style and choice of content vary widely and should add to reader interest. The use of dollar values, usually in inaccessible storage or destroyed, is very limited but does not detract unduly from the historical value of the statement. The personal recollections of the writers and contributors, general as they are after so many years, do catch the most significant of these past events.

Names appearing at the head of each statement indicate that the writer or writers forwarded an essentially complete manuscript. Some District activity statements are not completely in the writer's own wording because of condensation, in which case an appropriate credit line is given at the beginning of the statement. This arrangement hopefully will protect writers from responsibility for possible inaccuracies resulting from additions, revisions, and considerations made by the author of Volume V and final editorial changes. Statements with no credit lines were prepared entirely by the author from available material.

ALABAMA

Condensed from documentation by William J. Powell

SURFACE WATER BRANCH

The District office was located in the Post Office building in downtown Montgomery during the decade, and all of the staff was headquartered there until a Subdistrict office was established at Cullman in 1956. The staff of about eight at the beginning grew to nearly 20 persons as the program increased in magnitude. The primary activity was the operation of the gradually expanding network of stream-gaging stations (which numbered about 75 in 1947), including the construction of gage structures at additional sites (especially on smaller streams) because such data were needed by industry, municipalities, and other Federal agencies. Stream-gaging stations on the common boundary stream with Georgia and in the drainage basin of the Tennessee River in Alabama were operated by the District staffs in Georgia and in Tennessee. In 1948, the responsibility for operating the gaging stations in the Tennessee River drainage basin was assumed by the Montgomery office. Other activities included information on low-flow characteristics of streams, flood frequency, hydraulic information for highway design, and preparation of reports on the surface-water hydrology of selected areas.

At the beginning of the decade, the District was funded by the cooperative program with the Alabama Geological Survey (AGS) ($7,500 from each, Federal and State), the Mobile District of the Corps of Engineers (Corps) ($14,385), and allocations from the USGS Federal program funds ($6,885). The cooperative program with the AGS was increased by 50 percent or more during the 1948–49 biennium. The Tennessee Valley Authority (TVA) began its financial support in 1948.

By the end of the decade (fiscal year 1958 figures), the AGS remained the primary cooperator ($55,000 both sides), but participation by other State and municipal agencies (Highway Department, Department of Conservation, Water Improvement Commission, counties of Calhoun and Tuscaloosa, and city of Birmingham) brought the total of the cooperative program to slightly more than $100,000 (both sides). Federal program funds (about $17,000) and transfers from the Corps (about $14,000), TVA ($4,000 plus), and Federal Power Commission licensees ($2,700) brought the District budget to about $140,000.

During 1947, District personnel furnished streamflow information to 419 interested persons or organizations. Near the close of that fiscal year, collection of streamflow information on many ungaged streams in the southeastern section of the State was initiated.

In 1948, District personnel provided about 200 stream-discharge values to a State Water Improvement Advisory Commission that was conducting a pollution survey. It began on a small scale, as an analysis of floodflows for use by the Alabama Highway Department in the design of highway bridges. Within the overall gaging station network, both existing and planned, a special category was established and referred to as "water-supply stations." These sites were usually on streams where water-supply development might be needed (this special designation was discontinued in 1949 because of lack of financial support). A total of 85 gaging stations were in operation in the State as of 1948.

Early in 1949, a report on the surface waters of southeastern Alabama was completed. Preliminary work was begun on compilation of records for a second report for east-central Alabama.

In 1951, the flood of March and April produced record peak discharges at many places in Alabama and adjacent States. It was a notable flood on the basis of both the severity of flooding and the broad area covered. In Alabama, only the southeastern section of the State was spared major flooding conditions. A special report entitled "Floods of March–April 1951 in Alabama and Adjacent States" was prepared as Water-Supply Paper 1227-A (1953). Also during 1951, detailed studies were made of the surface-water supplies relative to water use, population changes, and industrial expansion for the purpose of outlining a program that would ensure reasonably adequate streamflow data for the State's expanding water uses. That year the Alabama State Legislature, on being advised of the deficiency of available water-resources data in Alabama, made funds available for an expansion of the cooperative water-resources investigation program. This strengthened program ($21,000 from each side) was put into effect in the biennium starting October 1951. The existing gaging-station network was analyzed during this period as to its balance and completeness. Several gaging stations were discontinued and 16 were established. During this period, there were approximately 94 stations in operation in the State. Other surface-water activities included the collection of discharge information of ungaged streams, chemical analysis of water samples, and the preparation of USGS Circular 342, "Magnitude and Frequencies of Floods in Alabama" (1954).

During 1953, concern was expressed over the decrease in financial support from other Federal agencies for maintaining an adequate stream-gaging network. In 1954, during a period of abnormally low rainfall, numerous informal reports were made to cities, industries, engineers, businesses, and governmental agencies in response to requests for data. During 1955, the deficiency in available quality-of-water information on streams was identified as a problem.

During 1956, concern was expressed over the increase in use of water and the need to expand the gaging network to supply information to meet the needs of water managers. In that year, the cooperative program with the AGS supported the collection of records of daily stream discharge at 51 stations, and other programs provided support for 52 other stations. A project to define drainage boundaries and to compute the area of those drainage basins was underway, making use of available topographic maps, photographs, and photo mosaics. A special report was prepared for a Federal agency in which all discharge data collected in the Coosa and Alabama River basins were compiled, analyzed, and presented in report form. All streamflow records prior to September 1955 were analyzed and compiled into a report of flow-duration tables to be published later as an open-file report.

Also in 1956, 44 requests for water-supply information were answered, of which 20 were for power and navigation needs, 19 for pollution abatement, 34 for flood control, 43 for drainage problems, and 15 for miscellaneous purposes. In the long-range plan for the procurement of surface-water data, the State had previously been divided into five areas in which the stream discharge and hydrology were to be described in special reports of the AGS. Area Number 1 included southeastern Alabama; Area Number 2, east-central Alabama; Area Number 3, west-central Alabama; Area Number 4, southwestern Alabama; and Area Number 5, Tennessee River basin.

In 1957, a report on drainage-area data for Alabama streams was completed and issued to a limited number of interested agencies. This report furnished information on the size of drainage basins above 972 specific locations on rivers, bringing to a conclusion a project that had been in progress for several years. Also during 1957, a start was made on a special study of the low flow of streams.

D.H. Barber, who had been district engineer (except during periods of military service) since 1934, retired in June 1947. He was succeeded in August 1948 by M.R. Williams who transferred from the Georgia District. Members of the staff, who served during the entire decade, included S.C. Moore, L.B. Peirce, and Ms. A.L. Hardin. Others included O.D. Bowen, Jr. (1952–54); N.R. Bozeman (1956 on); R.W. Carter (to 1948); P.W. Cole (1956 on); J.H. Countryman (1953–54); W.C. Griffin (to 1952); J.R. Harkins (1956 on); W.M. Howell (1948–52); F.D. King (1955 on); C.L. Marshall (1953 on); G.J. McInnes (1955 on); J.F. McCain (1956 on); G.H. Nelson, Jr. (1955 on); J.L. Nix (1954–56); J.F. Patterson (1952 on); W.N. Phillips (to 1948); W.H. Robinson (1951 on); Ms. M.K. Scarborough (1949–55); R.A. Smith, Jr. (1948–49); G.F. Smoot (1948–52); J.S. Stallings (1952 on); M.R. Stewart (1948 on); C.H. Tate (1950–55); J.S. Thompson (1953–54); and Ms. V.L. Welch (1955 on).

Among the reports identified in the 1962 (first) edition of WRD's "Water Resources Investigations in Alabama" and which were probably prepared or were published during the decade are: "Water Supply of the Birmingham Area" by W.H. Robinson, J.B. Ivey, and G.A. Billingsley (USGS Circ. 254, 1953); "Water Resources of the Mobile Area" by W.H. Robinson, W.J. Powell, and Eugene Brown (USGS Circ. 373, 1956); "Floods in Alabama, Magnitude and Frequency" by L.B. Peirce (USGS Circ. 342, 1954); "Floods of July 1956 in Clarke County" by L.B. Peirce (USGS Open-File, 1957); "Floods of April 1955 in Southwestern Alabama" by L.B. Peirce and C.H. Tate (USGS Open-File, 1955); "Drainage Area Data for Alabama Streams" by

J.S. Stallings and L.B. Peirce (USGS Open-File, 1957); "Flow Duration Data for Alabama Streams" by L.B. Peirce (Alabama Water Improvement Comm. pub., 1957); and "Hydrology and Surface Water Resources of East-Central Alabama" by L.B. Peirce and Eugene Brown (AGS Spec. Rept. 22, 1955).

GROUND WATER BRANCH

The District headquarters was located in Smith Hall on the campus of the University of Alabama in Tuscaloosa until 1951, when it moved to Building 6, Smith Woods, also a part of the campus. All of the staff, four persons or less in the late 1940's, were assigned there except for periods when field headquarters were used at Huntsville (1951–54; 1956 on); Montgomery (1952 on); Brewton (1955–56); Bessemer (1955 on); Linden (1955 on); and Sheffield (1955 on). The total staff increased to nearly 20 persons by the end of the period.

At the beginning of the decade, studies of the geology and ground water of several areas were in progress. The report for Wilcox County was half-completed, and investigations in Huntsville and the vicinity of the Montgomery area, as well as in the Tennessee valley, were in progress. A report updating an earlier publication on the springs of northern Alabama was also underway. Periodic water-level measurements were being made on 21 wells and one spring.

The District was funded primarily by a cooperative program with the AGS providing $15,000 (both sides, Federal and State) in 1947 and $13,500 in 1948 and 1949. Dr. Walter B. Jones was the State Geologist. Local cooperation for county studies included the cities of Huntsville, Anniston, and Sylacauga; the Tuscumbia, Sheffield, Colbert, Lauderdale, and Calhoun County Boards of Commissioners; and the Escambia, Marengo, and Calhoun County Boards of Revenue.

In 1948, information on ground-water problems was given in response to requests from 34 private citizens, 35 industries, 41 municipalities, 12 State offices, and 8 Federal agencies. Also in 1948, a report on southeastern Alabama was completed. It included a summary of all available surface-water information in that area of the State, the results of some hydrologic studies, and results of investigations on ground water and quality of water. (Three of the authors of that report later became chiefs of their respective branches: R.W. Carter, M.R. Williams, and P.E. LaMoreaux.) It was published as AGS Special Report No. 20. In 1950, detailed investigations were in progress in Mobile, Baldwin, Wilcox, Houston, Tuscaloosa, Madison, and Monroe Counties. The number of sites where periodic water levels were measured had increased to 33 observation wells and one spring.

In 1951, the use of ground water for irrigation created a demand for additional ground-water information. The District's program during this period was divided into two types of project activities: complete reconnaissance-studies coverage of the State and detailed county studies. The reconnaissance studies included the collection of data on quantity and quality of ground water developed for public and industrial supplies. The studies also provided a general evaluation of the occurrence of ground water. The entire State at this time had been covered by reconnaissance studies, excluding the nine-county area of Cleburne, St. Clair, Randolph, Coosa, Clay, Elmore, Tallapoosa, Lee, and Chambers Counties in the Piedmont of eastern Alabama. The reconnaissance study for the Piedmont was planned for completion in 1953.

The detailed county studies required an intensive effort because they were directed at a complete and accurate report of ground-water availability in each of the counties. These detailed studies provided a geologic map and included an inventory of all municipal, industrial, school, and irrigation wells, and a report on most of the private wells. Most of the county studies were conducted in cooperation with AGS, but cooperative programs with the municipalities of Monroeville, Huntsville, and Montgomery supplemented the AGS program and permitted the collection of more detailed information specifically needed by those municipalities for the development of ground-water supplies.

By 1954, one of the District's objectives was to complete one county study per year. The cooperative program during that year with AGS had increased to $32,000 (both sides). There was a notable increase during 1954 in the number of requests for information because of drought conditions during the year. The District received and answered 80 requests from municipalities; 117 requests from industries; 39 requests from State and Federal agencies; 53 requests from irrigators or those developing irrigation; and 155 requests from other private parties. Prior to 1953, few requests to aid in the development of irrigation supplies were received.

During 1956, local funds were made available where critical local problems existed, and facts from these studies answered some of the more serious water problems at that time. Areas considered in these special studies included those in and around Huntsville, Montgomery, Anniston, Tuscumbia, Sylacauga, Linden, and Demopolis. Detailed ground-water reports for Madison and Monroe Counties, and reconnaissance reports on Marengo and Montgomery Counties and the Piedmont of eastern Alabama were at the State printers for publication. Most of the ground-water reports resulting from the program were published by the AGS.

By 1957, the ground-water investigations program had been reorganized to supply, insofar as was financially

possible, the needs for geologic, hydrologic, and quality-of-water information as follows: (1) a series of county-by-county detailed investigations of ground water for the entire State; (2) detailed projects in response to critical water shortages or depletion of ground-water supplies in local areas; (3) quick reconnaissance studies to supply basic data for areas where the demand was immediate; (4) projects where water-resources or geologic data were needed to aid the State economy and or national security (for example, studies at the Huntsville Guided Missile Center at Maxwell Field in Montgomery, studies of the Birmingham strategic iron ore, and studies of the oil development of Choctaw and Escambia Counties); and (5) an observation-well project to show water-level trends in the principal water-bearing formations to forewarn of the depletion of sources of water supply. As the decade ended, studies were underway in Madison, Calhoun, Colbert, Lauderdale, Morgan, Tuscaloosa, Marengo, Wilcox, Montgomery, Macon, and Escambia Counties, the Sylacauga area of Talladega County, and the Birmingham area of Jefferson County. In summary, the principal ground-water problems of the period were the inadequacy of information on which to base analyses of the occurrence, availability, and chemical character of ground water to assist in meeting the needs for water for industrial, municipal, and domestic uses; saltwater encroachment in the Mobile area; ground-water contamination at Huntsville; and excessive water-level declines in the Montgomery municipal well fields.

P.E. LaMoreaux was in charge of the District during the decade, having held that position since 1945. He was assigned to the District in 1943 as a junior geologist. W.J. Powell, who transferred to the District from the Colorado District in 1954, succeeded LaMoreaux in 1958. G.W. Swindel, Jr., was the only other member of the District staff who served during the entire decade. G.T. Malmberg (1951–54) was in charge of the Huntsville field headquarters, and H.L. Reade (1951–54) was in charge of the Montgomery field office.

Other members of the District staff (period of service during 1947–57 shown) include: Ms. K.P. Adams (1956 on); B.L. Bailey (1956 on); Jack Baker (1951–54); J.H. Burks (1956 on); J.W. Cagle, Jr. (1955 on); L.V. Causey (1954 on); H.T. Downing, Jr. (1951–53); C.W. Drennen (1954–55); B.L. Floyd (1954–55); H.R. Gamble (1955–56); R.G. Grantham, Jr. (1955 on); H.B. Harris (1955 on); L.J. Hill (1951–52); G.H. Hodges (1955–56); L.J. Huhn (1955 on); J.B. Ivey (1951–53); D.B. Knowles (1954 on); C.R. Lanphere (1948–50); T.L. Logan (1955–57); J.D. Miller, Jr. (1955 on); G.K. Moore (1956 on); J.G. Newton (1954 on); H.J. Nyholm (1953–54); D.M. O'Rear (1953 on); R.R. Peace, Jr. (1956 on); Ms. J.H. Ray (1954–55); Ms. A.J. Roberts (1956 on); T.H. Sanford, Jr. (1953 on); J.C. Scott (1952 on); V.M. Shamburger (1951–53); Ms. S.P. Simpson (to 1955); T.A. Simpson (1953 on); Horace Sutcliffe, Jr. (1952–56); E.B. Thurston (1953 on); L.D. Toulman (1951 on); and L.R. West (1956 on). (See credit line at end of Alabama statements.)

QUALITY OF WATER BRANCH

Such program activities that existed were under the jurisdiction of the Fayetteville, Ark., District until 1953 when the Ocala, Fla., District took over the work. In response to a WRD Circular dated June 11, 1951, G.A. Billingsley reported that chemical-quality analyses were made from water samples taken periodically by GW Branch staff from 24 observation wells under its cooperative program with the State. Analyses were made also of samples taken periodically at eight stream-gaging stations that were supported by other Federal agencies. Temperature was also measured periodically in 15 wells. The Fayetteville District staff participated also in the interbranch study of the water resources of the Birmingham area in 1951 (USGS Circular 254, 1953) as did the Ocala staff in a joint study of the Mobile area in 1953 (USGS Circular 373, 1956). By 1958, shortly after the end of the decade, a program analysis indicates that the Branch participation in the Division's Mississippi embayment investigation had ended in fiscal year 1957, but that water-quality analyses for the Department of Defense and the U.S. Fish and Wildlife Service continued.

(The foregoing statements of the activities of the SW, GW, and QW branches in Alabama are largely from condensations of and extracts from a 23-page documentation by W.J. Powell during October 1975. Powell, chief of the Alabama District at that time, prepared the summary as a test to determine whether sufficient historical data for 1947–57 might still be available in District files to serve as a base for State-by-State descriptions of activities of that decade for use in Volume V. Although Powell was successful in getting such documentation for Alabama, many other districts (now at Division level) retained so little historical data that plans for field activity statements were sought from available knowledgeable persons for each Branch.)

Territory of Alaska

SURFACE WATER BRANCH

By R.I. Mayo with segments furnished by M.J. Slaughter and A.O. Waananen

Stream gaging in Alaska in the era following World War II began when the Survey sent hydraulic engineers

A.O. Waananen (Albany, N.Y., District) and W.W. Dean (Portland, Oreg., District) to Alaska in August 1946. They were to investigate the need for streamflow data in the programs of natural resource development of the Territorial and Federal Government in Alaska.

Prior to the 1947 fiscal year, funds were not available to the Water Resources Division for investigations in the Territory. However, during 1908–12 and again in 1913, the Survey's former Alaskan Branch, in connection with mineral-resources investigations, sponsored studies of water supplies for hydraulic mining operations in interior and western Alaska, and a water-power reconnaissance in south-central Alaska to which personnel from the Division were assigned. In 1915, the U.S. Forest Service, in order to evaluate the water-power resources of the Tongass National Forest in southeastern Alaska, started a stream-gaging program. This program continued until 1921 under the supervision of G.H. Canfield, who was later district engineer in Portland. The program was cut back in 1921, and the Forest Service and Federal Power Commission permittees continued stream gaging until 1938 when the number of gages was reduced to two. These two gages were continued into 1947 and perhaps beyond.

Waananen and Dean inspected these two stations, built three new recording stations, reinstalled a recorder at one of Canfield's old stations, and established staff gages at Sitka and near Anchorage. They continued the reconnaissance during summer and fall 1946 at Anchorage, Fairbanks, Chitina, Cordova, Seward, and Valdez in south-central Alaska, returning to their respective District offices in November. Field work was resumed in April 1947 by R.I. Mayo, an engineer in the San Francisco, Calif., District office, who was on leave and who decided to remain in the Territory of Alaska and continue stream gaging there.

The Alaskan Branch provided office space in a small wooden building that had been used during World War II by the Forest Service to house their field personnel at the Juneau subport. W.S. Twenhofel, Jr. was in charge of this office. Frank Steger, geologist, and C.J. Hoff, a former WRD employee from San Francisco, were also stationed here. Field crews of the Geologic and Topographic divisions were directed from this field office during the summer months. A University of Washington glacier research program on the Juneau ice cap, under the direction of Dr. Maynard Miller, also was serviced from this office.

A District office was established in Juneau in February 1949. R.E. Marsh, district engineer in the Bismarck, N. Dak., office, came to Alaska in August 1948 on a reconnaissance mission. He transferred to Alaska in February 1949, becoming the Survey's first district engineer in the Territory. At about this same time, M.J. Slaughter, engineer in the Chattanooga, Tenn., District office, transferred to Palmer to establish a Subdistrict office. This office had jurisdiction for all stream gaging west of longitude 141. The Juneau office moved from the subport to the Territorial and Federal building in 1953.

Between 1946 and 1948, funding for the Alaska work was entirely through the Division's Federal program. Transportation was furnished by the U.S. Forest Service and the several cities and villages involved in the program. Gradually during the decade, funding became available from the Bureau of Reclamation, Corps of Engineers, Alaska Railroad, the Territorial Department of Health, and several cities and villages. By 1957, the monies contributed by cooperating agencies amounted to about 25 percent of the total funding.

The slow expansion of the stream-gaging network in Alaska was largely because of problems in transportation. There were no roads connecting the towns in southeastern Alaska, and transportation was mostly by boat and airplane. The Forest Service furnished Ranger boats at the beginning of the period, and charter planes were used to reach out-of-the-way gages. After the District office was established in 1949, a 75-foot motor vessel was purchased. Marsh renamed it the "*Watres*," a contraction of water resources, and it was used in conjunction with chartered planes for the rest of the decade. Transportation was even more difficult west of longitude 141 because of the great distances and lack of roads to many of the gage sites. As cooperative funds became available, gages were established along the Yukon River and on other streams that were previously inaccessible by road.

Personnel in Alaska in 1949 consisted of Marsh and Mayo in Juneau, and Slaughter and W.H. Krabler in Palmer. By the end of the decade professional and subprofessional personel had increased at both offices. G.F. Smoot transferred from Alabama to Palmer in June 1952. E.J. Denison transferred from Utah to Palmer in 1954. The Juneau Subdistrict staff was increased by the transfer of H.C. Beaber from Grand Junction, Colo., and T.M. Davey from Tucson, Ariz., in 1954. With the additional professional personnel, the stream-gaging program was expanded and several special studies were accomplished. The "Compilation Report for Alaska" (WSP 1372, 1957) was completed in July 1955, the "Alaska Index Map" in April 1956, and the "Stream-Gaging Program Review" in August 1956.

The number of stream gages increased from 8 in southeastern Alaska and 2 in central Alaska in fall 1946 to 22 gages in southeastern and 38 in central and interior Alaska in September 1957. Three additional gages in southeastern and five in central Alaska were established and discontinued during the decade.

Unique situations in the Alaska stream-gaging program were largely due to the extreme northern topography and

climate. Staff gages installed at native villages along the Yukon River were regularly forced out by ice during spring breakup. Local observers marked points along the bank for the engineers from Palmer to survey for a gage-height record. An annual guessing contest as to the exact date and time of the occurrence of the breakup of the ice on the Tanana River at Nenana and the Chena River at Fairbanks included prizes of more than $100,000 for holders of winning tickets. Obviously streamgagers had to hold off drilling holes in the ice at these locations before spring breakup.

Another interesting part of the south-central Alaska gaging program was a study of the Lake George breakout, which usually occurred in late May or early June. This study was part of a cooperative program with the Alaska Railroad for early warning in regard to the time and magnitude of peak flow at railroad bridges about 20 miles downstream from Lake George. This lake was formed by the damming of a river valley by an advancing glacier on one of the river's tributaries. Water that accumulated behind the glacier during fall and winter was released in spring, with as much as 1 million acre-feet of water leaving the lake in a week's time. In January 1954, Mayo and an engineering aid, Juan Munoz, survived a plane crash in the cold waters of Chatham Strait, and 2 weeks later Mayo, Smoot, and an aid spent a cold night on a beach because high winds and ice floes damaged their landing skiff. They met a grizzly bear and several moose along the trails, but they faced no exceptional problems. It was reported that one stream gager from Palmer was treed by an inquisitive moose.

There were a number of positive results from the use of data collected during this period and in subsequent years. Two pulpwood plants and several hydroelectric plants were constructed in southeastern Alaska. Several powerplants were constructed in interior Alaska and design data were furnished to various government agencies for water-power studies and municipal water-supply and waste-disposal design.

GROUND WATER BRANCH

Condensed from statements furnished by D.J. Cederstrom, F.W. Trainer, and R.M. Waller

Ground-water studies, begun in 1945, were expanded during the decade. The investigative personnel (essentially summer detailees) headquartered in Juneau during the early years of the period gradually were organized into a year-round staff at Anchorage, which was given District status in 1952. D.J. Cederstrom, who had been in charge of the Virginia program since about 1937, was reassigned to direct the Alaska work early in the decade. Although he continued to reside in Charlottesville, Va., he spent considerable time in the field in Alaska during summers from 1947 to 1955 and winter 1948–49. His leadership of the Alaska District personnel ended with his assignment to Libya in June 1955. He was succeeded in Anchorage by R.M. Waller, who transferred from the Santa Barbara, Calif., office in July 1954, and remained as district geologist until 1963. F.W. Trainer, who began summer and fall details to Alaska in 1948 as a member of the Virginia District, transferred to Anchorage in 1952 and remained until he joined the GW Headquarters staff in January 1956. All of the others named in the following project statements were detailees. The District staff grew to a maximum of four persons in 1953, and then decreased to one or two by 1957.

Funding for the program during the early part of the decade was exclusively from an item in the gaging streams appropriation entitled "Water Resources of Alaska." Approximately $40,000 was made available during fiscal year 1948 for SW and GW activities. Such funds continued to be available during the period although the identity of the Alaska funds was lost in subsequent changes in budget formats. Program data available for fiscal year 1958 shortly after the end of the decade shows that $23,000 from the Federal program was allotted to the District for "areal investigations" and that $2,950 (both sides, Federal and Territory) was spent in cooperation with the Territorial Department of Health.

Beginning with an inventory of water-supply wells in the Fairbanks area in 1947, Cederstrom conducted a test-drilling project there in 1948. He was assisted by F.W. Trainer in summer and E.G. Otton during fall. During winter 1948–49, Cederstrom, assisted by Territory Health Department (THD) personnel, made a reconnaissance of ground-water resources available to selected communities from southeastern Alaska to Nome and Kotzebue, 60 miles north of the Arctic Circle. Test drilling was completed in summer 1949. Trainer moved to Palmer to begin a ground-water study of the Matanuska Valley and Cederstrom went to Kotzebue to begin drilling with a rig loaned by the U.S. Army. The drilling project was completed the following summer. Of the total depth of 323 feet, the upper 220 feet were drilled through frozen ground. An "experimental" jet rig was built in Palmer by a driller from Virginia. Test drilling was done also in Palmer and Anchorage in 1950.

Jet drilling was continued at Anchorage by Leonard Reynolds in summer 1951. A cable-tool rig, rented from the THD, arrived after a year's delay in delivery because of factory and steamship strikes. That winter the U.S. Army used Cederstrom's experience in arctic drilling by hiring him to secure additional data on this activity from firms in Montreal, Ottawa, and Winnipeg, Canada. During 1952–53, Cederstrom and Trainer shared

responsibility for the cable-tool drilling in Anchorage. D.A. Morris assisted Cederstrom during the 1953 season. Cederstrom traveled to the Pribiloff Islands where he was successful in locating a well site for the Fish and Wildlife Service. In 1954, G.C. Tibbits assisted Cederstrom with additional test drilling in Fairbanks, and R.M. Waller assisted F.W. Trainer in completing the Anchorage study in 1955. G.H. Ramsey, a Survey driller, expedited the Anchorage drilling program.

With technical advice from Survey personnel, personnel from the city of Anchorage drilled and test pumped its first water-supply well, which was placed in operation in winter 1956–57. The "warm" (39° Farenheit) ground water moving through the underground mains gave the city its first wintertime relief from frozen mains caused by the colder surface supplies. With this experience, the city established a wellfield during the next 2 to 3 years.

In an effort to demonstrate that supplying water for domestic use from the coastal bedrock wells at Juneau was feasible for U.S. Federal Housing Authority-approved housing loans, Waller and THD personnel core-drilled in 1955 a 2-inch hole at a 30-degree angle and obtained a flowing well a few feet above high-tide level. The driller was so impressed with this opportunity that he started a well-drilling business in Juneau and later in Ketchikan.

As a result of the ground-water reconnaissance that Waller made during 1955 at U.S. Air Force radar sites at Indian Mountain and Cape Lizburne, and an earlier one made by Trainer at Sparrevohn, the Air Force began a continuing cooperative program with the Alaska District in 1959. The objective was to assure adequate water supplies at remote sites.

During 1955–56, Waller, in informal cooperation with the THD, reactivated a reconnaissance of village ground-water resource appraisals begun by Cederstrom in 1948–49. By 1955 or 1956, THD and the U.S. Bureau of Indian Affairs each had a drill rig, one a barge-transported piece of equipment and the other a lighter rig that could be brought in by airplane. Waller had to determine which equipment was to be used at each location. He recalls that "villages in the lower Kuskohivin were visited first (a week after I married an Anchorage schoolteacher)." A flowing well was drilled through 609 feet of frozen glaciofluvial deposits in 1956, but the artesian well area collapsed shortly afterwards. The village drilling programs continued, leading to more formal cooperation with THD and further assistance to the Bureau of Indian Affairs. Waller recalls that, despite the dangers and frustrations associated with the program, "seeing the natives get a good clean water supply was gratifying."

In his letter dated January 14, 1983, F.W. Trainer writes: "The WRD Program in Alaska during 1947–57 was unique among all the district programs in that it saw the conception and initial growth of studies in an enormous region of technical and logistical challenge that had previously been virtually untouched in the sense of modern hydrologic investigations. This is particularly true of the GW program, which comprised both reconnaissance studies of regions and topical problems, and detailed areal investigations. These studies were conducted during a period of rapid economic and population growth concurrent with intensive development of ground-water supplies in several areas, notably at Anchorage. For example, during 1947–57, the number of drilled waterwells in the Anchorage area increased from about 10 to 20 to more than 600. The Survey's program during this period provided the first deep, large-capacity test wells in the area, and it served by example and through advisory participation to foster the successful drilling of large production wells by personnel of other agencies and the city."

QUALITY OF WATER BRANCH

By George W. Whetstone

The QW Branch program in Alaska was initiated in 1948 by C.S. Howard as a part of the expanded Bureau-level investigations of the natural resources of Alaska. A laboratory was constructed in the Wright building in Palmer in June 1949 by R.T. Kiser who was on detail from the regional laboratory in Salt Lake City. Water samples were collected from streams along the highway system and two daily stations were established on Ship Creek near Anchorage and the Tanana River at Big Delta.

In April 1950, Kiser was succeeded by G.W. Whetstone, who transferred from the Charlottesville, Va., laboratory. The program was expanded, and J.B. Kindler, chemist, joined the laboratory staff in July and, in spring 1951, Ms. J.B. Casey, chemist, was hired. The program expansion during 1950–51 included the establishment of five additional daily stations and 39 partial record stations.

In February 1952, R.B. McAvoy, chemist, joined the staff as replacement for Kindler. In July 1952, in response to program discussions with the Corps of Engineers, a sediment program was developed and sediment stations were established on the Susitana, Tanana, and the Matanuska Rivers. F.C. Ames was detailed to the Palmer office to assist in the planning and development of this program. In 1953, George Porterfield, from the Austin, Tex., District, was detailed for the summer months and C.E. Behlke, assistant professor of Civil Engineering, University of Alaska, was hired as a WAE engineer to assist with the sediment program. J.H. Moor, engineer, was hired full-time in fall 1953.

Funding for the QW program during 1949–57 increased from about $25,000 to approximately $50,000.

The bulk (about 80 percent) of the funding came from the Federal program. Additional funds, however, were furnished by the U.S. Air Force for training personnel in analytical techniques during the development of the White Alice and DEW line (Distant Early Warning sites) projects in northern Alaska and Canada. F.B. Walling, chemist, transferred to Palmer in 1954 from Austin, Tex., and succeeded G.W. Whetstone in 1957 as district chemist.

Highlights of the program in the early 1950's included, in addition to the traditional cooperation between the branches, strong programs in support of Geologic Division objectives in the Territory. Arrangements were made with Geologic Division field parties for the collection of water and sediment samples at locations away from the main transportation net. Immediately after the eruption of Mt. Spurr in about 1953, volcanic ash samples were collected by QW Branch personnel in the counties of Anchorage and Valdez and shipped to Denver for analysis by Geologic Division personnel. The effects of volcanic ash on the quality of water of Ship Creek were monitored during July and August, and G.W. Whetstone presented a paper on the subject at the AAAS meeting in Fairbanks in spring 1955.

From conversations with S.K. Love and J.V.B. Wells during their visit to Alaska in 1951, permission was obtained to jointly publish surface-water and quality-of-water data in a single volume in the Water-Supply Paper series. Alaskan data had not been published since the reconnaissance studies in the early 1900's. The first joint volume was WSP 1372 (1957), "Compilation of Quantity and Quality of Surface Waters of Alaska, Through September 1950." Subsequently, all surface-water and quality-of-water data were published in the same volume.

ARIZONA

SURFACE WATER BRANCH

By Roy B. Sanderson

J.H. Gardiner, appointed district engineer in 1938, continued in that position until his death in 1956. In 1952, Gardiner had been given the additional responsibility of serving as Geological Survey representative on the Interior Department Field Committee Region 4 (Colorado River-Great Basin) and also of coordinating program plans for the Division in that region. He was succeeded as district engineer by D.D. Lewis, who transferred from a similar position in Nebraska. Gardiner's principal assistants from the beginning and through most of the decade were J.A. Baumgartner and J.S. Gatewood. Baumgartner remained until June 1956, when he began an assignment in Iran, where he contracted an illness that soon claimed his life. He was succeeded by W.L. Heckler who also served as acting district engineer during the interim between Gardiner's death and Lewis' move to Tucson. Gatewood was placed in charge of a field unit of the Special Reports and Investigations Section of the Branch and his headquarters remained in Tucson. He was assisted by Alfonso Wilson. Gatewood retired in 1957.

The District was staffed with about 20 persons at the beginning of the decade, but program changes and growth required about 25 employees by the decade's end. Usually about half were stationed at District headquarters in the Post Office building in Tucson. The balance were headquartered at as many as seven area offices, one of which, Boulder City, was in Nevada and is described under the activities of that State. Of the others, those at Phoenix and Safford were the largest, having as many as five employees in each in some years. Usually, two were stationed in Yuma and from one to two in Flagstaff and Lees Ferry. One employee was stationed at Grand Canyon during the first few years of the decade and during periods of high runoff thereafter.

S.O. Decker was in charge of the Phoenix office until succeeded by G.T. Smith in 1950. He in turn was succeeded in 1954 by R.B. Sanderson who had been on the District headquarters staff. R.H. Munroe supervised the work of the group at Safford until 1950. Winchell Smith directed that activity until 1955 and was succeeded by A.V. Todd. M.D. Dykers was in charge at Yuma until 1950, then C.T. Jenkins for the next 2 years, and Angelo Dalcerro for the balance of the period. A.G. Hely was in charge of the Flagstaff office until October 1956 when he transferred to Pennsylvania. J.E. Klohr was responsible for the gaging program at Lees Ferry until 1950, G.E. Johnson for the next 5 years, and D.C. Tidball from 1955 through the rest of the decade.

C.T. Pynchon continued in charge of the administrative services in the District until 1952, when he was placed in charge of the Division's Administrative Services Section with three or more employees who handled those functions for both SW and GW Branch personnel in Arizona. The section was under the direction of the council chairman.

Curtailment of all but absolutely essential construction and rehabilitation during the war years resulted in a dire need for these activities at the beginning of the decade. An extensive rehabilitation and new construction program was initiated with Sanderson in charge. Some of the new gaging stations were located at damsites in canyons with precipitous cliffs rising hundreds of feet. Transportation of equipment and material from canyon rims to the bottom involved the use of costly cable highlines and trails. Notable among these new stations was one on the Little Colorado River near Cameron where construction

included a 1,200-foot highline, a 64-foot stilling well, an overnight cabin, a measuring cable, a trail to the canyon bottom, and later a 1,000-foot-high access cableway to eliminate expensive and time-consuming dirt-road travel by pickup truck (WRD Bull., May 20, 1954, p. 35).

Early in the decade, funding for new gaging stations was provided primarily by the Bureau of Reclamation as part of its investigation of sediment load in rivers, and which were to be used in the study of reservoirs on the Colorado and Little Colorado Rivers. Stations built later were financed by other Federal agencies and within the cooperative program. The importance of the discharge and sediment records of the Colorado River at Lees Ferry, which were necessary for allocation of Colorado River water under the Santa Fe Compact of 1922, justified the procurement of Federal funds for a major overhaul of the living quarters, a new silt laboratory, and improved water system. Communication between the District office and Lees Ferry by radio, installed May 18, 1947, not only provided current streamflow data to all interested parties, but proved a morale booster for the resident hydrographer (WRD Bull., May 10, 1947, p. 100). A new silt laboratory was constructed at the Colorado River at Grand Canyon residence to replace the old laboratory destroyed by fire in 1946. Major rehabilitation of the gaging station structures at Grand Canyon were also completed.

The District staff was involved in the preparation of two major reports during the decade. A compilation of records of surface waters in the Lower Colorado River basin, 1888–1950, was published as WSP 1313 (1954). This report involved a review of all published records during the period. Changes were made where warranted and periods of no record were estimated in order to complete months or years, thus increasing the value of the record. The compilation report was prepared under the supervision of Gatewood and District personnel were assigned as needed. A compilation of flood data in Arizona, 1862–1953, was prepared under the direction of Smith and Heckler and published as an Open-File Report. The ''Water Wheel,'' a District monthly publication used to keep area and residency offices aware of what was happening of Survey interest throughout the State, was continued during the decade. Nothing but praise came from District personnel concerning this publication despite the sometime inconvenience of making a contribution. The ''Water Wheel'' contributed to high morale in the District.

The principal cooperator during the decade was the State through its State Land Department, and an excellent relationship existed between Survey and State personnel. Another, and one of the most vocal in its support for Survey records and water-measuring techniques, was the Salt River Valley Water Users Association. Jake West was their chief hydrologist. The operation of the association's network of dams, reservoirs, diversions, and canals required current water data. These data were provided by the Phoenix area office. All area offices furnished hydrologic data to meet the needs of cooperators.

GROUND WATER BRANCH

By Leonard C. Halpenny

Statewide Program

During 1947–54, the main thrust of the work conducted by the Arizona District was related to the cooperative program with the State Land Department. A Subdistrict office was maintained in Phoenix throughout 1947–57. The District office in Tucson was headed by S.F. Turner until mid-1951, by L.C. Halpenny until early 1955, and by J.W. Harshbarger through the end of the period. The assistant district chiefs during the period were L.C. Halpenny (1947), R.L. Cushman (1948–54), and L.A. Heindl (1955–57). The Phoenix office was headed in succession by Harris McDonald, H.M. Babcock, H.N. Wolcott, and D.G. Metzger.

By mid-1948, the State Legislature had enacted the first legislation directed toward limiting development of ground water for irrigation of newly developed agricultural lands. Under this legislation, the State Land Department was directed to ask the Geological Survey, under the cooperative program, for additional ground-water data throughout the State. The individual basin reconnaissance investigations that had been initiated in late 1945 were effectively completed by the end of 1947. The next task was to develop data in greater depth for the most heavily developed ground-water basins. These included the upper and lower Santa Cruz basins, the Florence-Coolidge, Eloy, and Maricopa-Stanfield areas in Pinal County, and the Salt River basin in Maricopa County. Land Department officials needed maps that delineated basin boundaries, within which ground-water critical areas could be established. Updated maps that showed irrigated lands and well locations were needed annually. An annual inventory of wells in these areas and an annual inventory of ground-water withdrawals also were required. Public hearings were scheduled on the proposed establishment of specific ground-water critical areas, and the Survey was asked to testify as to factual basic data at each hearing. The first area established under this legislation was the Eloy Critical Area, on April 4, 1949, followed in 1951 by the Queen Creek-Superstition Critical Area, the Gila-Santa Cruz Critical Area, and the Salt River Valley Critical Area. In 1954, three new areas were established,

Marana, Tucson, and Sahuarita-Continental; additions were made to three others, Queen Creek-Superstition, Eloy, and Gila-Santa Cruz. In 1956, the Salt River Valley Critical Area was enlarged. As a part of this work, the Survey was asked in 1952 to prepare a consolidated report summarizing all of the available ground-water data for the Gila River basin in Arizona, the Willcox basin (interior drainage), and the Douglas basin (drainage into Mexico).

During the decade, close professional cooperation developed between the District office and the Departments of Geology and Agricultural Engineering of the University of Arizona. The Arizona Geological Society was founded in 1947, and three of the charter members were from the District office. Three of the Branches of the Division (SW, GS, and QW) moved closer together and eventually merged in 1963. From 1947 on, C.T. Pynchon of the SW Branch kept accounting records for the GW Branch. J.S. Gatewood (SW), J.D. Hem (QW), and L.C. Halpenny (GW) finalized Water-Supply Paper 1103 (1950) as a Division project. From 1948 through 1957, technical sessions were held annually in the fall, attended by all members from local SW and GW districts.

In addition to the State cooperative project and Navajo project, work was conducted in Federal financial cooperation with the Bureau of Indian Affairs (BIA), the Bureau of Reclamation, the International Boundary Commission, the National Park Service, and the Corps of Engineers. Other financial cooperators were the city of Phoenix, the city of Flagstaff, and the town of Safford.

The published reports of investigations conducted during the decade by District personnel, exclusive of the Navajo project, include the following: "Use of Water by Bottom-Land Vegetation in the Safford Valley" by J.S. Gatewood, T.W. Robinson, B.R. Colby, J.D. Hem, and L.C. Halpenny (WSP 1103, 1950); "Geology and Ground-Water Resources of the Douglas Basin" by D.R. Coates, R.L. Cushman, and J.L. Hatchett (WSP 1354, 1955); and "Water Resources of Bill Williams River Valley Near Alamo" by H.N. Wolcott, H.E. Skibitzke, and L.C. Halpenny (WSP 1360-D, 1956). In addition, more than 20 Open-File Reports were prepared and copies mimeographed for interested persons.

Of the approximately 46 members of the District (exclusive of the Navajo project) who were on duty during the decade, most are identified in the list of personnel as of January 1956 in the appendices. Others who remained several years but left the District prior to that time and are not identified in the 1956 listing include F.I. Bluhm, K.J. DeCook, D.R. Coates, J.H. Feth, P.W. Johnson, A.E. Robinson, and Ms. M.J. Scott.

Navajo Project

The "Navajo project" was a large part of the activities of the Arizona District personnel through most of the 10-year period. Work began on a limited scale on January 2, 1948, when Halpenny and S.C. Brown were sent to the Navajo Indian Reservation for a month to select sites for wells to supply water for schools already under construction. It became evident at once that the available geological data were inadequate to permit a piecemeal approach to selection of well sites. Accordingly, the BIA was urged to approve and finance a reservation-wide geologic mapping program that included the Hopi Indian Reservation. The program was planned to include well drilling and well testing, and an inventory of all existing wells and springs.

The project as proposed in 1948 envisioned major work in parts of three States, Arizona, New Mexico, and Colorado, plus a little work in Utah. During the 1½ years from the time work began until the Navajo project was formalized and financed, Halpenny and Brown were assigned full time to the Navajo work. Brown resigned from the Survey in mid-1948 and was replaced by H.A. Whitcomb. To coordinate the work, a project chief was appointed who would conduct the work in all four Districts (and States) as might be required and report to and coordinate with the District chiefs (GW) of all four States. Halpenny was the appointed project chief, effective July 1, 1949, the date the project was officially approved and financed.

Also effective July 1, 1949, J.W. Harshbarger joined the Survey as chief geologist for the Navajo project. Others who joined at that time were C.A. Repenning, J.W. Irwin, and S.C. Galloway. Later arrivals were J.T. Callahan, J.P. Akers, R.L. Jackson, M.E. Cooley, G.E. Davis, Bill Kam, W.F. Hardt, Marlene Ferguson, George Smith, Mrs. C.L. Hicks, E.L. Gillespie, Don Greene, and Kay Thompson. The first stages of the work included obtaining full stereo-pair, aerial-photo coverage of the region and aerial-photo mosaics in 15-minute quadrangle-map size, and the development of an accurate base map. Skibitzke developed a map projection best suited for the area to be mapped. Work was begun on preparing a map of each quadrangle showing geology, wells, springs, roads, and other natural and cultural features. Geologic sections were measured and described and, as the data began to accumulate, fence diagrams were prepared from the sections and from well logs.

Prior to January 1951, the Navajo project personnel lived mainly in Albuquerque, Phoenix, and Tucson. In each 3-week period, they worked on a basis of 15 days in the field, 2 days on travel, and 2 days off. During this period, a "bunkhouse" headquarters was maintained, first at Tohatchi, N. Mex., and later at Fort Wingate, N. Mex. Early in 1951, a project office was established in Holbrook at the Navajo County Fairgrounds, and many of the personnel moved their families to Holbrook.

The Navajo project plan was for completion of field work by June 30, 1955, followed by a 2-year period of

report preparation. The field work was completed on schedule. Then most of the personnel transferred to other assignments, and report preparation began to lag behind schedule. Cooley was assigned the task of coordinating report preparation and did a yeoman job of completing the assignment under the direction of Harshbarger. Halpenny left the project in October 1951 to become District chief (GW) for Arizona. Harshbarger moved back to Tucson in 1955, when he replaced Halpenny as District chief.

Following the completion of the Navajo project field work in 1955, the Survey maintained one employee, first in Holbrook and later in Flagstaff, to assist the BIA and the Navajo Nation in the selection of well sites and the collection of well test data. This work was financed by the BIA and the Navajo Nation, and continued into the 1960's.

Although numerous short reports were prepared and held in the "open-file" during the decade, it was not until during 1969–72 that the findings were formally published in Professional Paper 521, Section A through E. The 20 members of the Navajo project staff are identified above or in the 1956 listing in the appendices. The total number of personnel in the District and Navajo project increased from 11 employees in 1947 to as many as 38 late in the decade.

QUALITY OF WATER BRANCH

Water-quality studies conducted in Arizona were under the direction of the Albuquerque, N. Mex., District. District chief C.S. Howard reported (in response to a WRD Circular dated July 15, 1947) that the quantity and nature of suspended sediment were being determined at several gaging stations in the Colorado River basin. District personnel later (July 2, 1951) reported that they were collecting daily sediment-discharge records at 6 stations, chemical quality at 10 stream locations, and temperature at 15 points. By the end of the decade (based on the fiscal year 1958 report), the above data network continued at about the same magnitude, but a much greater effort was made in securing records of chemical quality and temperature from observation wells.

In 1949, the District established a two-person field headquarters at Holbrook, with R.E. Cabell in charge, in order to participate more effectively in the Navajo project. The headquarters was closed in 1952. All other activities of the Branch in Arizona were conducted by personnel who had headquarters outside the State. In June 1957, however, shortly after the end of the decade, L.R. Kister, Jr., established a Subdistrict office in Tucson.

The program had two primary sources of support. The most stable funding was from the Federal program allotments. Other funds were received from several other Federal agencies, primarily the Bureau of Reclamation, according to fiscal year 1958 program statistics.

ARKANSAS

SURFACE WATER BRANCH

Condensed from documentation by L.D. Reid

The District headquarters was located in the Post Office building in Fort Smith during the entire decade. Since its establishment in 1928, the District had had jurisdiction over the programs for both Arkansas and Oklahoma. Early in 1948, however, a separate District was established in Oklahoma. The Arkansas headquarters staff remained at seven to eight persons during the balance of the decade. A one-man field headquarters was maintained at DeQueen during the latter half of the decade to give better coverage to some fast-rising streams in that area. Several of the stations were taken over from the Corps of Engineers. The one-man field headquarters at Harrison was closed in September 1947.

J.L. Saunders was district engineer during the entire decade, having been in that position since 1938. S.K. Jackson, his principal assistant, transferred to Oklahoma City in January 1948 to take charge of the newly-established Oklahoma District. J.L. Patterson then served as second in charge for the balance of the period. G.L. Haynes, Jr., on the staff since 1941, transferred to Wyoming in 1949. Hydraulic engineers R.C. Gilstrap and J.D. Warren joined the District staff at mid-decade. K.W. Walker, L.D. Reid, and S.R. Kennedy were members of the staff during the entire period. O.J. Jacobs was stationed at DeQueen.

The network of stream-gaging stations at which daily-discharge data were collected grew from about 50 sites during fiscal year 1947 (Saunders' reply to a WRD Circular dated July 15, 1947) to 58 sites as of 1951 (response to a WRD Circular dated June 11, 1951), to as many as 78 by the end of the decade (program analysis of February 1958). Saunders stated that, as of 1947, "the major streams of the State . . . are now being fairly adequately gaged" but that "the extension of the Corps [of Engineers] activities to include investigation of local flood-protection projects has emphasized a dearth of actual streamflow records for the smaller streams." L.D. Reid recalls (written commun., 1982) that this deficiency in coverage was lessened by the Corps and the Survey who separately established and maintained several gaging stations during this period, some of which are still operating.

Of the 78 stations reported for fiscal year 1958, 9 were supported by Federal program funds, 35 under the

cooperative program with the Arkansas Geologic and Conservation Commission, 23 by the Corps of Engineers, 1 by the U.S. Public Health Service, 9 by the U.S. Soil Conservation Service, and 1 by permittees and licensees of the Federal Power Commission.

Saunders also stated (1947) that one of the Corps of Engineers' critical needs was to secure "immediate reports of flood discharges at gaging stations located above reservoirs . . . for use in proper operation of control gates" at the reservoir outlets. At the time, there were "three major" Federal flood-control reservoirs within the State and three more in the process of completion.

Reid's further recollections (1982) of District personnel during the decade are historically valuable. He remembers district engineer Saunders as being "well informed about the entire State" and having a good relationship with all of his staff. He feels that the two most outstanding members of the staff were probably Patterson "who went on to be one of the outstanding flood specialists in the Nation, and Mrs. B.W. Vines, who not only served as District clerk but became adept at working up streamflow records."

GROUND WATER BRANCH

By Harlan B. Counts

District headquarters remained at the University of Arkansas in Fayetteville until 1949 when it moved to Little Rock where it remained throughout the decade. The relocation was made so that the District office would be near the major State cooperating agency. A field headquarters at El Dorado was closed in August 1947; another was established at Little Rock in 1948, which became the District headquarters in 1949.

R.C. Baker, in charge of District work since 1946, was made district geologist in 1947 and continued in that capacity until he left to become U.S. Geological Survey Advisor in Pakistan in 1954. He was succeeded by P.E. Dennis, who transferred from the North Dakota District at Grand Forks. H.B. Counts was on the staff from 1949 until he transferred to Georgia to become project engineer at Savannah. J.H. Criner, Howard Klein, F.E. Onellion, and D.B. Tait were on the District staff for one or more years during the middle of the decade. R.W. Ryling, R.T. Sniegocki, and J.E. Reed joined the staff in 1952, 1953, and 1955 respectively.

As of July 1951, District personnel collected about 630 water-level records and 440 temperature records from about 630 observation wells under the cooperative program with the Arkansas Geology and Conservation Commission and the Arkansas University Agricultural Experiment Station. By the end of the decade, the number of records had increased to about 1,430 water level, 229 well discharge, 938 chemical quality, and 750 temperature. The Corps of Engineers, the U.S. Army and Air Force, and the Arkansas University Engineering Experiment Station funded the collection of some of the above records during the latter part of the decade.

Most of the ground-water investigations in Arkansas during the decade were published by the cooperative agencies or were open-filed. One was published as USGS Circular 241 (1953).

The following projects and reports were completed and (or) published during the decade: "Ground-water resources of the El Dorado area of Union County" (R.C. Baker and F.A. Hewitt, 1948); Ashley County (F.A. Hewitt, R.C. Baker, and G.A. Billingsley, 1949); Jefferson County (Howard Klein, R.C. Baker, and G.A. Billingsley, 1950); and water-level changes, eastern Arkansas, 1938–53 (H.B. Counts and Kyle Engler, 1954). Also, statewide ground-water resources (R.C. Baker, 1955); southwestern Arkansas (H.B. Counts, D.B. Tait, Howard Klein, and G.A. Billingsley, 1955); Chicot County (F.E. Onellion and J.H. Criner, 1955); Drew County (F.E. Onellion, 1956); "Studies of artificial recharge in Grande Prairie region" (R.T. Sniegocki, Arkansas Academy of Science, 1956); and part of Lonoke, Prairie, and White Counties (H.B. Counts, 1957).

The following reports were open-filed during the decade: "Notes on ground-water conditions in Bradley, Calhoun, Cleveland, Dallas, Drew, Grant, Jefferson, and Lincoln Counties" (F.E. Onellion, 1955); "Memo on ground water for irrigation" (P.E. Dennis, 1957); "Chemical character and use of ground water" (M.E. Schroeder and R.T. Sniegocki, 1957); and "Progress on artificial recharge, Grande Prairie" (R.T. Sniegocki, 1954; 1955; 1956; 1957). The following report was published as USGS Circular 241, "The ground-water resources of Columbia County, Ark., a reconnaissance" (D.B. Tait, R.C. Baker, and G.A. Billingsley, 1953).

QUALITY OF WATER BRANCH

By Granville A. Billingsley

A laboratory had been maintained at Fayetteville since 1945, but it did not gain District status until 1950. The facility moved from a surplus Army barracks building on the University of Arkansas campus to 205 Ozark Street in Fayetteville in 1955. At the beginning of the decade, the laboratory served not only work in Arkansas, but also that for Tennessee and for that part of Missouri outside of the Missouri River basin. By 1950, the area of the District's responsibility included Arkansas, Tennessee (through 1952), Mississippi, Alabama, and the lower

(southern) part of Missouri. District activities are described under the State in which they were conducted.

G.A. Billingsley succeeded I.W. Walling as resident chemist in 1946 when Walling established and took charge of the laboratory in Stillwater, Okla. Billingsley was appointed district chemist in 1950, and held the position until he was designated district chemist for the Carolinas in 1953. J.W. Geurin, who had been on the staff since 1948, succeeded him and remained in charge until 1956 when he was placed in charge of the Ocala, Fla., District. Geurin was succeeded by M.E. Schroeder who had been district chemist in Virginia. Other senior staff members included J.H. Hubble (1951–54); H.G. Jeffery (1952–57); Ms. D.M. Parrish (1945–48); T.B. Dover (1947); Ms. I.A. Knight (1949–51); D.S. Conner (1950–53); D.J. Kessinger (1951–52); M.C. Bowman (1952–53); J.P. Reed (1954–57); and Ms. D.S. Scott (1949–57).

The cooperative program with the University of Arkansas Bureau of Research, which began in 1945, continued into the decade, which, in the late 1940's, became the University of Arkansas Department of Research, Institute of Science and Technology. H.G. Jeffery recalls that sometime between 1954 and 1956, the University of Arkansas Engineering Experiment Station (UAEES) took over as cooperating agency and continued through the end of the decade.

Quality-of-water studies in Arkansas were intensified at the beginning of the 1947–57 decade to determine the mineral content of the streams with respect to their industrial, agricultural, and domestic uses. Systematic records of surface-water quality were collected throughout the State, with particular attention given to the Ouachita River and its tributaries and the Arkansas River proper. In the Ouachita, an interstate stream, the mine drainage, industrial wastes, oil field brines, and other pollutants seriously impaired its water quality, not only for use in Arkansas but also for use downstream in Louisiana.

As of 1951, water-quality records were being collected on a daily basis at 28 points and periodically at an additional 51 locations in Arkansas streams. By fiscal year 1958, the number had decreased to 18 daily and 48 periodic records. The records were published annually in two geographic segments of the Water-Supply Paper series: "Quality of Surface Water for the United States—Part 7–8" and "Quality of Surface Water for Irrigation, Western States."

Reports prepared and published, as indicated parenthetically, from the detailed records collected include a series on the chemical quality (or composition) of surface waters of Arkansas for 1951–52 by Hubble (USGS open-file, 1956); for 1956–58 by Schroeder (USGS open-file, 1961); for 1949 by Geurin (University of Arkansas of Institute Science and Technology (UAIST), 1951); and for 1945–55 (summary) by Geurin and Jeffery (UAEES Bull. 25). Also published were an interbranch report by J.L. Saunders and Billingsley in 1950 on surface-water resources of Arkansas (UAIST Research Series 18 and also Arkansas Resources and Development Commission, Division of Geology, Bull. 17), and an analysis of spring waters of the Hot Springs National Park area, appendix 1, radioactivity of thermal waters and its relationship to the geology and geochemistry of uranium, by Billingsley and Hubble in 1953 (UAIST).

The District staff also participated in the study and reporting of ground-water resources of Arkansas in collaboration with GW Branch personnel. The Columbus County reconnaissance was published by D.B. Tait, R.C. Baker, and Billingsley in 1953 (USGS Circular 241). The chemical character and use of ground waters in Arkansas was documented by R.T. Sniegocki and Schroeder in 1957 (USGS open-file). Baker, F.A. Hewitt, and Billingsley reported on the El Dorado area in Union County in 1948 (University of Arkansas Bureau of Research, Research Series 14). Billingsley also participated in the ground-water studies and reports in a part of southwestern Arkansas (Arkansas Geol. and Cons. Comm., Circ. 2, 1955), in Ashley County (UAIST Research Series 16, 1955), and in Jefferson County (UAIST Research Series 19, 1955). As the decade closed, District personnel were conducting a number of relatively new projects, including participation in the interbranch artificial recharge project near Stuttgart; the establishment of two sampling stations for determination of daily chloride levels for the U.S. Public Health Service; participation in the Arkansas Water Study Commission activities (Geurin was Secretary of its Water Quality Work Group at the time he left for Florida); and plans for a sediment-trap efficiency study in the Six Mile Creek basin near Paris in cooperation with the U.S. Soil Conservation Service.

California

SURFACE WATER BRANCH

By R. Stanley Lord and Lee R. Peterson

H.D. McGlashan, who had been appointed district engineer in 1912, (Follansbee, v. I, p. 284) continued in that position until his retirement in 1948. (See *WRD Retirees* newsletter dated August 1975 for biographic memoir.) He was succeeded by R.C. Briggs who had been assistant district engineer. Briggs continued to head the District until his retirement in 1956. R.S. Lord succeeded Briggs and continued beyond the end of the decade.

The personnel of this large District were well decentralized during the decade. This is understandable when

one considers the great north-south distances, the variety of local water problems to which the program was directed, and the need for frequent liaison with local cooperating officials. As of January 1948, about 80 percent of the approximately 40 employees in the District were about equally divided between the District headquarters in San Francisco and the Los Angeles office. The remaining personnel were stationed at 10 field headquarters, seven of which were supervised directly from San Francisco, and the remainder supervised by the Los Angeles office.

It is noteworthy that only one employee was stationed at Sacramento, the State Capital, at the beginning of the decade. Locating the District office in Sacramento had been suggested on various occasions, but McGlashan, a very good friend of Ed Hyatt, State engineer, never felt the need for the District office to be in close proximity to the seat of State government. When Briggs was appointed district engineer, the question of moving the District office to Sacramento was again considered. Briggs strongly preferred leaving the office in San Francisco but agreed that an "Area Office" should be established at Sacramento. This was part of a gradual organizational restructuring of the District.

With the establishment of the larger office in Sacramento, the State was divided into three areas, each under a GS-12 engineer-in-charge. Personnel of the Los Angeles Area Office continued to handle the program within the office's traditional boundaries. Sacramento area office personnel were assigned the work in the Sacramento and San Joaquin basins (the Central Valley area). The San Francisco Area Office had jurisdiction over activities in the north coastal basins, the San Francisco Bay region, the south coastal basins as far south as San Luis Obispo, and the streamflow work required under terms of the various permits and licenses issued by the Federal Power Commission. Later, when the Survey adopted the term "Area" to designate its new regional structure, the California District area offices were changed to "Subdistrict" offices to avoid confusion with the Washington office terminology.

Increased work because of the addition of gaging stations, including those on small streams which required more response time, and to a change in policy for government employees that required payment of overtime for work in excess of 8 hours per day (including travel time), made it necessary to further disperse field personnel. Three field headquarters were established under each area (subdistrict) office, as follows: Personnel stationed at Eureka, Santa Rosa, and Atascadero reported to San Franciso; employees at Redding, Merced, and Visalia reported to Sacramento; and the personnel at San Bernardino, Cachuma, and Escondido reported to the Los Angeles office. Except for the establishment and closure of field offices, the normal transfer of professional employees, and the gradual doubling of District personnel during the decade, there was reasonable stability with respect to deployment—that is, until the end of the decade, when the District office moved from San Francisco to Menlo Park where the Survey was building its western regional field center.

As of January 1948, members of the senior staff at District headquarters were R.S. Lord, George Anthony, Jesse Arnold, H.F. Matthai, A.H. Perraca, H.J. Sexton, and Winchell Smith. As of January 1956, the District office staff had grown from about 15 persons (in 1948) to about 27 with the senior staff members listed as R.S. Lord, Jesse Arnold, C.F. Hains, and T.O. Miller. In 1954, the area office with about 12 employees had been established at District headquarters with L.R. Peterson in charge. As of 1956, Peterson's principal assistants included W.A. Brownlie and S.E. Rantz. In the District office, Ms. H.C. Smith, long-time district clerk, retired in 1948 and was succeeded by Ms. M.A. Moritas. Avery Rogers was designated as administrative assistant in 1953 and served until 1954 when Ms. Rose Isaacman became the senior clerk. She was designated as administrative assistant in 1957.

The Los Angeles office with a staff that varied from 9 to 17 employees was under the direction of H.M. Stafford until 1949, when he transferred to take charge of the Sacramento office and was assigned additional responsibilities at Division and Bureau levels. He was succeeded in 1950 by D.R. Woodward who had been in the Salt Lake City, Utah, District. In 1952, Woodward was assigned to the Director's staff in Washington, D.C., and W.M. Littlefield took charge of the Los Angeles Subdistrict for the balance of the decade. The senior staff members as of January 1948 were H.C. Troxell, W.C. Dickinson, and O.J. Whitman. As of January 1956, the listing included H.C. Troxell, Walter Hofmann, M.B. Scott, and G.M. Thayer.

The Sacramento office, initially a one-man field headquarters, was under the direction of F.C. Craig until H.M. Stafford was placed in charge in the mid-1950's with a staff that varied from 16 to 18. As of January 1956, the senior staff included F.C. Craig, W.W. Dean, and A.C. Swanson. Stafford also represented the CHE in program planning and liaison for the Pacific Southwest and the Director on the USDI Pacific Southwest Field Committee.

Four of the field headquarters were maintained throughout the entire decade. San Bernardino was the largest with a staff that varied from two to five persons. Jarrett Oliver was initially in charge, followed by M.B. Scott and G.L. Lang. H.E. Dahman handled the work at the Atascadero location until replaced by J.D. Hungate. D.A. Dudley, at times with one assistant, was

assigned to the Redding headquarters. Responsibility for the SW program at Merced was initially carried by D.L. Milliken, followed by Harry Hulsing, P.B. McGraw, W.H. Chambers, and D.S. Ewing.

Ten or eleven other field headquarters, usually staffed by one or two individuals, were maintained during portions of the decade. However, by the end of the period, each area (subdistrict) office had three field headquarters, generally staffed with two or more persons. In addition to being responsible for the field work in the vicinity, personnel in these offices did all of the initial computations for the streamflow records assigned to that office.

The five field headquarters that were operating at the close of the decade (in addition to the four that were maintained throughout the decade) were staffed as follows: T.R. Dosch was in charge of the Eureka office, followed by D.S. Ewing and then R.E. Whiteman. G.L. Gwinn was originally in charge at Santa Rosa and was followed by Jesse Arnold. T.A. Cooper handled all the work assigned to the one-man office at Visalia. In southern California, G.E. Stanton was in charge of the Cachuma office, which had moved from nearby Solvang where C.E. Burgess was in charge. E.L. Hogue was in charge at Escondido in 1956, followed by D.F. Thoreson at the end of the decade.

As of the end of the decade (fiscal year 1958 data), the District program had reached a level of nearly $900,000 which was about 65 percent of the total funds for the Division in California at the time. Of the total District funds, about 5 percent was financed from the Federal program, about 15 percent from other Federal agencies, 8 percent from Federal Power Commission permittees and licensees, and the balance from a Federal-State program that included three State, seven county, and about five city agencies, departments, and districts.

The California Department of Water Resources was, by far, the largest cooperating agency with a decade-end allotment (both sides) for stream gaging that approached half a million dollars. The next largest segment of the stream-gaging program was supported by the Federal Power Commission permittees and licensees and, in descending order, the Corps of Engineers and the Bureau of Reclamation.

As of 1951, the District staff collected records of daily discharge at more than 500 locations on streams, canals, and other open channels. Nearly 300 of these locations were supported under the cooperative program. Records of daily stage only were taken at an additional 335 points on rivers, other waterways, and reservoirs. Daily storage was calculated and reported for about 40 reservoirs. Water temperature also was measured daily at about 370 open-channel locations. District personnel extended the data-collection program to include periodic water-table observations in nearly 300 observation wells. These wells were in the Mohave Desert region and were deemed to be important for continued observation following completion of the investigation of this region in California by D.G. Thompson (WSP 578, 1929). This well-measuring program was conducted by SW Branch personnel because there were no GW Branch activities being conducted in California until 1940, when the GW Office opened in Long Beach.

Although the stream-gaging program was by far the largest of the activities, there were numerous other types of investigations, including those of major floods and droughts. The dry years from 1944 to 1951 in southern California were documented in WSP 1366 (H.C. Troxell, 1957). Troxell also prepared the Survey's first Hydrologic Atlas (map, HA-1) on the hydrology of the San Bernardino and eastern San Gabriel Mountains, Calif., in 1954. Rantz spent 21 months in 1948 and 1949 assisting U.S. Weather Bureau and Corps of Engineers personnel in the processing and analysis of data from which runoff from snowmelt in western mountain areas could be forecast for about five major rivers (WRD Bull., Nov. 1949, p. 79–81).

The floods of November–December 1950 in the Central Valley basin (WSP 1137-F, 1954), of January 1953 in western Oregon and northwestern California (WSP 1320-D, 1959), and of December 1955 in California and adjacent States (WSP 1650, 1963) diverted the staff from normal or routine activities for long periods of time. The floods also resulted in extensive reconstruction of gaging stations and rescheduling of publication dates for streamflow records and special investigations.

The flood of December 1955 is worthy of special note. During the week preceding Christmas, northern and central California were subjected to the greatest flood in the area's history of recorded streamflow. The intense flood-producing storms covered an area of 100,000 square miles, more than 60 percent of the gross area of the State. On some streams, the peak discharges are believed to have been greater than the near-legendary floods of 1861–62 (WRD Bull., Aug. 10, 1956, p. 26).

Walter Hofmann, the coordinating area flood engineer, directed all the indirect measurement work. Some 290 slope-area surveys and determinations of flow over dams were made, of which 190 were in California and 100 in other States. District engineers from Pennsylvania to Hawaii, at the request of the Branch chief, sent experienced "slope-area" personnel to San Francisco to make up the survey parties. Some of the 20 men in the advance crew arrived on Christmas Day and were on their way to the field the next day. S.E. Rantz directed the survey work out of the Eureka office. Among the out-of-state engineers assigned were W.P. Somers (Salt Lake City, Utah); S.D. Breeding (Austin, Tex.); H.F. Matthai, J.M. Terry, and W.C. Vaudrey (Denver, Colo.); V.K. Berwick

(Helena, Mont.); E.D. Stenstavold (Pierre, S. Dak.); and M.A. Benson and Tate Dalrymple (Washington, D.C.).

The field parties, composed of out-of-state and resident engineers and technicians, worked a 7-day week for 2 months under the most miserable conditions. It rained on 68 of the 91 days from December 1 to February 29, and at Crescent City in the northwest corner of the State, a total of 73.90 inches of rain was measured. The men worked from 9 to 16 hours a day because there were notes and graphs to work up at night. There were rugged hills to climb, swift rivers to cross, and poison oak to avoid. The California District owes a sincere debt of gratitude for the work these men did to obtain the data on peak flows for the flood report. Although time and nature will cover the scars and highwater marks along the rivers, our records will always be available for future planning. And it could happen again!

GROUND WATER BRANCH

By Joseph F. Poland

The SW Branch of the Survey has cooperated with various California State agencies continuously since 1903 in stream-gaging activity. However, the GW Branch, after making several ground-water studies in cooperation with the State Department of Engineering in the decade ending in the early 1920's, conducted no further cooperative studies with the State until 1948.

J.F. Poland recalls attending a public meeting with Orange County cooperators about 1944 in company with Branch Chief O.E. Meinzer. Meinzer reported that Harold Conkling of the State had contacted him before the start of the San Gabriel investigation (about 1920) to ask for a cooperative ground-water study by the Geological Survey. Meinzer declined because no experienced people were available, so the State recruited and trained its own personnel. Meinzer told our Orange County audience that he had never turned down a cooperative investigation since then on the grounds of a lack of trained personnel.

State Cooperation Beginning in 1948

In 1947, the State Legislature directed the State Water Resources Board to make an investigation of the water resources of California. The investigation was conducted by personnel of the Division of Water Resources of the Department of Public Works. Plans called for presenting results in four bulletins covering water resources, water use and requirements, plans for development of water resources, and a summary report on "The California Water Plan." Faced with major studies to update resource appraisals, the State sought the aid of the GW Branch of the USGS in the study of ground-water basins. In March 1948, a cooperative agreement was made between the Survey and the Division of Water Resources, Department of Public Works, State of California (later the Department of Water Resources), that provided for an investigation of the ground-water resources of ground-water basins in California, with special reference to geologic features. The first activity of Survey personnel under the cooperative agreement was to investigate the geologic features and to estimate the total ground-water storage capacity of the near-surface, water-bearing deposits in the Sacramento Valley, an area of about 5,000 square miles. This study began in 1948 and was completed in 1951. A peg model of the Sacramento Valley, based on drillers' logs, was constructed to aid in recognition of hydrologic units and geologic features. Nine major lithologic types were identified and each was distinguished by a different color on the pegs. The peg model was very useful in subdividing the near-surface deposits into hydrologic units for making the estimates of ground-water storage capacity. The estimated storage capacity of the deposits, 20 to 200 feet below land surface, was 38 million acre-feet. The principal investigators and authors were F.H. Olmsted and G.H. Davis. Publication of the report as WSP 1497 (1961) was delayed until results of the Solano County investigation were available.

In 1950, investigations began in the Mendota-Huron area (on the west side of the San Joaquin Valley); in the Santa Rosa and Petaluma Valley areas of Sonoma County; and in the Napa and Sonoma Valleys. All of these studies were completed in 1955 but the WSP reports pertaining to them were published in 1957, 1958, and 1960, respectively. In the Mendota-Huron study, G.H. Davis was the principal investigator, and he was assisted by six men in the field work, an extensive well-canvass and water-level measurement program. This study was financed in part by USGS Central Valley funds and in part by the State cooperative program.

In the Santa Rosa-Petaluma area, G.T. Cardwell was the principal investigator under the immediate supervision of J.E. Upson. In the Napa-Sonoma area, Fred Kunkel was principal investigator; Upson, as immediate supervisor, made substantial contributions and so co-authored the report (WSP 1495, 1960).

Following the completion of the Sacramento Valley study in 1951, Branch personnel began a study in 1952 of ground-water conditions and storage capacity in the San Joaquin Valley, an area of about 10,000 square miles. The ground-water pumpage for irrigation was about 8 million acre-feet a year in 1952. The estimated ground-water storage capacity between depths of 10 to 200 feet below land surface was 93 million acre-feet. The principal investigators and authors were G.H. Davis, J.H. Green,

F.H. Olmsted, and D.W. Brown. The report, completed in 1956, was published as WSP 1469 in 1959.

Also in 1952, R.E. Evenson began a reconnaissance study of the geology and ground-water features of the Eureka area, under the supervision of A.R. Leonard. The report was completed in 1955.

In 1953, in connection with its appraisal of the upper Klamath River basin in California, the State asked the GW Branch to make reconnaissance studies of the geology and ground-water features of three ground-water basins—Scott, Shasta, and Butte Valleys. Seymour Mack completed the report on Scott Valley in 1955, which was published in 1958 as WSP 1462, and also the report on Shasta Valley in 1957, published in 1960 as WSP 1484. P.R. Wood completed the study in Butte Valley in 1957, and the report was published in 1960 as WSP 1491. All three studies were under the immediate supervision of A.R. Leonard until his transfer in 1955.

In 1955, as part of the cooperative program with the State, Branch personnel began a study on the use of ground-water reservoirs for storage of surface waters in the San Joaquin Valley (the cooperative program with the State began in 1948). It is highly significant that by 1957, 10 useful reports of very good quality had been completed, 8 of them by authors making their first ground-water study. All 10 were published subsequently as Water-Supply Papers.

Cooperation with Counties

Cooperation with Los Angeles County and nine local cities ended in 1948 upon completion of the report on the geology, hydrology, and chemical character of ground waters in the Torrance-Santa Monica area. Cooperation with Orange County agencies continued from 1949 through 1952 with A.A. Garrett reporting yearly on the status of saltwater contamination in the coastal part of Orange County.

In Santa Barbara County in 1947, 5 years of work culminated in completing and making available to the county and the public four reports on the ground and surface-water resources of the county. The principal authors were J.E. Upson, G.F. Worts, and H.G. Thomasson. As a principal objective, the ground-water reports estimated the total amount of water perennially available in the several ground-water basins. As a first step, the Bureau of Reclamation plan for development of all available waters in the county called for construction of Cachuma Dam on the Santa Ynez River to impound floodwaters, as well as a transmountain tunnel to deliver the water to five south-coast communities, of which Santa Barbara was the largest. In 1949, in response to this development, the county and the Bureau of Reclamation asked the Survey to make a more detailed appraisal of ground water in the Santa Ynez River basin which was needed for preparation of a long-term operating agreement between the Bureau of Reclamation and the county. This report by H.D. Wilson was completed in 1956.

Cooperation with San Bernardino County began in 1957 with the study of the Lower Chino basin area, an appraisal of ground-water outflow escaping into the Santa Ana River. Principal investigators and authors of the report completed in 1949 were A.A. Garrett and H.G. Thomasson. This was the first of several studies of underflow out of San Bernardino County basins. Work on the San Bernardino basin and Bunker Hill dike began in 1950 and was completed at the end of the decade. Results of the study are in a report by L.C. Butcher and A.A. Garrett. Reports on underflow out of two other areas were nearing completion in 1975; chief investigators were L.C. Butcher and W.L. Burnham.

Work for Other Federal Agencies

In 1948, the Bureau of Reclamation in Sacramento planned to construct a dam on Putah Creek in Solano County to capture wasted floodwaters so that they could be used for irrigation in the county. To provide basic data for planning and operation studies, Reclamation asked the Branch to make an estimate of both the total and the usable ground-water storage capacity within the depth range of 20 to 200 feet below land surface, and to determine where and how artificial recharge could be accomplished. About half the cost of the work was paid from Federal funds appropriated to the Survey, and half was from funds appropriated to the Bureau of Reclamation but earmarked by Congress to be used for work by the Survey. The studies, made chiefly by H.G. Thomasson and F.H. Olmsted, were completed in 1955 and published in 1960 as WSP 1464.

In 1950, new studies for military agencies began in southern California. The first, funded by the Navy, was a study of the water resources of the Camp Pendleton Marine Corps base at Oceanside. The second, funded by the Air Force, was an appraisal of water resources at Edwards Air Force Base near Muroc, with emphasis on source of supply and perennial yield. Both studies were continued to the end of the decade, chiefly under the immediate direction of G.F. Worts through 1955 and then under the direction of Fred Kunkel.

Other ground-water studies for the military during the decade included appraisals of water resources for Twenty-nine Palms Marine Corps Base, Ft. Mugu Naval Base in Ventura County, and Invokern Naval Base at China Lake. In all of these studies for the military, the information provided resulted in the development of adequate water

supplies. Principal collectors of essential ground-water data in the last half of the decade were L.C. Butcher, Fred Kunkel, F.S. Riley, and W.L. Burham.

Land Subsidence Studies

Continuing subsidence posed problems to the existing Friant-Kern and Delta-Mendota Canals and the proposed California Aqueduct. Therefore, the Commissioner of the Bureau of Reclamation held a joint conference in Washington in May 1954 with officials of the Geological Survey and the U.S. Coast and Geodetic Survey to make preliminary plans for a cooperative program to study the subsidence problem. As a result, in December 1954, an Interagency Committee on Land Subsidence in the San Joaquin Valley was established at Sacramento. The first major action of the Committee was the preparation of a proposed program of investigation. The GW Branch received $100,000 in the 1956–57 fiscal year for the program. Half the funding was from a new cooperative program with the State and half was from Federal program funds alloted for Mechanics of Aquifers research. Poland headed up the subsidence program. G.H. Davis and B.E. Lofgren were the senior staff members.

Organization and Senior Staff Assignments

J.F. Poland, who was designated district geologist in 1946, directed the ground-water program until 1956, when he became a research geologist in order to give his full attention to the research program in land subsidence. He was succeeded by G.F. Worts, Jr., who had been on the District staff since 1948. District headquarters was in Long Beach until 1948, when it moved to Sacramento with the beginning of a cooperative program with the State on the hydrogeology and storage capacities of ground-water basins. The January 1949 personnel listing shows a staff of eight at Sacramento with Worts and H.G. Thomasson, Jr., as senior staff members. The official personnel listing of July 1, 1957, soon after the end of the decade, showed Wort's principal assistant to be H.D. Wilson. G.H. Davis and B.E. Lofgren were on Poland's staff beginning with the studies of land subsidence in the San Joaquin Valley.

The Long Beach facility, a Subdistrict office subsequent to 1948, was from that time under the supervision of A.A. Garrett. In 1953, he was succeeded by Worts. In 1955, Worts returned to Sacramento as assistant district chief, leaving Fred Kunkel in charge for the balance of the decade. Anne G. Husted, who was a member of the staff at Long Beach at the beginning of the decade, continued her role as district clerk at Sacramento.

The Santa Barbara Subdistrict was under the direction of J.E. Upson II from 1943 until he moved to Sacramento in 1949 and to New York in 1952. He was succeeded by M.A. Warren who in turn was succeeded by H.D. Wilson. Wilson continued in charge until he left for Sacramento in October 1956 as assistant district chief. G.F. Worts, Jr., was Upson's principal assistant until the former transferred to Sacramento in 1948.

A field headquarters at Claremont was used during 1953–54. Another at Berkeley was staffed during 1954–56.

The total district staff grew from fewer than 10 persons in the first part of the decade to a maximum of about 40 in 1953, then declined to less than 30. Somewhat more than half of the staff was at District headquarters. The staff of the Long Beach Subdistrict was next in size, varying between 4 and 11 persons, with 3 to 6 persons usually attached to the Santa Barbara Subdistrict.

In 1953, T.W. Robinson, who had been in Carson City, Nev., conducting research on evapotranspiration and phreatophytes, moved to Menlo Park as staff engineer to conduct additional studies. In November 1956, H.E. Thomas, who had been staff geologist with headquarters at Salt Lake City, was appointed Branch area chief with headquarters at Menlo Park.

QUALITY OF WATER BRANCH

Prior to 1951, the QW Branch had no personnel in California. Analyses and other work was conducted by the regional laboratory staff in Salt Lake City, Utah. In that year, I.W. Walling, who had been in charge of the District office in Stillwater, Okla., established a District office and laboratory in space provided by the Division of Irrigation, University of California at Davis. The facility was used in the newly-begun cooperative water-quality program with the State. In 1952, the office and laboratory moved to space adjacent to that of the GW Branch in Sacramento and remained there during the balance of the decade. Walling resigned in 1956, and was succeeded by Eugene Brown. In July 1956, there were 23 on the District staff, slightly more than twice the number that were there in 1952. As of 1957, Brown's senior staff included R.P. Orth and D.E. Sloan.

In 1954, C.S. Howard, who had been regional chemist in charge of the regional laboratory in Salt Lake City, moved to Menlo Park as staff chemist to assist and guide in the formulation, coordination, and review of chemical-quality and sediment investigations in all or portions of 10 western States, plus Hawaii and Alaska. He remained in that position until March 1957, when he joined the newly-established Branch area headquarters staff for a few months until his retirement in July 1957.

One of the objectives of the study in the Mendota-Huron area by GW Branch personnel was to locate any zones of inferior chemical quality that might affect recharge potential. In 1951, samples were collected from 803 wells for chemical analysis. In cooperation with the State Division of Water Resources, QW Branch personnel made complete analyses of 45 samples and partial analyses of 758 samples. Most of the work of the QW Branch staff from 1951 into 1957 was on chemical-quality and sediment analysis in cooperation with the California Division of Water Resources. [*Author's note:* The final paragraph describing the investigational program was furnished, on invitation, by J.F. Poland. Howard, Walling, and Brown of the QW staff are deceased. Other senior staff members were not located.]

TECHNICAL COORDINATION BRANCH

H.V. Peterson, staff geologist in charge of the Survey's activities under the S&M program, had his headquarters in Los Angeles until 1951, when it moved to Salt Lake City. As of January 1948, Peterson had a staff of six, the senior member, K.R. Melin, having transferred to Billings, Mont., in October 1947. Melin was succeeded by C.F. Hains, who transferred to the SW Branch in San Francisco in March 1949. As of January 1950, three of the staff of five were at field headquarters in San Diego. The activity there was discontinued in 1950 or 1951.

In 1951, G.E. Harbeck, Jr., who had been in the Washington, D.C., office of the Branch, established a headquarters in San Diego with a staff of six persons where, as staff engineer, he assisted in the analysis of the Lake Hefner water-loss investigations. Harbeck transferred to Denver in 1952 and, by 1953, the San Diego headquarters was closed.

COLORADO

SURFACE WATER BRANCH

By Cavis B. Ham

The Denver District, which included both Colorado and Wyoming, underwent many changes during the 1947–57 decade: A change in leadership, an increasing awareness of interdisciplinary relations, an increase in senior personnel (from 2 persons to 10 in grades GS-11 and above), and a large increase in personnel who did not have engineering degrees. At the start of the decade, SW was the dominant Branch but, by 1957, it represented about half of the Division's effort in the two States. In 1947, as it had been since 1910, the District office was still the distribution office (and library) for free publications of the Survey, but this function was taken over by the Bureau's newly established Administrative Division in about 1950.

In 1947, District headquarters was located in the New Customshouse in downtown Denver. About this time, a surplus World War II Remington Arms plant a few miles west of the city became available to Federal agencies and was named Denver Federal Center. Assistant Director Nolan wanted all Survey activities in the Denver area "under one roof" and the Federal Center provided this opportunity. One large factory building was remodeled into office, laboratory, drafting, library, and equipment (shop) space. Remodeling work was so slow that SW personnel moved into an adjacent, partly-demolished, temporary wooden building in 1951, and remained there for 2 or 3 years until quarters in the permanent building were ready. However, that "one roof," even though large, was never enough to cover all of the activities of all of the Divisions.

The following statement covers the District's activities in Colorado. The Wyoming segment of the program, together with the field organization that conducted the activities and the agencies that gave cooperative support, is described under that State.

The major portion of the Colorado program was conducted in cooperation with the State Engineer and the Water Conservation Board as major cooperators, and with the Denver Board of Water Commissioners, the city of Colorado Springs, and the Arkansas River Compact Administration as minor participants. The many years of cooperation with the State Engineer was directed toward the operation of a network of hydrologically significant long-term gaging stations in connection with the administration of local water rights. The program with the Water Conservation Board dealt with the establishment and operation of short-term project stations, usually those needed for U.S. Bureau of Reclamation planning.

The only subordinate office in Colorado at the beginning of the decade was at Montrose, which was staffed with two professionals and two subprofessionals. It moved to Grand Junction in 1951, a location more convenient for supplies, communication, and interagency contacts. In 1949, a one-man office was established in Lamar to take care of the additional work required by the Arkansas River Compact between the States of Colorado and Kansas, as well as activities formerly conducted by the State. In 1952, a one-man headquarters was started in Durango for operation of stations in the San Juan basin, formerly handled out of Grand Junction and Montrose. Personnel of the Bureau of Reclamation project office and a Colorado Division of Irrigation engineer, also at this location, provided cooperative liaison.

In September 1951, a compilation unit was established in the District headquarters to review and assemble all Colorado and Wyoming streamflow records prior to

September 1950 as a part of the nationwide 1950 compilation reports (WSP's 1301 through 1319). The unit consisted of three senior engineers and several assistants, including a few college students who plotted hydrographs from 4 to 8 p.m. The unit completed its assignment in 1957.

Personnel

Robert Follansbee, who had been district engineer since 1912, continued in that position until July 1948 when F.M. Bell, formerly district chief for Georgia (1937–41) and Tennessee (1941–48), succeeded him. Follansbee had requested this change so he could complete his series of four volumes of the history of the Division. He retired in June 1949 and died in July 1952.

Follansbee had completed the first volume on a "time-available-from-other-duties" basis many years earlier, and he had hoped to finish the other three on the same basis. However, as less and less time from other duties became available and as the time for mandatory retirement approached, he realized he must devote his full time to writing and editing if he was to finish the project.

F.M. Bell continued to direct District activities until January 1957, when he was designated Branch area chief for the Rocky Mountain area under the 1956 reorganization of the Division. He was succeeded by J.M. Terry who had been assistant district engineer since August 1954. Terry had transferred to the District from the Chattanooga, Tenn., District in 1951 as a technical consultant for several special projects. He continued as district engineer until his death in November 1957.

J.H. Baily, who had joined the District in 1930 (previously chief hydrographer, State of Colorado), was office engineer at the beginning of the period and became assistant district engineer when that position was established in July 1948. He reached mandatory retirement age in July 1954, but within a year or two became a "reemployed annuitant" and worked almost full time in charge of analysis and computation of streamflow records for the rest of the decade. H.H. Odell began his Survey career in the District in 1935 and, except for his war service (1942–46), remained until he transferred to the Georgia District in September 1957. He was office engineer from July 1948 until he left. H.P. Eisenhuth had been in the District since his appointment in 1929 and was in charge of the Sheridan, Wyo., office at the start of the period. He remained there until it closed in February 1950. After a detail to Washington, D.C., Eisenhuth transferred to the District office. In September 1951, he joined the compilation unit and was in charge of it from April 1954 until the unit was dissolved (work completed) in 1957.

L.F. Hanks, who started his surface-water career in Denver in 1929 but transferred to the Nebraska District when it was formed in 1941, returned to the District early in 1949 to reactivate the Kemmerer, Wyo., office. He served there until his death in June 1949. G.N. Mesnier transferred to the District from Rolla, Mo., in April 1949. In addition to other duties, he supervised, for the Washington office, the classification of all stream-gaging stations in the Colorado River basin as either "primary" or "secondary." The work for the Colorado River basin was so successful that Mesnier was assigned the organization of a classification review for the entire country. He completed that review and then transferred to Washington, D.C., in August 1957. C.B. Ham had been in the District since his appointment in 1936 and remained throughout the period. He was in charge of the compilation unit from its inception until April 1954. In April 1957, he was assigned to a 6-month project on performance of current meters at Colorado State University in Ft. Collins.

W.C. Vaudrey, in charge of the Riverton, Wyo., office, came to District headquarters in 1952. He was with the newly formed compilation unit until the project neared completion in 1956 and was then appointed to head a new special reports unit. H.C. Beaber was in charge of the Montrose and Grand Junction offices until 1954 when he transferred to Juneau, Alaska. He had been in Montrose since his appointment in 1941 except for a period of war service from 1942–46. In 1951, he moved from Montrose to Grand Junction. E.J. Tripp transferred to the District from Santa Fe, N. Mex., in October 1954 to replace H.C. Beaber in Grand Junction. During 1955, Tripp's office personnel established 22 gaging stations in a single construction season. In April 1957, he and E.A. Hopper made the first District attempt by helicopter to reach and open high-altitude (about 9,000 feet) gaging stations before the snowmelt started; however, because of severe winds for four consecutive days, only two of the planned six stations were reached. In April 1957, Tripp transferred to the District office in Denver to become assistant district engineer. K.S. Essex, who had been in the District since 1944, remained until 1956 when he transferred to the equipment development laboratory in Columbus, Ohio. During his stay in Denver, Essex served as the District's part-time unofficial equipment specialist and safety engineer.

C.R. Sieber was appointed to the Montrose office in 1945 and moved to Grand Junction in 1951. Soon after that he resigned to take a non-Federal assignment in Afghanistan but, after a few years, returned to the Branch, this time in the New Mexico District. R.W. Moor had been in the District since 1942 and was in charge of the Douglas, Wyo., seasonal office in 1947. He was placed in charge of the Lamar, Colo., office when it was established in 1950 and remained there for the rest of the

period. A.N. DePaulo also had been in the District since 1942. He remained in Denver throughout the period and was in charge of summer construction crews much of the time. By the end of the period, he was in charge of field operations. E.B. Hodges transferred to the District from North Carolina in about 1952 and remained in the Denver office until he transferred to the reports section in Washington, D.C., in 1955. R.E. Whiteman was appointed about the time the Grand Junction office was established (1951) and remained there for the rest of the period. He succeeded E.J. Tripp as engineer-in-charge in 1957, having been office engineer for a few years before that.

R.J. Snipes, who transferred to Texas in 1950, returned to the District in 1953 and was assigned to the compilation unit. He became office engineer in September 1957, succeeding H.H. Odell. E.A. Hopper, who transferred to the SW Branch from the Bureau of Reclamation in 1946, remained in the Montrose, Grand Junction, and Durango offices throughout the period. Ms. Nellie L. Esterly was district clerk from 1927 until her retirement in 1955, although by that time her title should have been "fiscal officer" as District finances became more than a full-time responsibility. Ms. L.M. Larson Elliott was Esterly's assistant from 1935 or earlier until 1946, when she was assigned to a newly formed fiscal section.

GROUND WATER BRANCH

Condensed from documentation by S.W. Lohman and Thad McLaughlin

The Denver District included Colorado and Wyoming until June 1949, when a District office was established in Wyoming. Colorado District headquarters was in the New Customshouse until 1950, when it moved to the newly established Denver Federal Center. The headquarters staff, which was made up of about five persons in the late 1940's, varied between six and nine in the mid-1950's, and increased to about 15 as of July 1957. The first field office in Colorado opened at Ft. Morgan in April 1947 and was staffed by one person, except during investigations pertaining to the Missouri River basin project from 1948 to 1952, when as many as four persons were stationed there. A one-man field office was maintained at Monte Vista from 1948–53, one at Durango in 1955–56, and one at Towaoc in 1956–57.

S.W. Lohman was district geologist for the first part of the decade, having served in that position since August 1945 when the District was established. From 1945 to 1951, he represented the GW Branch at meetings of the Arkansas-White-Red Basins Interagency Committee. In 1951, Lohman was appointed staff geologist and as such was a consultant and advisor on scientific and technical aspects of ground-water investigations in nine States of the Rocky Mountain area. In November 1956, he became the first Branch area chief for the 12 States of the expanded Rocky Mountain Area under the 1956 Division reorganization plan. Lohman maintained his headquarters at the Denver Federal Center during his latter two assignments.

Thad McLaughlin succeeded Lohman as district geologist in 1951 and continued in that position until 1959, when he was appointed Branch area chief. He had previously been Lohman's principal assistant and had been on the District staff since 1945. W.J. Powell, another member of the staff, also joined the District in 1945 and remained until 1954, when he transferred to Tuscaloosa, Ala. W.D.E. Cardwell had joined the Survey and the District in 1950 and, except for about 18 months in charge of the Holyoke field headquarters staff, continued in Denver through the end of the decade. L.J. Bjorklund was in charge of the Ft. Morgan field office from its establishment in 1947 until 1952, when he moved to Torrington, Wyo. The Ft. Morgan program, greatly reduced, was handled by N.M. McNeill, a part-time employee, during the balance of the period. J.H. Irwin supervised the Durango and Towaoc offices. G.H. Chase, E.D. Jenkins, H.E. McGovern, R.O. Smith, P.T. Voegeli, and W.G. Weist served at District headquarters during the last part of the decade.

In 1954, the hydrologic laboratory moved from Lincoln, Nebr., to the Denver Federal Center and A.I. Johnson was placed in charge. The physical and hydrologic tests on rock and soil materials, formerly made for the Missouri River basin projects, now became a nationwide service to Branch personnel. In 1956, the laboratory staff established a stock of many types of equipment used in ground-water studies and began renting such (with operators when desired) to District offices of the Branch upon request. Johnson's principal assistant was I.S. McQueen who had come from the Idaho District in 1954. He transferred to the Denver staff of the TC Branch in 1956. The laboratory staff remained at three persons during 1955, but expanded to 12 by July 1, 1957, not including a field unit in Kentucky that was established in 1957.

The District program during the late 1940's and early 1950's was devoted largely to projects under the Missouri River basin (MRB) program. That program declined during the balance of the decade. The Federal-State program, which began in 1945, continued until 1952 when the $7,500 appropriated by the Colorado Legislature was vetoed by the Governor. The District finances were temporarily augmented by additional funds from G.H. Taylor, who was in charge of the ground-water studies for the MRB program, until cooperative funds were restored in 1953. A rapid expansion of the cooperative program began in the following year (1954), no doubt

aided by the severe drought of the early 1950's. The Colorado Water Control Board (CWCB) was the sole cooperator until 1956, when the Denver Water Board began its participation.

The major projects during the late 1940's and early 1950's included the following: Big Sandy Creek valley, in cooperation with the CWCB with McLaughlin as project chief (published as CWCB Bull. no. 1); South Platte valley, a MRB program study under the direction of L.J. Bjorklund (WSP 1378, 1958); San Luis valley, financed by the Bureau of Reclamation with W.J. Powell as project chief (WSP 1379, 1958); Baca County, in cooperation with CWCB with McLaughlin as project chief (WSP 1256, 1955); and Grand Junction artesian area by Lohman without benefit of formal financing (PP 451, 1965). Lohman also wrote a geologic history of the Colorado National Monument (published in black and white by the National History Association in 1965 with an expanded version in full color as USGS Bull. 1508 in 1981).

The principal studies made later in the decade and their financial support, project leaders, and publications included: Lower South Platte valley, MRBP funds, L.J. Bjorkland and R.F. Brown, WSP-1378; Frenchman Creek basin, MRBP funds, W.D.E. Cardwell and E.D. Jenkins, WSP-1577 (1963); Ute Mountain Indian Reservation, Ute tribal funds, J.H. Irwin, WSP 1576-G (1967); Denver metropolitan area, in cooperation with Denver Water Board and CWCB, G.H. Chase, project chief, CWCB Basic Data Report no. 15 and USGS Geol. Map I-731; Cache la Poudre valley, MRB funds, L.A. Hershy, WSP 1669-X (1964); and Fountain valley, CWCB funding, E.D. Jenkins, WSP 1583 (1964). Also published were a series of county investigations in cooperation with CWCB as follows: Prowers County, P.T. Voegeli, WSP 1772 (1965); Washington County, H.E. McGovern, WSP 1777 (1964); Yuma County, W.G. Weist, WSP 1539-J (1964); and Kit Carson County, G.H. Chase, CWCB Basic Data Report no. 10 and a USGS unnumbered Open-File Report.

All of the studies proved to be helpful to the local economy, saving money for the farmers and aiding well drillers and water users. The advice of District and project chiefs was increasingly sought because of their knowledge of Colorado's water problems. Lohman, for example, was called as *amicus curiae* at the Grand Junction District Court to help settle a dispute between artesian well owners. He was also called as a witness for the Corps of Engineers and later by the city of Denver in suits held in Denver and Castle Rock respectively.

Those serving on the District staff during the latter part of the decade and not identified above are likely listed in the directory as of January 1, 1956, in the appendices. Space limitations preclude an identification of all personnel.

QUALITY OF WATER BRANCH

By John D. Hem and Russell H. Langford

Responsibility for Branch programs in Colorado in 1947 was split between the Lincoln, Nebr., Regional office and the Albuquerque, N. Mex., District office. The Regional office had jurisdiction over the Missouri River drainage basin and the District office the Arkansas, Rio Grande, and Colorado basins. In 1948, the Salt Lake City, Utah, Regional QW office was established and took over the Colorado River basin activities. There were six daily chemical-quality sampling stations on the Colorado River and its tributaries in the State at that time, some having continuous records dating from the early 1930's. This program was federally funded.

Chemical quality of water leaving the State was monitored by daily sampling of the South Platte River at Julesburg, the Arkansas River at Fort Lyon, and the Rio Grande near Lobatos. These, too, were federally funded, mostly by transfer of money from the Bureau of Reclamation and the Corps of Engineers. The Rio Grande station, however, had been established about a year earlier, and at first it was a part of the New Mexico State Engineer-Albuquerque District co-op program. The Julesburg station was funded by the "Irrigation Network" program of the USGS.

Areal studies of water quality conducted for the Missouri River basin program and in cooperation with the Bureau of Reclamation on the Arkansas River through 1957 were coordinated with the Colorado GW and SW District offices by frequent informal contacts. Work financed by the Federal-State cooperative program was limited to analytical services and related consultation for areal ground-water studies.

The staff of the Lincoln office participated with their colleagues in the GW Branch in three studies of ground-water resources, and prepared sections of the published reports of these investigations on the chemical quality of the water. Included were the lower South Platte River valley (WSP 1378, H.A. Swenson, 1958); Frenchman Creek (WSP 1577, E.R. Jochens and R.A. Krieger, 1963); and parts of Weld, Logan, and Morgan Counties (HA-9, F.H. Rainwater, 1958). Also underway during the decade was a cooperative study of runoff and sediment transport in the Kiowa Creek basin of eastern Colorado. The study, financed by the U.S. Department of Agriculture, was conducted by personnel of the SW Branch, Colorado district, and the Lincoln QW Branch office. Results of the trap study were later summarized in two published reports by J.C. Mundorff (WSP's 1798-A in 1964 and 1798-D in 1968), which described the sediment transport of streams and the efficiency of reserviors in the basin.

The Branch's first installation dedicated solely to the conduct of research was designed and installed by staff of the Lincoln office in Building 25 of the Denver Federal Center in 1953. J.D. Hem, district chemist in Albuquerque, was put in charge of this facility and he transferred to Denver late in 1953. John B. Weeks had transferred from Washington, D.C., earlier in the year to begin setting up instruments. This laboratory and some related activities constituted what later might have been called a "thrust program," the main objective being to determine the naturally existing levels of radioactivity in the waters of the United States. Constituents determined included uranium and radium, and gross beta and gamma-emitting constituents. The gross beta and gamma-emitting constituents are almost entirely artificially produced by nuclear fission and fallout from weapons testing. Frank Barker, from AEC's Los Alamos Laboratory, joined the staff in 1954, and R.C. Scott, a geologist from the Boise, Idaho, GW District office conducted the geologic portion of the study. Scott transferred to Denver in about 1956.

The main emphasis in this study was on radioactivity in ground waters, especially those associated with aquifer systems that could be well characterized. This aspect of the work was summarized in Professional Paper 426 in 1962. Personnel of the QW installation were active in some of the local water-resources studies in Colorado. During 1954, in response to a request from officials of a Soil Conservation District in the South Platte valley just north of Denver, a reconnaissance of ground-water quality of that area was made by Hem and Weeks. Extensive pollution was revealed, mainly from sodium chloride, in shallow ground water on and downslope from the Rocky Mountain Arsenal, and a preliminary report submitted to the Corps of Engineers suggested that this condition had resulted from the disposal of chemical wastes in unlined ponds on the Arsenal property. Because the topic was sensitive, this report was not released by the Corps. The Corps did finance a more detailed study conducted during the ensuing 2 years by personnel of the Lincoln QW office, who prepared a definitive report tracing the path of the contamination in the subsurface until it discharged to the South Platte River downstream from the area. (This problem has continued to attract the attention of researchers and others to this day.) In addition to his other activities, Hem in 1956 and 1957 completed writing the first edition of Water-Supply Paper 1473 (Study and Interpretation of Chemical Characteristics of Natural Water) which was finally published in 1959.

A reorganization of Division activities brought F.C. Ames to Denver as QW Branch area chief for the Rocky Mountain area in 1957, and the Denver QW activity was broken up into several separate projects. The radioactivity studies were headed by Frank Barker, with principal aids W.A. Beetem and J.S. Wahlberg who studied ion-exchange processes. Hem began a study of the chemistry of iron in water, aided by E.P. Oborn and M.W. Skougstad. Pioneering applications of chemistry to ground-water system descriptions were made in this work.

TECHNICAL COORDINATION BRANCH

Condensed from documentation by G.E. Harbeck, Jr.

No Branch personnel were headquarterd in Colorado during the decade until 1952, when G.E. Harbeck, Jr., who had been in San Diego, Calif., was appointed staff engineer and joined other Survey personnel at the Denver Federal Center. Harbeck's assignment was to represent the Branch and particularly its research section in connection with water-loss investigations and in interbranch and Division-level research. Also in 1952, B.N. Rolfe, a soils scientist, was designated to represent the Branch Headquarters research section in connection with soils research. His field headquarters was on the Colorado A&M College campus in Ft. Collins. H.J. Koloseus, also at Ft. Collins from 1953 on, was a member of Harbeck's staff.

In 1954, H.V. Peterson, who had served as staff geologist at Salt Lake City, Utah, moved to the Denver Federal Center under an assignment as Branch representative for Denver area coordination. He directed a S&M program staff of seven persons. The senior staff members included R.C. Culler and N.J. King, who had been on the Salt Lake City staff, and also assistant chief K.R. Melin and R.F. Hadley.

In 1954, the facility headed by Harbeck was designated the Water Loss Research Facility but no change was made in its activities. Its staff increased to about eight persons as of January 1956, the senior members being R.E. Glover and G.E. Koberg. Its activity at Ft. Collins was handled by H.J. Koloseus, Rolfe having transferred to Denver in 1955.

Near the end of the decade, the activation of the Division reorganization plan of 1956 caused a considerable change in the Branch facilities in Denver. In February 1957, Peterson was designated Chief of the General Hydrology (changed from Technical Coordination) Branch for the newly created Rocky Mountain area and was succeeded by K.R. Melin.

INTERBRANCH ACTIVITIES

The WRD Council was effective in coordinating the participation of employees of each of the District and

equivalent offices in Colorado in joint studies, especially those requested and funded by other Federal agencies. J.D. Hem (written commun., 1982) recalls that this was not an easy task, partly because of the fragmentation of local responsibilities within the QW Branch. In 1953, the Council set up an administrative services section using key personnel who had been on the SW District staff. Ms. N.L. Esterly, who had transferred from the General Accounting Office to the SW District staff in 1926, was in charge of the new section until her retirement in 1955. She was succeeded by H.B. Boyden who had been with the Bureau of Reclamation. The section had a staff that varied from three to five persons.

CONNECTICUT

SURFACE WATER BRANCH

By Mendall P. Thomas

The District office, which was located in the Federal building in Hartford during the entire decade, maintained a staff of professional employees that increased in size from about four persons during the late 1940's to as many as seven in 1956. No other headquarters locations were used.

B.L. Bigwood, district engineer since the District was established in 1929, continued in that position through the end of the decade. M.P. Thomas, second in charge, began his Survey career in Hartford in 1936. T.J. Irza had come in 1940 and M.R. Stackpole in 1948. Stackpole transferred to the New Jersey District in 1953, but returned to Hartford in 1955. W.L. Isherwood, Jr., had transferred to the District in 1944, but left in 1948 to join the staff of the reports section in Washington, D.C. Others who were with the District for shorter periods during the latter half of the decade included D.J. Dinoia, J.J. Ligner, P.H. Bedrosian, and E.L. Burke. Ms. E.K. Flood was district clerk until 1952, when she was succeeded by Ms. C.R. Scamone.

Cooperation

The Federal-State cooperative program furnished the major portion of funds available. The principal cooperator was the State Water Commission. Also cooperating were the cities of Hartford and New Britain.

Special Projects

During the decade, the principal hydraulic research effort related to a flood-magnitude-and-frequency study for streams in Connecticut and closely bordering territory. The formula derived was expected to provide reliable estimates of flood probabilities for ungaged streams. The State Board of Supervision of Dams and the State Highway Department participated as cooperating agencies.

The basic flood-discharge records through 1953 and other hydrologic data used in this study were compiled largely under the continuing surface-water programs maintained in Connecticut. Annual flood discharges for 44 stream-gaging stations whose records ranged in length from 10 to 40 years were used, and a regional flood frequency based on the ratios of all floods to the mean annual flood at these locations was determined. For ungaged areas, the mean annual flood value was determined by use of a floodflow formula based on the topographic characteristics of the drainage area and basin slope. The results of this study were published as USGS Circular 365, "A Flood-Flow Formula for Connecticut" (Bigwood and Thomas, 1955).

Unusual Hydrologic Events

In Circular 365 (1955), the floods considered to be the highest were those of September 1938 in the eastern part of Connecticut. Hardly had the report been published, however, when, in 1955, two hurricanes caused record-breaking destructive floods. The first hurricane, Connie, occurred during August 13–15 following a rapidly declining runoff period. Heavy precipitation during the hurricane soaked the ground and brought many streams to medium-high stages. This set the stage for hurricane Dianne which brought torrential rains to northwestern and north-central Connecticut during August 18–24. The floods in streams draining the areas of heaviest precipitation were extraordinary. Peak discharges of 300 to 500 cubic feet per second per square mile occurred in drainage areas of about 250 square miles. Towns in the valleys of the Quinebaug, Naugatuck, and Farmington Rivers were heavily damaged. By the time the flood peak occurred, bridges were washed out and highways were under water, and stream-gaging personnel could not travel until flood levels subsided. Many engineers from other districts had to be recruited to work on station rehabilitation and to make indirect flood measurements at regular gaging stations and miscellaneous sites.

Unusually heavy rains occurred again during October 14–16, 1955, and produced very high floodflows in the State, particularly along the shore in the southwestern part where flows exceeded those of August. Outstanding discharges occurred in the lower Housatonic and Naugatuck Rivers and on the smaller coastal streams from Bridgeport southwestward. Heaviest damage occurred in Westport, Norwalk, Stamford, Greenwich, Ridgefield,

New Canaan, and other communities in the same area. Surface-water records for these three floods were included in Water-Supply Paper 1420, "Floods of August–October 1955, New England to North Carolina" (Bogart, 1960).

Excessive ground-water recharge caused markedly unseasonal rises in water tables. Monthly rises in excess of 1½ feet resulted in record-high levels for the season in most observation wells.

Connecticut had about 40 continuous and many partial-record gaging stations in 1947. Drainage areas ranged in size from 4.12 to 994 square miles, with the exception of the drainage area above the station on the Housatonic River at Stevenson, which was 1,545 square miles. One of the continuous gaging stations, the West Branch Farmington River at Riverton, was demolished during the great flood of August 1955 and was rebuilt at another site upstream. Another station on the Nepaug River near Nepaug was so severely damaged in 1955 that operation was not resumed until 1958. Stations at three other new sites were established during the decade on streams with small drainage areas. The August flood made it apparent that stations on small drainage areas were needed.

During 1947–57, all records were used for various water-use studies, but the emphasis was on flood-magnitude-frequency relationships. The magnitude of the floods of August and October 1955 were so spectacular that they created unusual interest.

GROUND WATER BRANCH

The Connecticut program was conducted by personnel assigned to an area office established at Middletown in October 1947. It continued under the jurisdiction of the Jamaica, N.Y., District headquarters through the end of the decade. Middletown was a one-person office until the mid-1950's; the staff gradually increased to about five employees by the end of the decade. R.V. Cushman, formerly of the Albany staff, established the office and continued in charge. A.D. Randall joined the staff in 1953 as did A.M. LaSala, Jr., who transferred from Rhode Island in 1956. The field office established at New Haven in 1945, when Ms. E.J. Lowry transferred there from Jamaica, was no longer active at the beginning of the decade. Lowry went on "when actually employed" status in November 1946 and resigned in 1949.

The general program was summarized (written commun., 1983) by J.E. Upson, District chief, Jamaica: "Investigations in certain metropolitan and industrial areas in Connecticut were continued and completed in the early part of the decade, particularly ground-water resources of the Waterbury, Bristol-New Britain, and Naugatuck areas. With the establishment of the field office in Middletown at the end of 1946, the emphasis shifted to mapping of ground-water conditions in broad areas, such as the entire northern part of the Connecticut River valley, and the Framington River valley to the west. This reflected the broader interest of the State Water Resources Commission with which the cooperation was then carried on *vis-a-vis* with the municipalities which had been faced with local problems related to the war effort of the 1940's. In solving the problems, greater emphasis began to be placed on geologic mapping which led to the quadrangle mapping of geology and water resources of later years. Reports on the wartime studies were completed and published by 1955; reports of the broader-area investigations became available in the late 1950's and 1960's. Cushman did the former, and Cushman, LaSala and Randall did the latter."

Cushman records (career notes, 1947–57) that, among other specific projects, he conducted an investigation of the ground-water resources of the "extensive tobacco-growing area of the Connecticut River lowland in north-central Connecticut." He also prepared a brief report and a statewide map of the ground-water resources for use by the State Development Commission to locate industrial areas.

QUALITY OF WATER BRANCH

By Felix H. Pauszek

Some water-quality studies were made in Connecticut by the U.S. Geological Survey before 1947 as part of a national program to evaluate water resources of the United States. In 1934, a report was published (WSP 658) on the "Industrial Utility of Public Water Supplies in the United States, 1932". A follow-up report was published in 1954 in two parts (WSP's 1299 and 1300). A report on the salinity of the Connecticut River, a study conducted by C.S. Howard during 1934–39, was published (Bulletin S1) by the Connecticut Water Commission.

In 1955, a water-quality program was started by Branch personnel in cooperation with the Connecticut Water Resources Commission. The program was under the direction of the Albany, N.Y., District staff. The objective of the program was to obtain data on the chemical and physical characteristics of water resources in Connecticut for use in the promotion of industrial activity, in development of public water-supply sources, and in meeting the needs of those in agricultural research.

Fieldwork consisted of the collection of water samples throughout the State on a daily basis in some river basins and monthly or intermittently in others. Samples were analyzed in the District laboratory in Albany. Temperature measurements also were made at the time of sample

collection. Data on sediment transport had been obtained for the Scantic River at Broad Brook since 1952.

The results of the studies made during 1955–58 were published as Bulletin No. 1 by the Connecticut Water Resources Commission under authorship of F.H. Pauszek. The report included the Housatonic, Connecticut, Qwinnipiac, and Thames River basins.

The chemical and physical quality of surface waters in Connecticut ranged from good to poor, reflecting the influence of diverse geology, streamflow, and, in some areas, pollution. In the Housatonic River, drainage from limestone areas made the water moderately hard. In the Connecticut River basin, sandstone, shale, and crystalline rock contributed small amounts of mineral matter. Water from the Quinnipiac River basin also contained moderate concentrations of mineral matter. Generally, water from the Thames River was as good or better than water in other river basins throughout the State. The Naugatuck River showed effects of industrial pollution.

The program could not have been started and continued without the interest and support of W.S. Wise, Director, Connecticut Water Resources Commission. Records of discharge were furnished by B.L. Bigwood, district engineer, SW Branch, Hartford. Geologic information and water temperature data were furnished by R.V. Cushman, geologist-in-charge, GW Branch, Middletown. Chemical analyses were made by personnel of the QW Branch, Albany, N.Y.: W.A. Beetem, C.D. Albert, J.A. Shaughnessy, D. Tanski, and A.L. Mattingly. The program was under the immediate supervision of F.H. Pauszek, district chemist, in Albany.

Delaware

SURFACE WATER BRANCH

By Floyd F. LeFever and Arthur E. Hulme

Ten gaging stations and eight rain gages were in operation at the beginning of the decade. Two stations were added in 1951, one was added in 1952, and two were added in 1957. (One station was discontinued in 1956.) The State Highway Department (W.A. McWilliams, Chief Engineer) was the principal cooperator prior to 1956, when the State Geological Survey took over part of the statewide program. New Castle County Soil Conservation District and the city of Newark cooperated with funds for stations within their respective areas of interest. The Corps of Engineers assisted with funds for four stations. Brandywine Valley Association funds aided in the collection of records.

The program was under the College Park, Md., District throughout the decade. Personnel from District headquarters conducted the field and office work until February 1950, when the Dover, Del., Subdistrict was established. V.R. Bennion was district engineer until he was replaced in September 1949 by F.F. LeFever who, in turn, was replaced in April 1957 by J.W. Odell. (See personnel under Maryland for further details.)

The Dover office, first located at 313 South State Street, was established by LeFever assisted by J.A. Bettendorf, who was temporarily in charge until A.E. Hulme arrived in April 1950 by transfer from the Cambridge Subdistrict of the Lincoln, Nebr., District. Hulme remained in charge of the office until his transfer in June 1957 to the Texas District. Bettendorf served as his assistant until he transferred in January 1955 to the Wisconsin District. The staff was augmented generally by one or two additional engineers or aides. The office moved in 1953 to 604 Fairview Avenue. Ms. Dorothy Jones served as clerk-typist up to that time. She was succeeded by Mrs. M.S. Martin for the remainder of the decade.

In addition to the Delaware programs, the Dover office handled the field and office work of the nine Maryland Eastern Shore counties. Located in Delaware's capital city, the office personnel were able to provide better service to cooperating State agencies, as well as to service adequately the predominately small-area gaging stations and to expedite the program expansions east of Chesapeake Bay. Delaware ranked sixth among all states in station density per 1,000 square miles (table 1, pamphlet, ''Report of Committee on Stream Gaging Program''). Studies in connection with that report show the median drainage area size for gaging stations in both Delaware and the Maryland Eastern Shore counties (data from 1954 WSP) to be only slightly more than 20 square miles as compared with the U.S. median of 400 square miles (table 1, pamphlet, ''Report of Committee on Stream Gaging Program''). Four Delaware stations had less than 10 square miles of drainage area; the smallest, only 2.19 square miles.

GROUND WATER BRANCH

By Durward H. Boggess

Investigations in Delaware early in the decade were limited to problems of saltwater intrusion in the coastal area at Lewes and at Rehoboth Beach. This work was conducted from the Trenton, N.J., office under the direction of H.C. Barksdale. In 1950, an office opened in Newark, Del., under the direction of L.B. Haigler. The Newark office was under the supervision of W.C. Rasmussen of the project office at Salisbury, Md. Investigations at that time included a general statewide

study of the ground-water resources, including the establishment and operation of a network of about 16 observation wells. More intensive studies in New Castle County were begun during this period. Cooperating agencies included the Delaware Geological Survey (DGS) and the Delaware State Highway Department.

In 1952, D.H. Boggess transferred to the Newark office, which at that time was located in the basement of the post office on Main Street. Work continued in New Castle County, particularly in the Newark area. The Newark office also served as a base of operations for investigations in neighboring Cecil County, Md.

In 1954, I.W. Marine transferred to the Newark office, followed in 1955 by W.C. Rasmussen after he closed the Salisbury project office. Because of the enlarged staff, the Newark office relocated to 2070 Main Street, where it remained through the end of the decade. During this same period, a field office was established in Georgetown, Del., when R.A. Wilkens and O.J. Coskery were assigned to conduct an investigation of Sussex County. Mrs. C.R. Groot joined the Newark office on a part-time basis, making a total staff of five persons.

Funding during the decade for investigations in Delaware ranged from about $20,000 for the Federal-State program in 1951 to an estimated $35,000 in 1957. Most of the State funding was channeled through the DGS. Some additional funding was provided under the Federal program and from other Federal agencies.

By the end of the decade, a series of investigative reports were published, including "A Description of the Geology and Ground-water Resources of the Newark Area" by J.J. Groot, W.C. Rasmussen, and A.E. Hulme (DGS Bull. 2); "Geology and Ground-water Resources of Delaware" by I.W. Marine and W.C. Rasmussen (DGS Bull. 4); and the "Water Resources of Northern Delaware" by W.C. Rasmussen, J.J. Groot, and others (DGS Bull. 6). Annual records of fluctuations of ground-water levels in 56 observation wells were published near the end of the decade.

QUALITY OF WATER BRANCH

By Norman H. Beamer

The Branch staff conducted its limited program in the State through the Pennsylvania District. No Branch personnel were headquartered in the State during the decade.

The DGS, under J.J. Groot as director, cooperated in the establishment of a number of streamflow stations at which daily records of chemical water quality were collected. Two of the sites had specific conductance recorders. Periodic sampling was underway at three other locations. None of the stations was reported as existing in 1951. A compilation of such data for northern Delaware was prepared by E.F. McCarren and published as DGS Bulletin No. 6. Studies of the tidal reaches of the Delaware River, in which DGS was a cooperator, are described under the Pennsylvania program.

A study of the fluvial sediments transported by and the chemical quality of the water in Brandywine Creek was continued and enlarged during the decade. A sediment station, established on the creek at Wilmington in December 1946, continued in operation during the entire period. It was the first cooperative sediment station east of the Mississippi River. Chemical-quality data were collected from 1947 to 1950, in 1952 and 1953, and from 1956 on. Cooperation had been initiated with branch chief S.K. Love by Clayton Hoff, Director, Brandywine Valley Conservation Association. Hoff was a leader in soil conservation practices and proved to be a stimulating cooperative official.

The availability of an actual record of fluvial sediments made the Brandywine Valley an attractive area for WRD scientists L.B. Leopold, W.B. Langbein, M.G. Wolman and others to test theories concerning soil loss from various land-use practices. (As of 1984, the Brandywine Valley was still in use by the Philadelphia Academy of Sciences and universities as a study area.)

The District participated in an interbranch study of the ground-water resources along the Chesapeake and Delaware Canal during which N.H. Beamer and David McCartney further developed field techniques for the use of a newly developed battery-operated specific conductance continuous recorder (see New Jersey statement). The investigation was funded by the Philadelphia district of the Corps of Engineers whose engineers were studying the possible effects on the adjacent ground-water resources if the canal were widened and deepened.

DISTRICT OF COLUMBIA

SURFACE WATER BRANCH

By Floyd F. LeFever

A gaging station in operation on Rock Creek at Sherrill Drive in Rock Creek Park was funded by the National Park Service. Four tide gages on the Potomac River, including a recording gage with telemark at the foot of Wisconsin Avenue in Georgetown, were operated in cooperation with the District of Columbia Government. Extreme flood discharges passing the gaging station on the Potomac River 2 miles upstream from the Washington, D.C., boundary were measured at the 14th Street Bridge because of poor measuring conditions at Chain Bridge, the usual measuring site. Measured

discharges at 14th Street were adjusted for change in storage by using the tide-gage readings. A station was established on Rock Creek at Lyons Mill in Washington, D.C., on August 18, 1892, but the record was of short duration. Surface-water work in the District of Columbia was under the jurisdiction of the Maryland District.

GROUND WATER BRANCH

The only known activity of the Branch during the decade was an investigation by P.M. Johnston of the geology and ground-water resources of a 436-square-mile rectangular area centered around the District of Columbia. Johnston, on the headquarters staff of the Branch chief, accomplished the field work in the early and mid-1950's with report preparation likely near completion by 1957. The latter was published as WSP 1776 in 1964. A section on chemical quality of water was by D.E. Weaver and Leonard Siu. The work was financed by allotments of Federal program funds.

FLORIDA

SURFACE WATER BRANCH

By Archibald O. Patterson

In 1947, Florida was, in many ways, still a primitive State. Jacksonville was the business hub, Miami Beach glittered in gaudy splendor, Palm Beach was the posh winter residence for the unusually well-to-do, Tampa was a busy port, and there were less well-known spots of business activity elsewhere in the State. Over most of Florida, however, scrub cattle were free to roam the roads at will, and citrus plantings were confined to areas with soils that at that time were thought to be the only ones suitable for productive growth. Vegetable growing in southern Florida, and to a lesser degree in other parts of the State, was of considerable importance. There was phosphate mining in Polk County, and pine trees for the paper industry grew across much of northern Florida. Florida's population in 1947 was 2,540,000 (from Bureau of Economic and Business Research, College of Business Administration, University of Florida, Gainesville).

By 1957, cattle were behind fences and in improved and irrigated pastures. Stock had been upgraded, and agricultural experts had learned that oranges, grapefruit, and other citrus trees, if properly fertilized and watered, would grow profitably in sand. Groves had been planted on many acres where only scrub and turkey oaks had grown earlier, vegetable growing areas had been greatly expanded, and the pulp and paper industry had increased measurably. Citrus-concentrate plants had about replaced all of the old-style canning plants, and frozen orange juice became popular with most consumers. Permanent residents now numbered 4,169,000—a 64-percent increase in 10 years (from Bureau of Economic and Business Research, College of Business Administration, University of Florida, Gainesville). The population growth had begun what later was to approach almost asymptotic proportions. Superimposed on all of this was the rapidly growing tourist trade, as increasing numbers of winter and summer visitors came to enjoy Florida's beautiful beaches and fish-filled lakes and streams.

All of this rapid change, especially the increase in irrigated acres, imposed greatly increased demands on the water supply. Coupled with record floods and droughts that occurred in the decade, it was necessary that the Survey make an increased effort to gather water data as fast and as extensively as possible for use by planners of the water-management projects that were to follow these extreme hydrologic events.

The flood that struck southeastern Florida in fall 1947 was of record proportions. For a time, water covered most of the lower peninsula and, with one voice, the people demanded flood protection. The Army Corps of Engineers responded by preparing "A Comprehensive Report on Central and Southern Florida for Flood Control and Other Purposes," proposing a project estimated to cost $208,135,000 of which local interests were to furnish $29,152,000 and to provide all lands, easements, and rights-of-way necessary for construction and operation.

This project was endorsed by the State of Florida. To represent the State, the Division of Water Survey and Research was formed under the Florida Board of Conservation, and the Central and Southern Florida Flood Control District (CSFFCD) was created. CSFFCD was the first of five major districts to be created to manage water throughout the State.

A.O. Patterson, who replaced G.E. Ferguson as district engineer in August 1947, arrived only a short time before the 1947 south Florida flood. In response to D.B. Bogart's appeal for additional field parties to collect data, Patterson emptied the District and Subdistrict offices of their personnel and rushed them to help. Bogart, who headed the Miami Subdistrict office, managed to get small but much needed cooperative funds from a number of the smaller towns along the southeast coast. These funds were matched by Federal co-op funds, but no direct financial or field help was furnished by the Washington, D.C., office. An amazing amount of data were collected and plotted on maps of the flooded areas, and although no report was published, the data were greatly welcomed by the Corps of Engineers in the Jacksonville office to plan the central and southern Florida project.

In spring 1948, floods struck northern Florida, setting records that have yet to be exceeded in the 1980's. As often happens, unusual hydrologic events trigger action. In this case, the result was the initiation of a cooperative program to aid the State Road Department (SRD) in the design of bridge heights, locations, and openings. Tate Dalrymple and Patterson met with Scott Reynolds and Arthur West of the SRD and reached agreement on a program that was to be of great benefit. R.W. Pride transferred to Ocala to head up this work. Before Pride arrived, G.B. Harrell, Jr., and Patterson made one site evaluation at the request of the SRD, but the work started in a comprehensive way a bit later. A number of site studies and suggestions were made for the SRD to use as it saw fit and a flood frequency report was published.

About the same time, Patterson convinced Col. A.G. Matthews, chief engineer of the Division of Water Survey and Research, that there were streams in northern Florida where data were needed and a cooperative agreement was reached that resulted in the construction and operation of a number of new gaging stations for previously ungaged areas. Soon thereafter, through cooperation with the Corps of Engineers and the CSFFCD, a large network of stage- and discharge-data collection sites was planned and the stations were installed for the southern Florida project. Some of the stage-data stations were built in the most remote parts of the Everglades. A construction crew from Ocala, headed by M.S. Gardner, faced many difficulties in conducting their work mainly because of the difficulty of access. Bogart left Miami before much of this new work got underway, and the south Florida program was headed by J.H. Milliken, who was followed by J.H. Hartwell. Hartwell developed a deflection meter that was of great value in gaging the flow and its direction in the flat-sloped canals of the area. The CSFFCD extended as far north as Orlando, so much of the field work was done by the Sebring field office staff under Richard C. Heath and R.L. Taylor, and by crews from the Ocala office. W.R. Murphy, Jr., was placed in charge of the Sebring office in 1957.

Severe drought years occurred in Florida in 1954 and 1955, which prompted the 1955 Florida Legislature to enact Chapter 29748 that created a Water Resources Study Commission composed of two Senators, two Representatives, and three Members-at-large appointed by the Governor. The Governor designated one of his appointees, Byron E. Herlong, to serve as chairman, and the commission became widely known as the Herlong Commission. Patterson served as chairman of the Committee on Surface Water, which prepared the Surface Water section in the "Florida Water Resources" report to the Governor and to the 1957 legislature from the Herlong Commission. The drought continued through most of 1956 and this situation, together with the recommendations of the Commission, resulted in a new water resources law being passed by the 1957 legislature. This was a beginning of legislation directed toward wise management of the water resources of the State.

In 1954, the city of Jacksonville found itself in a situation regarding sewage disposal that required a continuous record of the ebb and flow of the St. Johns River that flowed through the city. At the request of E.T. Owens (city of Jacksonville), personnel of the Ocala office established a discharge station on the Main Street Bridge and, after a considerable amount of current-meter work, the resulting analysis was made by W.E. Kenner with an assist from Patterson, thereby furnishing the city with the data needed to alleviate its problem. These were the first continuous records at this site.

During the decade, cooperation between the Branches greatly improved, and several interdisciplinary studies were pursued, especially following the establishment of a QW Branch laboratory in Ocala and the unification of the ground-water offices into one District in Florida. Among these interbranch efforts were water resource studies of Alachua, Bradford, Clay, and Union Counties; St. Johns, Putnam, and Flagler Counties; Escambia and Santa Rosa Counties; Brevard County; and Hillsborough County. District personnel continued their work on the hydrology of lakes and springs, and were chosen by the Corps of Engineers to establish the first stage stations in Everglades National Park. The SW Branch also was recognized as the official drainage-divide authority in Florida and it's personnel defined the five major watershed areas that became the five State Water Management Districts several years later.

Funds for the District in 1947 totaled, from all sources, some $98,000 and reached about $235,000 in 1957, an increase of 140 percent. Personnel had doubled and rising costs, or inflation, were already being felt.

In 1947, the District headquarters was in the old Post Office building in Ocala where it had been since the District was established by D.S. Wallace in 1930. These quarters were controlled by the District Court for the northern district of Florida, and the U.S. District Judge at Jacksonville, with his entourage, had the Survey people move out into the halls for 2 weeks each year while court was in session in Ocala.

In 1950, the Corps of Engineers at Jacksonville offered to lend the Survey one of its buildings at Camp Roosevelt, 3 miles south of Ocala, for office space in return for the Survey's keeping an eye on the property. Storage and shop buildings were also offered, and on October 10 of that year, the SW Branch District office moved to these new quarters. Enough space was left over for the QW laboratory that came later. These buildings had housed the Corps of Engineers project personnel who were in charge of the Cross-Florida Canal work during the early

1930's. SW and QW offices remained at Camp Roosevelt until May 1961, when the two branches moved into space designed for them in a new Federal building in Ocala, which was an ideal location for the Florida program.

GROUND WATER BRANCH

By Hilton H. Cooper and Nevin D. Hoy

Until 1955, the Branch maintained two independent districts in Florida. One, with headquarters in Tallahassee, had been established in 1939 to conduct investigations in cooperation with the Florida Geological Survey. The other, with headquarters in Miami, had been established in that same year to begin the intensive interbranch investigations of the encroachment of saltwater into the municipal ground-water supplies in southeastern Florida.

The Tallahassee office shared quarters with the Florida Geological Survey in the basement of what was then known as the old dining hall of the Florida State College for Women (which became Florida State University in 1948). From 1948 to 1951, the office occupied rented space at 308 North Monroe Street, after which it moved back to the Florida State University campus into the basement of the new dining hall. Then, in 1957, it moved into the new Herman Gunter building on the campus at the corner of Tennessee and Woodward Streets. The staff of the Tallahassee District increased from five members in the late 1940's to about nine in 1955. H.H. Cooper continued as district engineer until 1952, when he became staff engineer to serve as advisor on ground-water programs in Mississippi, Alabama, Florida, Georgia, South Carolina, and Tennessee. Ralph C. Heath was acting chief of the Tallahassee District from 1952 to 1955.

The South Florida District office in Miami was located in the Aviation building on NW 27th Avenue until 1949, when it moved to Dinner Key on Bayshore Drive into office space owned by the city of Miami, one of the Survey's principal cooperators. The office remained at this location through the end of the period. G.G. Parker served as district geologist until 1949, when he transferred to Hanford, Wash., to work on an Atomic Energy Commission project. He was succeeded by N.D. Hoy who served as district geologist until 1955, when District functions were transferred to Tallahassee and Miami became an Area Office. The Miami staff increased from five at the start of the period to about 10 at the end.

When the two districts were combined late in 1954, M.I. Rorabough was named chief of the new District, and N.D. Hoy moved to Tallahassee to assume duties as assistant chief. The Miami office then became an Area Office under Howard Klein, geologist-in-charge. Near the end of the year, Heath moved to Albany, N.Y., to become district geologist of the New York District. By 1956, the Florida Staff consisted of 27 members: 17 engineers and geologists, 6 subprofessionals, and 4 clerical persons. In addition to the area office in Miami, field headquarters were being maintained at Daytona Beach, Lakeland, Saint Augustine, and Sanford. Names and positions of the Florida ground-water personnel at that time are given in Appendix B.

State, county, and municipal entities cooperating on ground-water programs during the decade included the Florida Geological Survey (FGS); the CSFFCD; the counties of Columbia, Dade, Hillsborough, Manatee, Pinellas, Polk, and Seminole; and the cities of Boca Raton, Dania, Daytona Beach, Delray Beach, Fort Lauderdale, Fort Myers, Fort Pierce, Lake Worth, Miami, Miami Beach, Naples, New Smyrna Beach, Pensacola, Pompano Beach, Port Orange, and Sanford. A few of these cooperators continued their programs throughout the decade; others did so for shorter periods. The total cooperative funds (both sides, Federal and State) for the ground-water program were about $95,000 in 1947 and increased to $210,000 in 1957.

Intensive ground-water studies continued in Dade County, with an emphasis on the potential effects of proposed water-control plans on the water resources, particularly for public water supplies. Research studies on saltwater encroachment, a continuing problem, were initiated. Descriptive studies of the ground-water resources of Lee and Charlotte Counties were completed. These studies outlined the areal extent, thickness, and quality of water of the aquifers, with an emphasis on the western parts of the counties.

In 1947, extensive and severe flooding occurred in central and southern Florida, and the Corps of Engineers initiated a comprehensive flood control plan consisting of the construction of hundreds of miles of canals and water control structures. As stated earlier, the CSFFCD was created by the State Legislature to operate and maintain the system after the Corps completed construction, and an extensive cooperative water-resources investigative program was begun with this new State agency. After the first few years, it readily became apparent that, for future development and protection of the water resources, the emphasis needed to be changed from flood control to water management, and emphasis rapidly evolved in this direction. In a large part, because of these cooperative studies, subsequent water-resources agencies created by the legislature were implemented as "Water Management Districts." The entire area of the State is now covered by five such districts.

Cooperative investigations were begun in the cities of Boca Raton, Delray Beach, Fort Lauderdale, Lake Worth, Naples, and Stuart. These studies were initiated primarily to evaluate the potential of the ground-water resources

as a source for the rapidly expanding municipal water-supply systems. Comprehensive investigations of the geology and ground-water resources of Highlands and Indian River Counties were completed.

An interesting study was made in the Lake Placid area to determine the feasibility of using past and current ground-water levels in predicting lake levels 3 to 4 months into the future in connection with the operation of water-control structures. In cooperation with the U.S. Air Force, Branch personnel also investigated the availability of ground-water supplies at several bases in the British West Indies. These bases were used for testing by NASA in their Mercury and Apollo programs.

During the period, annual ground-water level data reports were published. In addition, about 60 reports were published by the FGS, the U.S. Geological Survey, and other water-resource-oriented organizations.

QUALITY OF WATER BRANCH

Condensed from documentation by J.W. Crooks

By the beginning of the decade, the QW program in southern Florida had been greatly reduced in magnitude from that of the early 1940's as described by Follansbee in Volume IV, p. 378. For the rest of the State, the small cooperative program with the FGS to determine the quality of spring water was being reduced as data became adequate for the forthcoming report on Florida's springs.

No personnel of the Branch were headquartered in Florida during the decade until 1952. J.W. Crooks, however, had had earlier experience in the Florida program. A recent graduate in chemistry of the University of Miami, Crooks accepted a position in 1948 as a scientific aid with the local SW Subdistrict staff until he could find employment as a chemist. He helped establish a network of water-quality sampling stations on Everglades canals under a cooperative program with the newly created Central and South Florida Water Management District (CSFWMD). Although the salinity of the water was measured in the field office, the samples were sent to the Branch laboratory in Washington, D.C., for complete chemical analysis. In March 1951, Crooks transferred to the QW Branch as a chemist with headquarters in Washington, D.C. He was assigned to the D.C. laboratory to analyze water samples from the Everglades canals, from ground-water observation wells and springs in cooperation with the FGS, and from water used at several military bases, such as Patrick Air Force Base, the later site of the NASA base at Cape Canaveral.

With assurance of continuing cooperative programs with the CSFWMD and the FGS, as well as with Dade County and the city of Miami, the Branch established a laboratory in Florida that was also to have responsibility for investigations that might materialize in Georgia and Alabama. Eugene Brown, who was enrolled as a graduate student in the Department of Chemistry, University of Florida at Gainesville, was hired on a part-time basis in October 1951 with headquarters in Gainesville. He moved to Ocala as chemist-in-charge in June 1952. Earlier in the year, Crooks had begun ordering materials for the new laboratory and sending them to A.O. Patterson, district engineer, who had offered to make laboratory space available in the buildings loaned for his use by the Corps of Engineers at Camp Roosevelt. Patterson also had his construction staff build or install the needed partitions, laboratory benches, and other facilities. Crooks moved to Ocala in November 1952.

Crooks recalls that the initial annual budget for the program was only about $19,000, enough to support him and Brown, but inadequate for additional assistance. Thus, at the end of a typical day's work in the lab, with soiled beakers and other glassware piled high, there came the decision as to "who would wash and who would rinse." This chore eventually fell to J.B. Gore, a local high school student, who was hired in 1953. Gore became a physical science aid in 1954 and remained on the staff beyond the end of the decade. Among the items of field equipment loaned by Branch headquarters in Washington were a flame photometer and the first salinity meter designed for field use by the Branch and described by Follansbee (v. IV, p. 378). The number of samples analyzed grew with time, many collected by field personnel of the SW Branch. Crooks would normally fly to Miami every 2 weeks, use SW vehicles to collect canal and stream-water samples, and transport them back to Ocala for analyses.

C.G. Menke arrived from Nebraska in 1953 and remained a member of the staff beyond the end of the decade. Mrs. M.E. Wesley, a clerk typist with the local SW District, extended her assistance to the QW staff as well, and in 1954 transferred as its staff secretary. Mrs. Helen MacLean of the SW staff also provided bookkeeping services for the laboratory. L.C. Fincher, chemist, and L.M. Teboe, physical science aid, joined the staff in 1955. As of the end of the decade, the staff totaled about 12 persons.

GEORGIA

SURFACE WATER BRANCH

Condensed from documentation by A.N. Cameron

The District began the decade with a staff of about 12 people, 10 located at the headquarters in the Lowe's Grand

Theater building in Atlanta, and two conducting research at the Emory University field office at Newton. The Emory facility was deactivated in 1948, but the research work continued at a reduced scale in Albany. The Albany office was closed and the Tifton area office established in 1950. District headquarters moved to the new Peachtree-Seventh building in Atlanta in 1951, and then, in order to gain more space, to 805 Peachtree Street, N.E., in 1956. The Toccoa field headquarters was opened in 1955. By the end of the decade, the staff had increased about threefold and operations were directed out of Atlanta, Tifton, and Toccoa.

M.T. Thomson was district engineer during the entire period. A.A. Fischback served as assistant district engineer from 1947 to 1949, when he transferred to West Virginia as district engineer. He was succeeded by A.C. Lendo who served until 1953, when he transferred to Trenton, N.J. Lendo was replaced by A.N. Cameron who served for the rest of the decade.

The Administrative Unit, headed by Ms. A.L. Cain and assisted by Mrs. E.W. Hollowell, served personnel of all Branches stationed in Georgia for most of the decade. A subdistrict was created at Atlanta in 1956 to handle stream-gaging operations in northern Georgia. G.T. Condrey was placed in charge.

Like many others, the Georgia District came out of World War II with a backlog of several years of uncomputed streamflow records. By the end of the 1950 water year, with Lendo spearheading the effort, most of the backlog had been erased.

Cooperation

Total program funds increased about 30 percent during the decade. At the end of the period, the Federal-State cooperative program was supporting about 70 percent of the District activity. The principal cooperator was the Department of Mines, Mining, and Geology (DMMG) (Captain Garland Peyton, Director), who contributed about 75 percent of the State offerings. The other State cooperation was with the Highway Department and Emory University Field Station. The Corps of Engineers and the Soil Conservation Service provided funds for station operation, maintenance, and trap-efficiency studies through the transfer and repay programs. The Corps also furnished records for review and publication by the Survey. Other cooperation was with Federal Power Commission licensees, Crisp County, and the Georgia Power Company.

Activities

The number of daily-discharge stations increased very little during the decade (from 92 to 95). The emphasis was toward more accurate and timely records. About 15 nonrecording gages were replaced with continuous water-stage recorders. The demands for more hydrologic data were great, and the District chose the most efficient and economical methods of securing it. Gaps in the network were filled by adding about 80 flood crest-stage gages, and many miscellaneous sites were established where flows were computed by referencing base-flow measurements to nearby continuous-record stations. Several slope stations were added to improve discharge records at existing stations. The accuracy of flood discharges was improved by calibration of dams on the Chattahoochee River.

Early in the period, E.L. Hendricks completed the study of the hydrology of malarial ponds (WSP 1110-E, 1952) in cooperation with M.H. Goodwin, Jr., of the Emory University Field Station. This was one of the first hydrologic research projects for the SW Branch. Hendricks transferred to Baton Rouge, La., in 1948.

In the first year of the decade, several events occurred that significantly affected future program direction. Thomson, with the help of Tate Dalrymple, negotiated a program with the State Highway Department that included a balanced field laboratory program of flood-frequency analysis, bridge-site reports, and crest-gage networks, implementing ideas by M.R. Williams, C.M. Bunch, and R.W. Carter, and by C.E. Kindsvater of Georgia Tech. Carter transferred to Atlanta in 1948 and immediately enhanced the technical efforts of the District by taking a lead role in this new program of hydrologic studies. The work resulted in several important publications, including the first publication by the Survey of a flood-frequency report (Circular 100, 1951).

Carter began also to study the effects of multiple bridge piers on the passage of floodwaters. He was assisted primarily by Bunch, who directed the December 1948 flood measurements at a multiple span bridge on the Altamaha River at Doctortown. The following year, an outdoor laboratory channel was used at Prattville, Ala., with the assistance of the Alabama District staff. The results of these and later studies made at the Georgia Tech laboratory were published. To get more available flood data from the regular gaging-station network, many crest-stage gages were established at strategic locations, which included sites of possible future highway bridges revealed in confidence by the State Highway Department.

The logistics of operating this expanded network (many gage sites were more than 200 miles from District headquarters) led to the establishment of an area office at Tifton in 1950. The Tifton office, with Cameron placed in charge and with about one-half of the stream-gaging territory under its jurisdiction, virtually assured the success of the crest-stage gaging programs. The Tifton staff developed the ability to process the data for publication on a current

basis, resulting not only in better records but also at a 10- to 20-percent savings in effort. This procedure was continued during the following 2 decades.

Two other achievements of the Tifton office staff are noteworthy. One, a study of the variation in flow of Radium Springs near Albany, led to the establishment of research activity in the Yellow River area in northern Georgia that resulted in a better understanding of the areal variation in low flows. The project was designed by Thomson and Lendo, under the guidance of W.L. Langbein (TC Branch, Washington, D.C.). The other was a demonstration of how to measure both the water level and outflow of farm ponds using a single recorder. The technique was later used in northeast Georgia and in other States. H.A. Carlson succeeded Cameron when the latter transferred to Atlanta in 1953.

Laboratory research in stream hydraulics, which began when Kindsvater of Georgia Tech provided flumes and other backup support for District staff to calibrate low-flow measurement weirs in 1947, continued and led to other projects. These included the calibration of dams as measuring devices and the effects of spur dikes and other types of channel construction on stream discharge. R.W. Carter was placed in charge of this research for the Branch in 1952. Among the resulting reports, two published in 1956 and 1958 in the Journal, American Society of Civil Engineers, were judged by ASCE to be the best papers for the year. Carter and Kindsvater received ASCE's Norman Medal on two separate occasions. Carter, who transferred to Branch Headquarters as its research chief in 1955, was succeeded by H.J. Tracy.

The District's close cooperation with Georgia Tech extended beyond the use of its hydraulic research facilities. Many of its engineering students worked as members of the District staff in alternate quarters and, upon graduation, chose a career with the Survey. Included in this group are M.A. Lopez and F.A. Kilpatrick. Members of the District staff also took courses at Georgia Tech.

The 1954 drought was probably the most significant hydrologic event during the decade. Low-flow studies were begun a year earlier in the Yellow River basin, a rural area subject to urbanization. Minimum flows were measured at more than 1,000 sites, many ungaged, during the drought. Thomson and R.F. Carter reported the findings in DMMG's Circular no. 17, released in January 1955, and also through weekly (later monthly) releases. The statistical and areal techniques used were developed by Carter. Although there were a number of droughts in the early 1950's, the 1954 event caused a major agricultural disaster. Municipalities and industry also suffered. At times, the city of Griffin used the entire flow of the Flint River. Low-flow measurements showed a recurrence interval of 50 to 60 years or more.

Water problems resulting from the 1954 drought stirred interest by State officials and legislators in more adequate water laws. DMMG cooperator Peyton supported Thomson in his position that such a legal base should recognize not only surface water, but also ground water and the quality aspects of both. This position wisely prevailed despite the efforts of regional and national experts to limit the scope. The chairman of the Water Law Revision Committee asked Peyton to prepare a report on Georgia's water resources, and he, in turn, requested that it be a cooperative venture under Thomson's supervision. Thomson organized and conducted preparation of the report as an interbranch project, which became DMMG's Bulletin 65 published in 1956. This joint endeavor paved the way for a broadened program and the establishment of the GW and QW programs.

Several severe floods required special effort during the decade. Measurements revealed that the April 1948 flood in southern Georgia exceeded the 100-year recurrence interval in some areas. In November of that year, the maximum discharge of the Ocmulgee River at Macon was the highest in a long period of record. In November 1949, the Chattahoochee River carried a "50-year" flood, and the Etowah River at Rome had the highest discharge since 1920. The Cartecay River flooded in March 1951, and the Nottely River a year later. Early in 1955, a field headquarters was opened at Toccoa with Lopez in charge to facilitate a pilot watershed project in northeastern Georgia for the Soil Conservation Service (SCS).

District participation in nationwide projects by the Branch included compilation of records through 1950 (J.W. Rabon, local project chief), and regional flood frequency reports (under leadership of Bunch). Also, gaging-station network review (Rabon also headed this study), and preparation of flood hydrographs for small streams for SCS (Hendricks, assisted by L.E. Newcomb and others).

The District's program was strengthened substantially by the leadership qualities of Thomson, who was skilled in the selection of personnel and allowed them latitude in their work. He was "Mr. Water" to many people in Georgia who appreciated his efforts to express hydrology in simple terms and to provide decisionmakers with current water data in readily understandable formats.

In 1947, Thomson had publicly described the advantages to the city of Atlanta of the reregulation of the Chattahoochee River. The resulting million-dollar project saved the city an estimated $700,000 annually and permitted a tripling of the generating capacity of a steam-electric plant. Also about 1947, Thomson and fellow District chief, M.R. Williams (Alabama), organized the SE District engineers group to gain better representation with the Branch and Division chiefs and to improve interdistrict liaison. Thomson authored several extracurricular reports during the decade. All were well received by the Georgia water-resources community.

GROUND WATER BRANCH

Condensed from documentation by S.M. Herrick

S.M. Herrick was in charge of the Georgia program from 1947 to fall 1955, when J.T. Callahan assumed the duties of this office. After leaving the District, Herrick served all southeastern districts concerned with stratigraphic problems in the coastal plains east of the Mississippi embayment. District headquarters from 1947 to 1949 was at the State Capitol building in Atlanta. By 1952, office space had been acquired across the street from the Capitol at 11 Hunter Street. At the same site in 1954, the new State Agricultural building was completed, which afforded adequate office space for the rest of the decade.

Conducted in cooperation with the Department of Mines and Geology, the program was intended to include investigation of the geology and ground-water resources of Georgia. In order to accomplish this, in addition to the geologist-in-charge, the staff consisted of one professional geologist, a clerk-typist, and one or two subprofessionals. During the period, several changes in personnel occurred. In 1949, H.E. LeGrand, Herrick's principal assistant, was put in charge of the North Carolina program, creating a vacancy filled the same year by the acquisition of geologist G.H. Chase. In 1952, an exchange of personnel was arranged whereby Chase transferred to the California District and geologist R.L. Wait moved to Georgia from California later that year. J.W. Stewart joined the District in 1956 by transfer from Idaho.

A project office was maintained at Savannah during 1955–57 with M.A. Warren as engineer-in-charge. In spring 1956, he died tragically, creating a vacancy which was filled later that year by the transfer of H.B. Counts, an engineer from the Arkansas District. The reason for maintaining the Savannah suboffice was the necessity for a much-needed study of coastal aquifers in Georgia, particularly in the Savannah and Brunswick areas, where ground-water withdrawals for industrial and municipal supply were heavy. During 1955–57, in addition to the engineer-in-charge, the staff included one professional, a clerk-typist, and several technical assistants for the program. In March 1957, Wait transferred from District headquarters to Albany where he opened a field headquarters.

The magnitude of the cooperative program increased greatly during the decade. In fiscal year 1947, the USGS matched the Georgia Department of Mines and Geology's contribution of $6,000 (Follansbee, v. IV). Program documents for fiscal year 1958 show a total of $105,000 from both sides. Funds from other sources, relatively minor in amount, included monies from the Federal program.

Specific ground-water investigations, for which reports were published or manuscripts prepared for public information, are listed in the first edition (1962) of WRD's Water-Resources Investigations in Georgia. Those listings, which indicate accomplishments during the decade, are described below.

The geology and ground-water resources of the Atlanta area were described by Herrick and LeGrand in the Georgia Department of Mines, Mining, and Geology (DMMG) Bulletin 55 in 1949. A similar study for central-east Georgia by LeGrand and A.S. Furcron (DMMG staff) was issued in 1956 (DMMG Bull. 64). The chloride levels in water of observation wells in the Savannah area were reported by Herrick and Chase in 1952 (USGS Open-File Report). This followed a 1947 Open-File Report on earlier findings. In 1955, Herrick and Wait reported on the results of test drilling in the Georgia and South Carolina segments of the Savannah area (USGS Open-File Report). In the same year, Warren summarized the artesian water resources of the Savannah area and outlined the additional studies needed (USGS Open-File Report).

The staff also collaborated with personnel of the other Branches in reporting on Georgia's water resources. The Atlanta metropolitan area water resources were described in USGS Circular 198 by R.W. Carter and Herrick in 1951. The availability and use of water in Georgia was described by M.T. Thomson, Herrick, and E. Brown in 1956 (DMMG Circular 65).

Near the end of the decade (1958 values), the SW staff was collecting water-level data at 405 observation wells, of which 31 had recording gages. Well discharge was obtained periodically at 18 sites and water quality and temperature at 48 wells.

QUALITY OF WATER BRANCH

Branch activities in Georgia were under the jurisdiction of the Raleigh, N.C., District until 1953, when they were placed under the newly created Florida District with headquarters in Ocala. F.H. Pauszek and G.A. Billingsley, successive district chemists, Raleigh, recall that the program through 1953 was confined largely to making water analyses as requested by the GW Branch and at specified military installations for the Armed Forces. A program report by W.W. Hastings in 1951 reveals that arrangements had been made to collect and analyze water samples from 33 sites in Georgia for use in preparation of WSP 1299.

Cooperation with the Department of Mines, Mining, and Geology that began in 1940 and continued on a reduced scale to 1947 (Follansbee, v. IV) apparently did not extend into the decade. W.L. Lamar, district chemist,

Raleigh, until 1948, recalls (oral commun., 1985) that the cooperator wanted an increased program and a QW laboratory within Georgia, but that sufficient cooperative support by the State did not materialize and the program was discontinued. A program analysis for fiscal year 1958 indicates that the cooperative activity with Mines, Mining, and Geology did resume and, as of that year, included the collection of periodic chemical-quality data at 125 locations and fluvial-sediment data at 25 stream locations, and participation in several projects having GW Branch leadership. A study was made also of the efficiency of sediment-retention structures on the North Fork Broad River for the U.S. Soil Conservation Service.

Territory of Hawaii
(also Guam and Trust Territory)

SURFACE WATER BRANCH

Condensed from documentation by H.H. Hudson and M.D. Hale

District headquarters remained in the Federal building in Honolulu during the entire decade. The headquarters staff ranged in number from 10 to nearly 20, plus several Territorial employees. A field headquarters was maintained on the Island of Maui, with two persons assigned during most of the time. In 1952, the earlier headquarters on Kauai was reactivated with one hydrographer assigned. A third field establishment was officially opened at Agana on the Island of Guam in 1955, where surface-water studies were conducted in cooperation with the Island Government.

M.H. Carson, who had been in the District since 1919 and district engineer since 1928, continued in that capacity until his retirement in 1954. He had a dual role in that he was also, by virtue of his office, chief hydrographer for the Territory of Hawaii. In a sense, he was his own principal cooperator. An outdoorsman by nature, Carson preferred the rigorous fieldwork over office routines and made numerous trips to read the rain gage on Mt. Waialeale on the Island of Kauai. His retirement years were spent largely in San Jose, Calif., where he joined hiking clubs and continued to enjoy the outdoors.

Carson was succeeded by H.S. Leak who had joined the District in 1938 and was Carson's principal assistant. H.H. Hudson, who transferred to the District from New Mexico in 1954, served as assistant district engineer through the balance of the decade. W.E. Armstrong, who had initially joined the staff in 1928, continued to serve as office engineer until he transferred to the Boston District in 1950. G.T. Hirashima, who began his career with the District in 1929, succeeded Armstrong. George Yamanaga, who joined the District in 1943, remained through the decade, except during 1952–54 when he was on the staff at Branch headquarters in Washington, D.C.

Kenzo Tacumi was in charge of the program on the Island of Maui. Don Richardson, who joined the headquarters staff in 1952 by transfer from Portland, Ore., reestablished the field headquarters on Kauai in 1952 and was succeeded there by C.H. Tate in 1955, when Richardson joined the Branch Chief's staff in Washington, D.C. The field headquarters on Guam, activated by the part-time employment of J.S. Quinata in 1951, was later under Santos Valenciano, who transferred from District headquarters in 1955. Other professional-level staff members serving at District headquarters for extended periods during the decade included R.K. Chun (resigned in 1955), M.D. Hale (1952–54), and W.C. Peterson (1949–55). R.H. Monroe, who transferred to the District from the Arizona District in 1950, left in 1952 for the North Dakota District following the death of his wife and the need to be near relatives who could care for his young children. Hisashi Kanno, Hajime Matsuura, and C.A. Wyse joined the District's subprofessional staff in the late 1940's and continued through the decade. H.W. Beardin, a retired auditor who preferred the outdoors to office assignments, began his new career with the District in the late 1930's. He died of a heart attack in 1948 while nearing the Survey rain gage on the summit of Mt. Waialeale on the Island of Kauai. John Kaheaku, a Territorial employee assigned to the District in the 1920's, was placed on Survey roles as an engineering aid in 1954. Ms. M.A. Davidson, a Territorial employee assigned to the District since perhaps the 1920's and who was earlier responsible for most of the administrative and secretarial activities, served as a full- or part-time engineering technician during all or at least the latter part of the decade. The district clerk position was held by Ms. I.L. Schooler, who transferred from the Denver District, from 1952 to 1955 when she retired because of illness. She was succeeded by Ms. A.S. Horner, who had joined the District in 1953.

Although the Commissioner of Public Lands continued as the sole financial cooperator at the Territorial level during the decade, the Board of Agriculture and Forestry, Maui County, the city of Hilo, and numerous sugar plantations and affiliated irrigation and water companies provided various types of assistance in the operation of gaging stations. Employees of these agencies also made numerous discharge measurements to meet specific data needs, but the results apparently remained unpublished.

The number of gaging stations operated by the District staff on each of the islands at the beginning and at the end of the decade as shown in the annual data reports (WSP's) were Kauai, 32 to 31; Oahu, 22 to 37; Molokai, 9 to 11; Maui, 41 to 42; and Hawaii, 14 to 16. This gave a network growth of about 15 percent, largely on Oahu, where additional runoff data were needed for public

water-supply studies. In 1951, Carson reported having a stream (and diversion channel) network in which daily discharge was determined at 128 locations and periodic measurements were made at an additional 35 points. Roughly one-third of the stations were on diversion channels bringing stream waters to irrigated areas, especially on Kauai and Maui. Periodic stream-temperature measurements were made, most being on streams on the Island of Hawaii. The District staff continued to make periodic measurements of current water levels in a network of artesian-type observation wells in Honolulu and vicinity, an activity that had started perhaps as early as the 1920's.

As of 1951, rainfall was being recorded daily at three locations and measured periodically at 18 other sites. One of the latter was at the summit of Mt. Waialeale on Kauai where a special high-capacity rain gage had been read annually since about 1920. Carson reported that a recording rain gage was installed at the same site on May 15, 1949 (WRD Bulletin, February 1950, p. 2–6). The recorder, the 600-inch capacity holding tank, and the 6- by 8-foot shelter in which they were installed, were flown to the site by helicopter. (Hudson recalls that, on his arrival at the site, the helicopter pilot chose not to land because the clouds began to close in. Instead, his assistant tossed all of the equipment out the door. Nothing was damaged, but when the 80 or so pounds of lead clock weights hit the soft muck that mantles much of Waialeale, they literally disappeared and were recovered only after much probing and digging.) The rainfall record for Mt. Waialeale, averaging about 450 inches annually, is said to make the immediate area "the wettest spot on Earth."

The laboratory modeling of stream-gaging sites as a means of determining high-water ratings, begun in 1938 and strongly supported by Carson, was continued until near the end of the decade. By that time, numerous stations, including all of those on Guam, had been modeled under the direction of model specialist W.C. Peterson. A critical analysis made later showed several weaknesses in the ability to simulate actual on-site conditions in the models, including those of channel roughness, viscosity of the water, and the question of how far to continue the model downstream. Hudson began an effort to verify the model ratings by use of direct and indirect measurements. The results were so unsuccessful that modeling was dropped in 1956 or 1957 in favor of a rather intensive effort to build cableways and to train the stream-gaging staff in indirect-measurement techniques. The brief duration of floodflow, the inaccessability of stations, and unique channel-roughness coefficients left much to be desired in obtaining accurate high-water records. At least one flood report was prepared and published during the decade, that of the flood of August 1950 by R.K. Chun (WSP 1137-C, 1952).

The rigors and dangers encountered by stream gagers in Hawaii are legendary. Noteworthy is an account by Hale of a routine visit to a gaging station inside an Oahu mountain. The stream gager, once cleared by the health authorities who required a stool sample every 6 months, drove into the fenced Honolulu water-supply preserve, backpacked all equipment for nearly an hour up the mountain trail to the tunnel mouth, and by lantern light continued another quarter to half a mile into the mountain to the gaging station. After changing the chart, he then stripped (privacy was assured), lowered himself into the swiftly flowing, chest-deep, icy-cold water, strung a 20-foot tag line across the excavated channel, and measured the flow which had infiltrated from lava tubes upstream and which was considered a source of water for the city. Hale recalls that, despite the dangers, it was considered to be a one-man task and in those years no one questioned it. Another example of unique measures undertaken to gain access to remote stations, this on the windward coast of Molokai, is documented by Hale in the November 10, 1954, issue of the WRD Bulletin.

GROUND WATER BRANCH

Condensed from documentation by P.E. Ward

District personnel were headquartered in the Federal building in Honolulu during the decade with the exception of those who were stationed at an area office established on Guam in 1951. The number of personnel at District headquarters averaged about two persons plus one or two Territorial technical assistants. The Guam office had a staff of two or three professional personnel who also conducted studies in the U.S. Pacific Trust Territories.

G.A. McDonald was district geologist until 1948 when he resigned. He was succeeded by D.A. Davis. K.S. Takasaki entered on duty in 1949, and J.F. Mink in 1956. F.N. Visher arrived in September 1956 by transfer from the Nevada District. J.W. Brookhart, who transferred from the Maryland District in 1951, was in charge of the Guam Area Office until 1954, when he became geologist-in-charge of the North Dakota program. He was succeeded by E.W. Bishop who had come from the Florida District in 1954. Bishop resigned in 1955 and P.E. Ward, who was on the Indiana District staff, was selected to replace him. Theodore Arnow transferred to Guam from the Mineola, N.Y., District in 1951 and remained until 1954, when he joined the staff of the Texas District. V.C. Santos was also a member of the staff from 1956.

The program in Hawaii was conducted primarily in cooperation with the Territorial Division of Hydrography. Davis reported (program document, 1951) that as of that date, the following types of water data were being

collected periodically at the number of locations indicated: well discharge (2); lake or pond level (5); well water level or artesian pressure (33); chemical quality of reservoirs, lakes, or ponds (5); and chemical quality of wells (33). Daily tide stage was measured at one location. A 1958 report shortly after the end of the decade showed an expansion of the data network. Daily ground-water levels were collected at 15 locations and periodic ground-water levels at 38 locations. Well discharge was measured periodically at 215 sites, chemical quality at 30 sites, and precipitation at 16 sites. Numerous reports on ground-water resources are listed in the 1977 edition of "Water-Resources Investigations in Hawaii and Other Pacific Areas" that may have been based on field and office work during the decade.

P.E. Ward recalls (written commun., 1984) that the program in Guam and the U.S. Pacific Trust Territories during the latter part of the decade had four components or objectives: (1) to produce an overall assessment of the water resources of Guam in cooperation with the Government of Guam (USGS Professional Paper 403-H (1966) by Ward, S.H. Hoffard, and Davis); (2) to assist officials of the Trust Territories in developing and managing fresh water supplies for villages (work was done on Yap, Ponape, Truk, Angaur, Saipan, Rota, and other islands); (3) to assist the U.S. Navy and the U.S. Air Force on Guam in developing and managing their water supplies; and (4) to install and maintain a water-monitoring network. A program report submitted in 1958 showed that daily water-level records were being collected in wells on Guam. Periodic measurements of the following types were also made at the number of sites indicated parenthetically: water level in wells (2); well discharges (20); chemical quality of well water (15); well-water temperatures (10); water quality of springs (3); and water temperature of springs (2). No water records were reported for the other locations.

IDAHO

SURFACE WATER BRANCH

By Wayne I. Travis

The SW Branch continued to maintain two District offices in Idaho during the decade, one at Boise whose staff conducted normal District activities, and another at Idaho Falls that was established in 1919 for the collection of streamflow records and administration of water decrees for the use of storage and natural flow in the upper Snake River (Follansbee, v. IV, p. 175).

The Boise District headquarters, located in the Federal building at Eighth and Bannock Streets until 1957 when it moved to 914 Jefferson Street, maintained a staff that varied in size from about 15 at the beginning, to as many as 23 employees in 1952, to about 20 in 1957. T.R. Newell was district engineer and W.I. Travis the assistant district engineer during the entire 1947–57 period. Senior staff members at the beginning included C.C. Fisk (part-time); W.H. Krabler (who transferred to the Alaska District in 1948); T.O. Miller (who transferred to the California District in 1954); and C.A. Thomas and J.R. Spofford, who remained through the end of the decade. In the closing years, J.E. Cummans, A.L. Larson, C.L. Lawrence, and G.E. Lokke were among the key staff members.

Ms. E.H. Haugse, who served as district clerk and had joined the District in 1928 when C.G. Paulsen was district engineer, died in July 1947. Ms. D.C. Randall was district clerk for all but the first part of the decade.

The field residency, maintained at Bonner's Ferry to handle the stream gaging in the Kootenai River basin, was staffed by detailees from the Boise headquarters. W.H. Krabler was stationed there in 1947, T.O. Miller from 1948 to 1951, and S.C. Cordes in 1952. The office quarters were retained for the remainder of the period, but a full-time resident was not stationed at Bonners Ferry.

The Idaho Falls District had remarkable stability both as to location and staff. The office remained at 204 Federal building. Lynn Crandall, district engineer, together with hydraulic engineer H.C. Eagle and clerk-stenographer (later, engineering aid) Ms. Charlotte Elg, comprised the staff, and they remained throughout the decade.

Cooperation, State and Municipal

During the decade, the principal State support for the cooperative program of stream gaging and related studies continued to be supplied through Idaho's Department of Reclamation. The contribution of this State agency was $26,250 in 1947, of which $18,500 was distributed to the Boise District and $7,750 to the Idaho Falls District (Follansbee, v. IV, p. 64). Division of funds between the two districts was based primarily on the number of cooperative gaging stations in each District program. The State funding during the decade increased very little. Increases were based largely on an "increased cost-of-doing-business" basis and the cooperative program remained rather static. Activities of the Idaho Falls District relating to water-distribution responsibilities were supported fully by the State of Idaho and Water District 36 outside of the cooperative program. It should be noted that the above figures of State funding do not include work in the Bear River basin in southeastern Idaho, which was under the jurisdiction of the Logan project office in Utah.

For a number of years, there was an increasing awareness in the Boise District that funding for the cooperative

stream-gaging network was not keeping pace with increasing costs. The backlog of computations was increasing in the Boise District (the Idaho Falls District was not similarly troubled), thus delaying publication of data. In the 1949–50 biennium, in consultation with the State reclamation engineer, the cooperative network was reviewed and a start was made to reduce the number of stations to bring the workload more in line with funding.

Other Federal Agency Support

Substantial support for the collection of streamflow records was continued by the Corps of Engineers, the Bureau of Reclamation, and the Department of State. The Federal Power Commission provided funds derived from its permittees and licensees to cover costs of streamflow records pertinent to investigation or operation of water-power projects.

The Boise District continued the investigation schedules on the Kootenai River, in conjunction with the corresponding agencies of the Canadian Government, to furnish the information needed by the U.S. Department of State and the International Joint Commission. The commission used the streamflow records, Kootenai Lake storage data, ground-water level observations in lands above Kootenai Lake, and special studies of the U.S. and Canadian technical agencies (together with recommendations of the Kootenai Lake Board of Control) for a number of purposes. The information provided a base for authorizing storage levels in Kootenai Lake, for diking activity upstream from the lake, and for other considerations. The USGS participation was supervised by the Water Utilization Branch, Washington, D.C., and was authorized and funded by the Department of State. The district engineer of the Boise District, T.R. Newell, served as a member of the International Kootenai Lake Board of Control throughout the decade.

The Boise and Idaho Falls District staffs participated in a study to determine the depletion of runoff in the Columbia River and its tributaries caused by irrigation practices. This study was initiated at the request of the Columbia River Board of Engineers, and participation by the Idaho WRD personnel was nearing an end at the close of 1948.

An upsurge in ground-water development gave rise to the Thousand Springs gaging project. The purpose was to monitor the depletion of springflow to the Snake River as a result of ground-water pumping. This project started in 1949 with reconnaissance and preliminary planning funded by the U.S. Bureau of Reclamation, the Idaho Department of Reclamation, and the USGS. Record collection started in 1950 as a Federal project.

Minor funding for record collection or data reporting was provided at times by the Fish and Wildlife Service, the Bonneville Power Administration, and the Soil Conservation Service. Funding for the hydrometric work at the National Reactor Testing Station near Idaho Falls and the Idaho part of the federal stream-gaging network is discussed elsewhere in this report.

General Conditions

Although State agencies maintained a continuing interest in surface-water problems, the emphasis turned to ground-water sources for irrigation development. This interest was given special impetus by the proposal for large-scale withdrawal of ground water from the Snake River Plain aquifer in connection with the North Side Minidoka project of the U.S. Bureau of Reclamation and for private development.

Perhaps the most noteworthy hydrologic events demanding the attention of District personnel during the period were the floods that caused record or near-record peak discharges and volumes of runoff at many sites. Information is published in reports "Floods of May–June 1948 in Columbia River basin" (WSP 1080, 1949) and "Floods of December 1955–January 1956 in Far Western States" (USGS Circular 380, 1956). The winter 1955–56 flood was followed by uncommonly high runoff in May and June throughout most of Idaho.

Items of Special Interest in District Programs

A pilot study was made in 1951–52 to evaluate surface factors affecting streamflow recorded at Survey gaging stations in four basins in the northwestern States, including the Big Wood River in Idaho. The study for this basin was conducted under the supervision of E.G. Bailey. The report covering Big Wood River basin is contained in USGS Circular 192 entitled "Evaluation of Streamflow Records in the Big Wood River Basin, Idaho," by R.P. Jones (1952).

Further progress was made during 1953 and 1954 in reducing the backlog of computations in the Boise District. Considerable study also was given to the adequacy of data networks coverage, with particular emphasis on areas where water use was increasing rapidly. About 330 miscellaneous measurements of discharge were made in this connection. Considerable progress was made during 1953–54 in the renewal and repair of gaging-station structures, with special emphasis on structural safety in response to the Division's safety campaign.

Lynn Crandall, district engineer at Idaho Falls, was called on to give testimony regarding present and future depletion of Snake River waters at hearings before the Federal Power Commission in Washington, D.C., on

proposed developments on the Snake River below Weiser, Idaho. The Boise District staff supplied water records requested for these hearings, including blanket requests for all unpublished data collected within the basin.

Preliminary work was started in 1956 on records in northern Idaho as part of a nationwide program of flood-frequency studies. Beginning in 1957, continued study was given to improving the gaging-station network to obtain representative records from which flow data might be computed by correlation for a larger number of streams. This was part of a nationwide effort, with input requested from other Federal and State agencies.

GROUND WATER BRANCH

Condensed from documentation by R.L. Nace

Some landmark work on ground water in the Snake River basin during the 1920's was conducted by Lynn Crandall and H.T. Stearns. Much later, perhaps during the early 1940's, D.G. Thompson conducted a reconnaissance in the Malad Valley of Oneida County. He made no report but left some useful notes. P.P. Livingston followed this reconnaissance by setting up an elaborate network of observation wells in that valley which were maintained by the Salt Lake City office of the GW Branch until mid-1946.

R.L. Nace established an office in Boise, Idaho, in mid-July 1946. This was the beginning of sustained cooperation with the office of the State engineer (Mark Kulp). The first work in the new cooperative program was conducted in the Malad Valley, which consisted of an inventory of wells and the establishment of an improved network of observation wells. No recording instruments were available at that time and all records consisted of those made by hand measurements. The ground-water program operated on a financial shoestring and, as a result, no formal report on the area was issued. Nace released an Open-File Report on wells and springs in Oneida County in 1952.

In the 1940's, R.J. Newell, brother of WRD's T.R. Newell and Regional Director for the Bureau of Reclamation in the Northwest, asked Nace to report on the availability of ground water for irrigation of the North Side Pumping Division of the Minidoka project. Nace made a brief study in fall 1946, and his administrative report indicated that such irrigation was feasible. He formalized the findings (H. Doc. 721, 81st Cong., 2d sess., p. 157–207) and a followup report was published by E.G. Crosthwaite and R.C. Scott (Circular 371, 1956). These studies were important because they led to development of ground water and the release of surface water earmarked for use elsewhere. The North Side Pumping Division Project was the first project by the Bureau of Reclamation that was developed with ground water.

The Bureau of Reclamation requested a study for the use of ground water for the Michaud Flats Project in Power County. Nace, assisted by J.W. Stewart and Morris Deutsch, made an independent study that was published in 1954 (H. Doc. 385, 83rd Cong., 2d sess., p. 55–77). The report indicated that the use of ground water in this area was not feasible.

In 1956, the Bureau decided that it wanted an appraisal of the entire eastern Snake River basin. Nace prepared a project proposal that was accepted. M.J. Mundorff, who succeeded Nace in 1956, conducted that study with the help of E.G. Crosthwaite and Chabot Kilburn. Their report (WSP 1654, 1964) is a landmark in studies of the Snake River basin.

Financial cooperation with the State during the decade was always small, and sufficient only to support the observation-well program and a few reconnaissance studies. Aside from studies for the Bureau of Reclamation, work was conducted in Oneida County (four basins), the Raft River basin, the southern border area of the Snake River basin between Twin Falls and Pocatello, the Fort Hall Indian Reservation (all in southern Idaho), and in the Moscow area and Rathdrum Prairie of northern Idaho.

The Raft River basin study was important because a large amount of Federal land in the area was potentially open to desert-entry claims. Ground water was being developed for irrigation and the Bureau of Land Management needed a ground-water evaluation as a guide for permitting or rejecting desert land-entry applications. There were no funds for the study, which Nace conducted "with his left hand." In response to congressional demand, Nace (then associate chief of WRD) released a memorandum report and prepared Water-Supply Paper 1587 (1961), coauthored with S.W. Fader and H.G. Sisco, who did much of the basic-data collection.

Nace "whittled away off and on for some years" on the water resources of the Spokane River basin in Idaho and had a report in an advanced stage. Prior to completion, however, the basin was selected for inclusion in the series of so-called "Mahoney reports," and Nace turned his material over to A.M. Piper and W.D. Simons.

Another important project was a study of ground water in the Boise River valley. The Bureau of Reclamation had a plan for irrigating the Mountain Home project (south of the Boise Valley) by the upstream manipulation of surface water. W.G. Sloan, coauthor of the Pick-Sloan plan for the Missouri River basin, had become a freelancer and publicly proposed that ground water be used in the Boise Valley to replace surface water that could be used for the Mountain Home project. This proposal came to congressional attention because of Sloan's prestige. Pressure was put on the USDI and the Survey received a

directive from the Secretary to evaluate the proposal. No extra funds were allocated, but assistant branch chief A.G. Fiedler made $30,000 available and directed that the study be initiated and completed in the 1954 fiscal year. (Nace had earlier proposed a federally financed study of the Boise Valley for an estimated cost of $300,000.) The result, Water-Supply Paper 1376 by Nace, S.W. West, and R.W. Mower, was published in 1957. The report outlined a plan for development of ground water by means much different from those proposed by Sloan. The report, however, had little practical impact. Water users were not willing to relinquish surface-water rights in exchange for ground water, and the proposals, so far as Nace knows, were never carried out.

An outstanding event in Idaho was the appearance on the scene of the U.S. Atomic Energy Commission (AEC). The AEC wished to establish a large project for the development and testing of nuclear reactors. With the aid of the Survey, about 40 sites around the Nation were selected for evaluation. The choice ultimately narrowed down to two locations: the vicinity of Ft. Peck, Mont., and the Snake River basin in Idaho. Late in 1948, A.M. Piper, who coordinated Survey participation, asked Nace to work with him in a reconnaissance of the Snake River basin between Arco and Idaho Falls. Using knowledge of aquifer yields already developed by Nace, the two turned in an administrative report favorable to the project. AEC then hired consultants to make a detailed study of the labor market, schools, cultural facilities, economics, et cetera. The result was the selection of the Idaho site for the AEC project.

In response to a request by the AEC for a study of the geology and hydrology of the Idaho site, Nace drafted a proposal calling for services at a cost of $7,500 for the first year. Arthur Gorman of the AEC (a strong partisan of the Survey) glanced at the draft and told Nace to throw it away, saying "if it's worth only that much, it isn't worth buying." Encouraged by Gorman, Nace prepared a 10-year study plan that cost $125,000. The AEC approved, but suggested that a larger sum would be appropriate. Nace recalls that the actual first-year (fiscal year 1950) allocation was $137,000.

Although the AEC's stated plan was to proceed very slowly and in an orderly manner with its development, they soon asked Nace to choose a site for the experimental breeder reactor. This was done but, during construction, AEC distorted the Survey's proposals, and the site chosen by Nace later became the burial ground. (The allegation that Nace selected the site for the burial ground had no substance.)

Choice of other AEC construction sites followed in fairly rapid succession (chemical processing plant; materials testing reactor; submarine propulsion reactor; aircraft nuclear propulsion reactor; organic moderated reactor; and others). The consequence was that much of the District staff's effort went into specific studies and the overall Snake River basin study was delayed. Geologic and ground-water maps of the sites and reports on the geology and hydrology were completed. Initially these were classified reports, but they were later released to the open-file.

The District staff collaborated with the SW Branch staff by selecting springs to be measured along the 40-mile reach of the Snake River between Twin Falls and Bliss. Results of the study, which documented changes in spring discharge because of ground-water development, are published in WSP 1463 (1958).

Among the professional employees on the staff during the decade were J.W. Stewart, who was responsible for the basic-data program and special studies such as pumping tests; J.R. Jones, field party chief for early geological mapping and for National Reactor Testing Station studies; E.G. Crossthwaite, general field coordinator of cooperative programs who also made several significant area studies; and S.W. Fader, who participated in the basic-data program, quantitative studies, and report preparation. Eugene Shuter, a technical assistant, began his Survey career with fieldwork on the observation-well program and began the development of instrumentation and techniques.

Many other persons served in Idaho during the 10-year period. At one time, the District had a total staff of 27 persons. P.T. Voegeli once determined that 84 professionals had served in the Idaho District since its establishment.

QUALITY OF WATER BRANCH

By Herbert A. Swenson

Assessment of water quality in Idaho came under the jurisdiction of the Regional office in Salt Lake City until 1953, when operations were turned over to the newly authorized Portland District (see Oregon, QW Branch). Early field reconnaissance by C.S. Howard was later followed by similar surveys that defined in general terms the quality characteristics of many streams and lakes in Idaho. This background survey pointed up areas needing more intensive study. Both the Salt Lake City and Portland office personnel worked closely with the Boise District (GW) staff in defining water quality of wells and springs sampled in the District's ongoing cooperative ground-water program.

Federal program funds were the mainstay of the water-quality activity in the State, but in amounts that limited program expansion. Nevertheless, water problems were addressed. Requirements of the International Columbia

River Engineering Committee led to a study of chemical quality in Kootenai River basin waters. The impact of irrigation practices on selected reaches of the Snake and Boise Rivers came under study. Exploratory work began on measuring sediment discharges of the Coeur d'Alene River and its tributaries downstream from major mining activity. A brief study reported on suspended-sediment loads and particle-size distributions during high stages of the Kootenai River at Leonia and near Bonners Ferry.

Public water supplies for 16 cities in Idaho received attention. This work contributed to revision of WSP 658, "The Industrial Utility of Public Water Supplies in the United States," and documented such information as source of supply, water-plant treatment practices, average use and consumption, and storage capabilities, as well as quality of the raw and finished water. The Air Force provided funds for annual assessments of the quality of local water supplies used by bases and airfields in the State.

Network station operation, both irrigation and general purpose types, was of limited scope because of fund shortages. This program, beginning about 1950, served the Snake River and upper Spokane River basins, in part.

In summing up for the 10 years ending in 1957, the Survey's overall program in water quality in Idaho started from scratch and attained an adequate if somewhat stunted growth. Lack of cooperative funds restricted activity.

ILLINOIS

SURFACE WATER BRANCH

By Warren S. Daniels, G.W. Curtis, and D.E. Winget

The District program was sizable, requiring a staff that ranged from less than 20 in the late 1940's to more than 30 in some years near the end of the decade. The headquarters staff, which was located in the basement of the Post Office Annex in Urbana, moved to 605 South Neil Street in Champaign in September 1948. The move was made to provide needed additional space and a more desirable environment. By around 1957, office space had nearly doubled as a result of an addition to the building.

In 1955, a hydrologic unit was established at District headquarters with an initial staff of seven. A field headquarters, established in 1946 at St. Louis, Mo., for better access to gaging stations in southern Illinois, was closed in 1951, and the one-man office at Davenport, Iowa, was vacated in November 1947. One office on the south side of Chicago was located at Blue Island in 1948, then in Thornton through 1951. Another, at Peoria, opened in 1952 and was maintained through the end of the period.

J.H. Morgan continued to serve as district engineer through the end of the decade. His principal assistant, W.D. Mitchell, was placed in charge of the District's new hydrologic unit in 1955. W.S. Daniels was designated chief of operations in charge of the basic-data collection program. Senior staff members present at headquarters at times during the late 1940's included J.M. Busalacchi, L.H. Hanson, J.H. Montgomery, J.R. Stipp, and Alfonso Wilson. Those arriving later and remaining through the period included C.H. Benson, G.D. Booz, J.M. Carns, W.S. Daniels, R.G. Godfrey, O.G. Lara, J.W. Lawrence, A.W. Noehre, K.E. Ogata, D.E. Winget, and L.E. Young. Others on the headquarters staff for one or more years in the early 1950's were R.D. Black, G.L. Clack, Ms. J.K. Lichtenheld, A.E. Moenkhaus, and J.S. Windsor.

Busalacchi was resident engineer at the St. Louis headquarters at the beginning of the decade. He was succeeded by F.R. Walsh. E.W. Beckman was assigned to the Davenport office, J.M. Carns to Blue Island, and C.W. Sandifar to Thornton and later to Peoria. The mid-1950's period was characterized by a manpower shortage in the District, and a considerable part of routine field and office work was accomplished by using engineering students from the University of Illinois on a part-time basis. There was a large turnover of temporary employees during this time, but several stayed on after graduation and obtained engineer appointments.

The cooperative program with the principal State agencies, the State Water Survey (a division of the Department of Registration and Education), and the Division of Waterways in the Department of Public Works and Buildings, continued to expand. A cooperative program with the Department of Highways, Cook County, was initiated about 1948 to collect streamflow information on the many small streams in the metropolitan Chicago area. By 1952, records were being collected at 20 gaging stations supplemented by a network of crest-stage gages during the decade. The total District program expanded from 111 stations in 1947, to 145 in 1951, and to 158 by 1958. Total cooperative State and local funds increased from $36,000 in 1947 to about $75,000 in 1956, then dropped to about $70,000 in 1957, after which the growth trend resumed.

There were three outstanding floods during the decade, all affecting relatively small areas, for which special reports were prepared in cooperation with State agencies. State Water Survey Division Report of Investigation No. 14, "The Storm of July 8, 1951, in North Central Illinois," covered major flooding in the Vermilion and Mackinaw River basins. It is noteworthy that the Panther Creek basin, tributary to the Mackinaw River, was the site of a hydrologic project being conducted by the State Water Survey that incorporated a dense rain-gage network, ground-water level recorders, and radar equipment, as well as three gaging stations.

State Water Survey Division Report of Investigation No. 24, "The Storm of July 18–19, 1952, Rockford, Illinois and Vicinity," reported on flash floods within a very localized area caused by 11 to 15 inches of rainfall in a 36-hour period. A peak discharge rate of 1,230 cubic feet per second per square mile on Pelley Road Creek was the greatest known rate in Illinois.

"Floods of October 1954 in the Chicago Area, Illinois and Indiana," WSP 1370-B (1958), was prepared cooperatively with the Indiana District staff and reported on the greatest flood in the history of the region. Densely populated and highly industrialized, the region was subjected to unprecedented damage. Fortunately, however, the Cook County program was in full swing and provided good coverage of the flood. Subsequently, discussions began with the Cook County Highway Department to develop a program of floodplain delineation throughout Cook County. The program began in 1961.

As noted in Follansbee's Volume IV of the WRD History, a special studies unit was set up in 1945 under the technical direction of W.D. Mitchell and funded in the cooperative program by the State Division of Waterways. This developed into the formal establishment of the hydrologic unit in 1955. The research and analytical studies by personnel of the unit resulted in the publication by the Division of Waterways of the following interpretive reports, all by Mitchell: "Unit Hydrographs in Illinois (1948);" "Water-Supply Characteristics of Illinois Streams (1950);" "Floods in Illinois—Magnitude and Frequency (1954);" and "Flow-Duration of Illinois Streams (1957)."

Personnel of the unit started a research project investigating floodflows from small drainage areas (under 10 square miles) in 1955 in cooperation with the State Division of Highways. The original network consisted of 48 new stations, plus 10 stations in the existing surface-water data program. [Note: The GW and QW Branches had no formal investigative programs in Illinois during the decade except for those conducted by the GW District in Wisconsin.]

INDIANA

SURFACE WATER BRANCH

By Richard E. Hoggatt

The Indiana District continued to have administrative jurisdiction over both the Indiana and Michigan programs as the decade began. This unique arrangement continued until November 1950 under D.M. Corbett as district engineer. At that time, A.D. Ash, who had been in charge of the Lansing Subdistrict and had represented Corbett in day-to-day liaison with Michigan cooperators, was appointed district engineer for Michigan. The Michigan program activities during 1947–57 are covered under the heading for that State.

The total number of full-time personnel in Indiana nearly doubled during this decade. A staff of about 16 people was headquartered on the second floor of the Underwriters building at 445 North Pennsylvania Street in Indianapolis in 1947. In summer 1950, the office moved to 311 West Washington Street, the former Fair Store building that had been converted into office space by the State. In fall 1955, the office again moved, this time to 611 North Park, a complex called the "Printing Arts Center." The Center had formerly been the home office of the Real Silk Hosiery Mill.

Several field headquarters were maintained at various times during the decade. They were located in West Lafayette (1952–54), Bloomington (1955 on), Carlisle (1955 on), Plymouth (1955–56), and Valparaiso (1955–56).

Corbett was district engineer for the entire period, having begun in that capacity in 1941. His senior staff at the beginning of the decade was composed of J.I. Perrey, who supervised the lake-stabilization program which included 105 lake stations equipped with staff gages; L.W. Furness who was assigned to the highway bridge-site studies; and M.A. Benson and Anthony Homyk, Jr., who were responsible for the operation and analysis of 87 stream-gaging stations, 43 of which were equipped with continuous recorders. As these men transferred to other Survey offices during the early part of the decade, others moved in to take their place: L.E. Widman from Michigan; A.R. Green from Virginia; L.V. Page from Massachusetts; M.D. Hale from Hawaii; and J.B. Swing from Tennessee. Several newly-recruited engineers entered the District work force during this time: E.R. Buxton, H.L. Hoffman, R.E. Hoggatt, M.E. Shelley, Calvin Field, and C.E. Schoppenhorst. These men were assisted by several engineering aids and technicians, including L.W. Carrico, C.L. Alderson, Jack Longshore, Jean King, D.C. Perkins, Lorraine Pomp, Robert Hammond, R.G. Lipscomb, G.E. Nell, H.D. Gallman, and R.L. Stewart. Several college students from Purdue University, Rose Polytechnic Institute, and the University of Cincinnati assisted in both the field and office work during the first part of the period. In the second part of the period, several Indianapolis high school math and science teachers and students worked on a part-time basis to assist in the computation of discharge records.

During the decade, all aspects of the programs with cooperating municipal, State, and Federal agencies increased. The studies of Indiana's lakes greatly expanded through cooperation with the Indiana Department of

Conservation, Water Resources Division (C.H. Bechert, director), to include lake-depth contour mapping of all of the larger lakes. Flood studies were also greatly increased by obtaining many indirect measurements of peak flows at miscellaneous sites, preparing reports on floods of October 1954 and July 1957, and conducting flood-frequency analyses in cooperation with the Indiana Flood Control and Water Resources Commission. The Commission's staff consisted of J.I. Perrey (who had transferred from the District to the State in 1949) as chief engineer, as well as other former Survey engineers, including Max Noecker, M.C. Boyer, and H.L. Hoffman. The stream-gaging program nearly doubled through growth in cooperative programs with several municipalities, as well as with the State Board of Health, the State Highway Commission, and the Indiana Flood Control and Water Resources Commission. The program with the Corps of Engineers also expanded. During this period, the District's segment of the 1950 national compilation report was accomplished under Page's supervision. The only program discontinued during the decade (in 1951) was the highway bridge site study.

The organization of the District changed as the programs grew and new engineers and technicians were hired. Green served the District as its first "official" assistant district engineer beginning in 1953. In fall 1956, a hydrologic unit was created and Green was placed in charge. He was followed as assistant district engineer by Hale, who had served as office engineer beginning with his transfer to the District in fall 1954. The hydrologic unit was established to accomplish the work on flood reports, indirect measurements, and flood and low-flow frequency studies. Green transferred to the floods section in Arlington, Va., in 1956, and Hoggatt succeeded him in charge of the hydrologic unit.

The Lake Section under D.C. Perkins was enlarged to accomplish the lake mapping program. Stewart, who came from the U.S. Weather Bureau, was assigned to the section. Perkins and Stewart developed several new mapping techniques for the field surveys, as well as efficient office procedures in drafting the field data for a final reproducible map. The lake stabilization program continued through the decade and its importance was assured when legal water levels were established by the courts on the basis of daily gage-height records. A report on the hydrology of Indiana lakes by Perrey and Corbett was published as WSP 1363 in 1956. During this decade, field offices at Bloomington, Carlisle, Plymouth, Valparaiso, and West Lafayette were established. With the exception of West Lafayette, these were one-man offices in which the technician worked out of his home. The West Lafayette office was run mostly on a weekend basis by several students attending Purdue University who did stream gaging between classes.

When Hale moved into the assistant district engineer's job, Schoppenhorst was made office engineer and Swing was made field engineer. These men were responsible for the collection and analysis of data from the stream-gaging stations which had increased to 140 by 1957. In addition to stage and discharge records, temperature records at 11 sites were being collected as the decade ended. Cagles Mill, the first of several flood-control reservoirs to be built by the State, was placed in operation in 1953, followed by water-supply reservoirs for Bloomington (Lake Lemon) in 1953 and Indianapolis (Morse Reservoir) in 1957. The emphasis on flood control, water supply, recreation, and stream-pollution control greatly increased the need for the District's basic-data program.

Much attention was given by Corbett to the young engineers and engineering technicians on his staff. He encouraged the engineers to advance in their profession and to become registered professional engineers and members of professional societies. He gave more and more responsibility to the technicians as they grew in experience and technical capability. Corbett worked even harder to accomplish District goals when there appeared to be difficulties in the way. He personally headed up projects at Fort Benjamin Harrison in Indianapolis (1952) and at Scott Air Force Base near Belleville, Ill. (1957), to diagnose sewer problems for the 6th Army.

The decade ended just prior to one of the largest floods of record on small streams in central Indiana as a result of Hurricane Audrey in June 1957. The indirect measurement work was reviewed by M.S. Peterson, a flood specialist from Rolla, Mo., and the Washington, D.C., floods section chief Tate Dalrymple. Several of the District personnel had become familiar with flood-data collection through details to other districts as well as in Indiana during the decade. Detailees included Hale and King (to Kansas in 1950), Page (to New England in 1955), and Green and Hogatt (to California in 1956). The experience gained paid off for the District during subsequent floods in Indiana.

GROUND WATER BRANCH

By Claude M. Roberts and Fred H. Klaer, Jr.

The entire GW program was administered from District headquarters, the staff of which varied between five and nine during the decade. Space was shared with the SW Branch at the three different locations in Indianapolis which were used at various times during the period. F.H. Klaer, Jr., was district geologist until 1951, when he resigned to work for private industry. He was succeeded by C.M. Roberts, who had been on the CHE's staff in Washington, D.C. Members of the professional

staff at the beginning of the period included W.D. Thornbury, E.A. Brown, and R.W. Stallman. Later arrivals included G.E. Davis (1948–53); F.C. Mikels (1949–51); P.E. Ward (1950–55); R.V. Chafin (1951–53); J.S. Rosenshein (1954 on); R.J. Vig (1953 on); F.A. Watkins, Jr. (1954 on); W.A. Walker (1956); and D.G. Jordan (1956 on).

The cooperating agency during the decade continued to be the Indiana Department of Conservation, Division of Water Resources (hereafter referred to as "IDC"). Division chief C.H. Bechert helped greatly in maintaining an effective and productive cooperative relationship with the Survey. As noted below, IDC published the results of a sizable number of studies by the District staff in its bulletin series. The District also received a small annual allocation of Federal program funds for the operation of a few observation wells.

A major interest of the District staff continued to be the statewide observation-well program that, by the end of the decade, included about 170 wells located in 78 of Indiana's 92 counties, as well as the preparation of monthly summaries of water-resources information to be released by the State. The observation-well program was gradually expanded to include more of the principal aquifers in the State and to give greater coverage in areas under new investigation. Increases in the number and kinds of observations made enlarged the scope of the work. Water quality, previously given little attention, became a part of basic-data collection for all projects. Selected constituents covering common physical and chemical properties were also included.

The annual water-level reports were continued for inclusion in the Water-Supply Paper series covering the State. All data were open-filed pending publication. Under the cooperative program, pumping-test data, obtained by observers during tests conducted by well drillers and municipal and industrial water-supply companies at scattered locations in the State, were analyzed and placed on file in the Indiana office.

The year 1952 saw the beginning of significant growth in the cooperative program that continued throughout the decade. This came about through efforts on the part of the State to increase funding in order to accelerate the rate of investigational work.

Primary needs remained much as before. More and better basic data were needed to produce the kinds of reports required. Basic well data and other related information of good quality were needed in larger quantities to give a base for the determinations and descriptions of ground-water resources and delineation of problems. Manpower was a problem for a year or so but, with the arrival of sufficient personnel and an extensive training program, the staff soon became more productive.

Better relations were established with well drillers and consultants and also with water companies and industries using ground water. They all were involved in planning, exploring, developing, and using ground water, and were potential sources of information. Large quantities of useful information were collected from such sources with a minimum of additional effort. This was especially true when contacts were made during pumping tests and when inventories of water use were being prepared.

Changes in the type and scope of the investigational program required expansion of the work conducted. Reports for single counties were seldom practical. Increases in funding and basic-data collection made it possible to investigate multi-county areas. Areal ground-water investigations during the decade were typically within the boundaries of counties or groups of counties. These included Adams County (published in 1962); the South Bend area of St. Joseph's County (Klaer and Stallman, IDC Bull. no. 3, 1948); Boone County (Brown, IDC Bull. no. 4, 1949); Noble County (Stallman and Klaer, IDC Bull. no. 5, 1950) and Tippecanoe County (Rosenshein, IDC Bull. no. 8, 1958). By 1957, reports for several counties in the northwestern and west-central portions of the State were completed and "open-filed," but more formal publication had to be postponed until the funds became available to the IDC. (Investigations of other counties in these parts of the State were scheduled for a later period.) The ground-water resources of the Indianapolis area also were studied (Roberts, L.E. Widman, and P.N. Brown, USGS Circular 366, 1955), and the staff participated in the Indiana portion of the interstate-interbranch investigation of the water resources of the Louisville area, Kentucky and Indiana (USGS Circular 276, 1953).

A detailed study of the hydrology of Eagle Lake began in 1950, and the results were found to have significant research value: relations between the lake levels and the ground-water profiles adjacent to Eagle Lake that helped in the prediction of stages in that and other lakes were revealed. The record-breaking rainfall during 1951, which averaged about 15 inches above normal, caused several drainage problems that occurred when attempts were made to maintain the State-mandated lake levels. The heavy rainfall also increased interest in understanding the relations of surface drainage to ground water and lake levels.

QUALITY OF WATER BRANCH

Responsibility for Branch projects in Indiana was carried by the Columbus, Ohio, District staff. Program statistics as of 1951, and also WSP 1450 that reports on 1956 water-quality records, make no mention of direct cooperation with the State of Indiana or municipal agencies. W.L. Lamar, district chemist, reported in July 1951 that the District was collecting daily chemical-quality data

at five streamflow stations and periodic samples at two observation-well sites. The data collected daily was likely in cooperation with the Ohio River Valley Water Sanitation Commission as a part of an interstate investigation of the chemical character of the waters of the Ohio River, headwaters to mouth. The periodic analyses at well sites likely was for the GW District.

WSP 1450 includes water-temperature data at seven stream-gaging sites, the records having been begun at various times from 1952 to 1954. Such data may have been collected by surface-water stream gagers.

Program data for fiscal year 1958 shows that the Branch was then collecting daily chemical-quality and temperature data at three stream stations in cooperation with the Indiana Department of Conservation.

IOWA

SURFACE WATER BRANCH

By Lawrence C. Crawford and R.D. Schmickle

Headquarters

The District office remained in the hydraulic laboratory at the University of Iowa at Iowa City throughout the decade. Chemical-quality investigations and sediment-sampling equipment and techniques, under the leadership of P.C. Benedict, were also coordinated and initiated there for nationwide use. Benedict transferred to Lincoln, Nebr., in 1945. However, these and other related activities over the years, on the campus and at the engineering college, together with the Iowa Institute of Hydraulic Research, afforded the opportunity for employment of students for some prospective workloads. Such contacts also encouraged future association and employment as well as to establish good Survey relationships.

Council Bluffs, Iowa, Subdistrict Office

The Council Bluffs Subdistrict office was established in September 1949 with responsibility for the surface-water data program on the Missouri River and its tributaries in western Iowa. The mainstem Missouri River coverage eliminated involvement of other Survey districts. Thus, contact was more easily maintained for planning and conduct of work. Efficient operation of the gaging-station network was made possible through good communications with the division and district offices of the Corps of Engineers located in Omaha, Nebr., across the Missouri River from Council Bluffs. Office work covered complete and final preparation of all streamflow records.

Initially, personnel consisted of two engineers, G.W. Edelen and R.E. Whiteman, and a clerk-typist, Mrs. D.E. Hendrix. In 1954, Edelen transferred to Kansas and was succeeded by C.W. Sullivan, who was a key measurement man. During the outstanding April 1952 Missouri River flood, daily-discharge measurements made included the 4-mile-wide overbank flow at Sioux City and the several-mile overbank flow at Nebraska City; no measurements were made from any bridges. These discharge measurements, an outstanding achievement, were reported to the Corps of Engineers for flood forecasting purposes and for the Corps' Missouri River model activity at Vicksburg, Miss. The Sioux City measurements were made at the most upstream station used to document the flood that had its beginnings in Montana.

Personnel

Having been appointed district engineer in 1940, L.C. Crawford continued in that position and also as associate director of the Iowa Institute of Hydraulic Research until 1949, when he took charge of the Ohio District. He was succeeded by V.R. Bennion who had been district engineer of the College Park, Md., District. R.D. Schmickle, who joined the District in 1946 on his return from active military duty, was assistant district engineer until he transferred to a mine-drainage project in the anthracite fields of Pennsylvania. He was placed in charge of the Pittsburgh, Pa., Subdistrict in January 1957. In Iowa, Schmickle was succeeded by George Anthony, who came from a position in Pittsburgh that Schmickle had occupied.

M.C. Boyer assisted with special investigations on a part-time basis while pursuing his graduate studies. In 1949, while serving as assistant professor of mechanics and hydraulics and as research engineer with the Iowa Institute of Hydraulic Research, he edited Bulletin 33 published by the University of Iowa entitled "Third Decade of Hydraulics at the State University of Iowa." Boyer had an inspiring grasp of the people and the work of the Geological Survey. Other senior members of the headquarters staff who remained throughout the decade included Samuel Mummey, Jr., R.E. Myers, and H.H. Schwob, each a native Iowan willing and ready for any task. Iowa Highway Research Board Bulletin No. 1 in 1953, "Iowa Floods–Magnitude and Frequency," was authored by Schwob. Schwob deserves special commendation for the hydrologic and hydraulical studies and the leadership documented in the publications, State and Federal, for two decades.

Ms. C.E. Putz continued as district clerk through the end of the period. She entered on duty in the Washington, D.C., office in 1928. She transferred to the St. Paul

District in 1930; to Tuscon in 1933; to St. Louis in 1934; to Louisville in 1938; and to Iowa City in 1942. In October 1957, Ms. Putz transferred to the Social Security Administration after a career of nearly 30 years with the Survey, during which time she may well have served in more District offices than any of the Division's administrative personnel before or after. Some years after her transfer and retirement, she died in an automobile accident. In a letter to Crawford in 1982, Wayne Travis, who transferred to Idaho in the previous decade, wrote "it seems that of all friendships, those which were born in Iowa City have proved to be the most enduring."

Cooperation

The principal State cooperative funds for gaging streams, studying siltation, and preparing reports came from the Iowa Geological Survey, the Iowa Institute of Hydraulic Research, and the Iowa State Conservation Commission. Also, a number of Iowa cities and counties provided cooperative funds for individual gaging stations and for hydraulic studies of streams. The Corps of Engineers district offices at Kansas City, Mo.; Omaha, Nebr.; Rock Island, Ill.; and St. Paul, Minn., provided about 35 percent of the District's funds in 1949 for gaging streams and obtaining siltation data. Special cooperative support was also given by the Iowa State Highway Commission; the Natural Resources Council; the Iowa State Agricultural Experiment Station; and the Soil Conservation Service; and strong technical leadership came from Iowa State College. The entire program about doubled in size during the latter half of the decade, and the regular staff increased from 13 in 1950 to 21 a few years later. Total funds were increased from about $100,000 to more than $200,000 in 1958.

A number of leaders, such as President Virgil Hancher, Dean F.M. Dawson, (College of Engineering), Hunter Rouse (Director of the Iowa Institute of Hydraulic Research), E.W. Lane, and Joe Howe, all of the University of Iowa, deserve much credit. The Iowa Geological Survey was directed by A.C. Trowbridge and H.G. Hershey as successive directors and State geologists. All of these and a number of other Iowans—such as F.T. Schwob, Director of the Iowa State Conservation Commission, and G.L. Ziemer, who in 1949 became director of the Iowa Natural Resources Council—were associated with the cooperative-program activities in the previous decade that extended into the 1947–57 era of expansion.

An example of the statewide recognition of the water-resources effort may be found from Governor Beardsley's appointment of Hershey and Crawford as members of the first Iowa Water Resources Council in 1949, with confirmation of each by the Iowa Senate. Earlier, they had been appointed by Governors Hickenlooper, Blue, and Beardsley to several investigational and reporting commissions for recommendations concerning Iowa projects and intrastate ramifications. Through their association and work with State officials in Illinois, Indiana, and Ohio, the Annual Mid-Western States Flood Control and Water Resources Conference was organized in 1947 with the first meeting in Indianapolis, Ind. The 20th meeting of this Conference was held in Dayton, Ohio, in 1965.

While in Iowa and prior to his transfer to Ohio, Crawford was a member of, appointed to, or was president of, a number of public service agencies, including the Iowa Engineering Society, the Central Iowa Chapter of the American Society of Civil Engineers, the University of Iowa Faculty Club, and the Iowa City Zoning and Planning Commission. *The Des Moines Register and Tribune* gave him a citation of "Second Century Leader" in 1947, a recognition of accomplishments of leaders in their trade, business, and professional associations. This ongoing recognition of his service, in company with Hershey and others, strengthened public awareness of the USGS program during the decade and beyond, and an appreciation of the worth of Iowa's water resources. The words of a famous poem are fitting here: "Transverse the desert and then you can tell, what treasures exist in a cool deep well. Fall in despair on the red parched earth, and then you may know what water is worth" [Anon].

GROUND WATER BRANCH

By H. Garland Hershey

Headquarters and Personnel

The District staff varied from five to seven persons, all of whom were headquartered in the Geology Annex on the campus of the University of Iowa in Iowa City throughout the decade. In 1950, a new wing was added to the Annex, which doubled the office space for the growing Federal and State staffs. H.G. Hershey, who had been appointed district geologist in 1944, continued in charge until 1955 when he resigned to devote more time to his positions as State geologist and Chairman of the Iowa Natural Resources Council. E.H. Walker was acting district geologist from the time of Hershey's departure until June 1956. W.L. Steinhilber, who had come to the Iowa District in 1954 from the Bozeman, Mont., Subdistrict, was named district geologist in March 1957.

W.E. Hale, who had been on the staff since 1942 and served as Hershey's principal assistant during the late

1940's, left in 1950 to take charge of the New Mexico District. C.W. Lane came to the Iowa District in 1948 and transferred in 1954 to the Montana District. R.J. Jeffords was one of the senior staff members from 1948 to 1953 as were C.R. Murray (1950–53) and J.B. Cooper (1947–56). R.E. Hansen arrived in 1957. Olatha M. Tweedy came to the Survey as a new employee in 1953 and was a highly effective clerk-stenographer for the rest of the period.

The services of the Iowa Geological Survey personnel were also a part of the cooperative program. Senior State staff members during the decade were Mary C. Parker, Stanley Harris, Paul Horick, and Richard Northup. Their major role was in ground-water studies, interpretation, and mapping.

Cooperation and Program

The Iowa Geological Survey was the principal cooperator for the ground-water program. This cooperative effort started in 1938 and was continued through 1957.

Statewide aims in the ground-water program during that time included collecting and processing data on subsurface geology, depth to water-producing zones, quantities available, mineralogical quality, temperature, and well construction. The information resulting from this work was constantly in demand, and was furnished as a service to other governmental agencies, cities and towns, industry, and individuals.

The data collection on subsurface geology was greatly aided by the well drillers of Iowa who saved well cuttings at 5-foot intervals and furnished them to the State at no cost. They also furnished logs of their wells, casing records, data on water levels, and, where measured, quantities of water available. The wells ranged in depth from less than 100 feet to more than 2,000 feet. During 1947–57, about 6,000 sets of well cuttings with supporting data were received, a veritable gold mine of information.

Numerous special investigations and projects were underway at the beginning of the period and were continued during the decade. They included reports on the geology and ground-water resources of Cerro Gordo, Kossuth, Emmet, Clayton, Linn, and Webster Counties. Potentiometric, thickness, and structure maps of major aquifers were begun and updated as new data were acquired during the period. It was a decade of considerable progress.

QUALITY OF WATER BRANCH

By P.C. Benedict and R.H. Langford

The Branch staff participated, as a member of an Interdepartmental Subcommittee on Sedimentation (formally established in 1946), in a joint study of fluvial sediments throughout the decade, which began back in 1939 when the University of Iowa's Institute of Hydraulic Research was selected as the project headquarters. B.C. Colby, formerly an employee of the SW Branch, had charge of the project beginning in September 1946. In July 1947, Colby transferred to the QW Branch, reporting to P.C. Benedict, regional engineer, Lincoln, Nebr. Benedict represented the Survey on the committee, which was composed of representatives of the Departments of Agriculture, Commerce, and Interior, the Corps of Engineers, and the Federal Power Commission. In 1948, the project headquarters moved to the St. Anthony Falls Hydraulic Laboratory, University of Minnesota, in Minneapolis. Colby continued in charge of the project at the new location. Two daily records of chemical quality and temperature of stream water were collected by staff of the Lincoln regional office on the Iowa River at Iowa City and the Cedar River near Cedar Rapids during the decade.

KANSAS

SURFACE WATER BRANCH

By Elwood R. Leeson

In 1947, the surface-water program in Kansas was being conducted as a subdistrict operation under the direction of the Missouri District office in Rolla. The program in Kansas had been reduced to Subdistrict status in 1941 because funds were insufficient to support operations on a District scale. However, as a result of the increasing data requirements for the Missouri River basin program and for four Corps of Engineers districts (Omaha, Nebr.; Kansas City, Mo.; Tulsa, Okla.; and Albuquerque, N.M.) for their flood-management programs in Kansas, the program grew sufficiently by 1951 to permit return to full District status. Topeka continued to be the location of the Kansas District office through the remainder of the decade.

In 1947, the program consisted of the operation of 80 stream-gaging stations. Of these, 33 were financed by the Corps of Engineers, 13 by the Missouri River basin program, 5 by Survey Federal program funds (including four Republican River Compact stations, discussed in the Nebraska District activities statement), and 29 were in the cooperative program with the Kansas State Board of Agriculture. The stream-gaging program continued its growth so that it totaled about 107 stations at the close of the decade. Of these stations, 51 were funded by the Corps of Engineers, 16 by the Missouri River basin program, 4 by the U.S. Soil Conservation Service, 7 by the

Federal program, 27 in cooperation with the Kansas State Board of Agriculture, and 2 with the city of Wichita.

In July 1951, torrential rains caused statewide flooding of magnitudes not previously experienced. Travel by ground transportation was virtually impossible throughout the State. The relatively small District staff was almost completely overwhelmed by the magnitude and extent of the flooding, and only a minimum number of current-meter measurements could be obtained. Branch headquarters quickly recognized the need to provide extraordinary support to the District to enable it to meet its program commitments and, indeed, for the Branch to meet its basic responsibility to document a hydrologic event of such importance.

A special flood-report unit was set up in the District office staffed entirely by detail of highly qualified personnel from many places in the Nation. The unit, which was under the direction of R.E. Oltman, staff engineer, Lincoln, Nebr., assumed full responsibility for recovering all possible flood data from the field, including a large number of indirect peak-discharge determinations, the development of station rating curves, and the computation of daily discharges covering the entire period of flood runoff. Space does not permit listing the participants in this important undertaking, but special mention must be made of Hollister Johnson, Washington, D.C., headquarters, who provided major leadership for indirect peak-discharge determinations, and Tate Dalrymple, who made frequent visits from Washington for general overview of the work. Major review of the final product was provided by R.W. Carter, Georgia District, who checked the records for overall consistency by flood-volume and routing studies, and E.R. Leeson, Nebraska District, who reviewed station rating curves in the light of his extensive experience with streams having the unstable, shifting sand beds that are typical of streams in both Kansas and Nebraska. Leeson made several major revisions which were subsequently confirmed by Carter's studies. The resulting report, WSP 1139, ''Kansas-Missouri Floods of July 1951,'' was in print before the end of 1952.

The climate in Kansas ranges from humid in the east to semiarid in the west, but hydrologic conditions in the entire State can range from extreme drought to devasting floods. Following the 1951 flood, a series of drought years threatened a return to the infamous ''dust bowl'' conditions of the 1930's. With at least one small city in southeastern Kansas recirculating its sewage plant effluent through its water-supply treatment plant by mixing the effluent with the dwindling natural stream discharge, the district engineer suggested to the State cooperator that a statewide reconnaissance of base flows of ungaged streams would be of interest. Without benefit of formal programming or funding arrangements, every available person from both the Federal and State staffs were equipped with current meters and the entire State was blanketed with low-flow determinations, all within a matter of a few days. The results never were formally published, but were recorded by a mimeographed sheet prepared by the State office. The low-flow survey became an annual late summer or early fall event and the data collected proved to be of inestimable value in later years when regionalized low-flow studies were undertaken (for example, Prof. Paper 575-C, ''Two Methods of Estimating Base Flow at Ungaged Stream Sites in Kansas and Adjacent States,'' by L.W. Furness and M.W. Busby, 1967).

With the State having undergone the extremes of record flows and drought within a very few years, the political situation was ripe for the Governor and the legislature to take action. A State Water Resources Board was established and instructed to develop a State water plan directed toward better control and use of the resources. The Board selected R.L. Smith to serve as its executive secretary. Smith had an outstanding academic background in hydrology coupled with excellent programming and management skills. The immediate needs of the newly created Board for analysis and interpretation of existing surface-water data presented a golden opportunity to the District for the expansion and broadening of its cooperative program with the State.

Machine processing of data was emerging, and the District was successful in negotiating cooperative funding with the Water Resources Board to supplement Federal research-program funding from Headquarters for the purpose of determining the feasibility of transferring daily records of stream discharge to machine-readable digital tape. The upshot of this pioneering effort was that the entire file of Kansas streamflow data was put on tape and available for computer processing. This opened the door for the planning of a series of investigations and reports in cooperation with the Board.

The first project was the design of a data-collection network using concepts developed by the Washington Headquarters staff. The result was Kansas Water Resources Board Bulletin 4, ''Development of a Balanced Stream-Gaging Program for Kansas,'' by L.W. Furness (1957). The report presented several configurations of station networks entailing long-term ''primary'' stations in combination with short-term ''secondary'' stations, the latter being operated only long enough to establish satisfactory statistical correlation with the ''primary'' stations. The network configurations were designed to permit programming judgmental decisions based on an acceptable balance among annual operation costs, number of years to achieve complete areal coverage of the State, and probable accuracy of the regionalized runoff characteristics portrayed by the network. The report was used as a programming guide in the District in years to come. Other studies that were either underway or scheduled by the end

of the decade included a series on Kansas streamflow characteristics, which includes the following sections: Part 1, Flow duration; part 2, Low-flow frequency; part 3, Flood frequency; part 4, Storage requirements to sustain gross reservoir outflow; and part 5, Storage requirements to control high flow. The District also entered into a cooperative program with the Kansas State Highway Department for a network of 100 small-area flood-discharge stations aimed toward a small-area flood-frequency report. This program also provided for site studies of the hydraulic characteristics of bridge openings under conditions of flood discharge.

The total Federal staff of the District consisted of eight or nine persons in 1947 and remained at about that level, with personnel losses and gains being about equal until early 1956. During 1956 and 1957, the staff grew to 17, reflecting primarily the addition of personnel qualified to conduct the hydrologic studies in cooperation with the Water Resources Board. Also, beginning in 1955, the District used, on a reimbursable basis, the services of the staff of the QW Branch area office in Norton for District stream-gaging activities in northwestern Kansas.

One-man field headquarters were maintained at Hays (1947–53), at Norton (1947–51), and at Eureka (1952–56). A Subdistrict office was established in Ellinwood in 1956 with a staff of five. (A field headquarters existed at Liberal during the entire decade, but had no responsibilities for work in Kansas. Personnel of this office reported to the Oklahoma District. The office was located in Kansas because there was no suitable location for an office in Oklahoma in the area of operation.)

J.B. Spiegel served as engineer-in-charge of the Kansas Subdistrict with the office in Topeka from 1947 until 1951, when the District was restructured and he was named district engineer. He served in this capacity until 1952 when he was named staff engineer-in-charge of the Topeka field unit of the special reports and investigations staff section. He retired in January 1957, completing a 43-year career with the SW Branch. In 1954, G.E. Edelen transferred from Iowa to assist Spiegel, took charge of the Topeka unit in 1956, and joined the District staff in Topeka in March 1957.

E.R. Leeson transferred from the Nebraska District in December 1952 to succeed Spiegel as district engineer and remained in that position through the rest of the decade. H.P. Brooks served as principal assistant to Spiegel while the Topeka office was a Subdistrict and became assistant district engineer when the conversion to District status was made in 1951. E.J. Kennedy, who transferred from the Kentucky District in 1953, succeeded Brooks as assistant district engineer and continued in that position for the rest of the decade. Other senior staff members who served under Spiegel during the first half of the decade included C.W. Sullivan, D.M. Bergstrom, and J.W. Clemans. In the latter half of the decade, the staff included J.P. Holliday, L.A. Bohner, C.V. Burns, T.J. Irza, D.W. Ellis, and C.V. Schroer. J.D. Rose served as chief clerk and Mrs. G.C. Kreipe as clerk stenographer during the entire decade.

A.J. Ferrin was at the Hays field headquarters (1947–52) and was succeeded by J.W. Clemans (1953–54). L.R. Lennington was at the Norton field headquarters from 1947 until 1950, when he moved to the Topeka District office. P.S. Marshal was at the Eureka field headquarters beginning in 1952, having moved there from Topeka. Marshal served at that location until 1956, when he moved to Ellinwood to become part of the staff at the newly established Subdistrict office under the direction of L.A. Bohner, who was there until the close of the decade.

GROUND WATER BRANCH

Period 1947–52

By Alvin R. Leonard

The program, as indicated by number of staff and availability of funds, remained relatively stable during the decade. The cooperative part of the program increased only slightly, but Federal funds for Missouri River basin projects increased substantially about 1950. Cooperative projects continued largely as county studies, principally in the western part of the State, but extended into eastern and southeastern Kansas with the advent of the "Flint Hills" projects. These projects started about 1948 when Howard O'Connor was hired as a State employee on the direct program. Several senior Kansas Geological Survey geologists, including R.C. Moore and J.M. Jewett, assisted on those projects, which emphasized stratigraphy and structural geology.

The number of people on the staff ranged generally from 8 to 12; however, the turnover of professional personnel was unusually great, with only the district engineer remaining more than 5 years. Nearly all of the staff were located at Lawrence in offices of the State Geological Survey on the University of Kansas campus. During the decade, from six to eight employees of the State Geological Survey were assigned to the District, some on a part-time basis. Field headquarters were used for various Missouri River basin projects for short periods at Concordia (1947–49), Scott City (1950–52), and Salina (1950–53) in Kansas, and Superior in Nebraska (1949–50).

V.C. Fishel, who had been in charge of the District office in Kansas since 1945, continued to direct ground-water activities through the decade. Fishel, a physicist

who specialized in laboratory and field analyses of permeability, was named district engineer in 1949. Because of several transfers and resignations, the only two professionals in the District at the beginning of the decade were Fishel and A.R. Leonard. The number of professional State employees on the State direct program also had been reduced substantially from earlier years, so the District was small and the staff inexperienced in the early part of the decade.

A considerable part of the cooperative work during the early years of the decade was devoted to completing studies started during World War II, largely in southwestern and north-central Kansas. This work involved getting reports finished, reviewed, and prepared for printing as State Geological Survey Bulletins. Included were reports for Pawnee, Edwards, Republic, Cloud, Barton, Stafford, and Jewell Counties; Pawnee Valley; the Kansas City, Kans., area; and the "Equus Beds" area in central Kansas.

G.C. Prescott joined the District staff in July 1948 and immediately started a series of county projects in northwestern Kansas. About one new county project was started per year and included Lane, Sherman, Cheyenne, Graham, and Wichita-Greely Counties. The Wichita-Greely project was started by a University of Michigan graduate student, J.R. Branch, who spent summer 1948 and 1949 collecting field data. Prescott completed collecting the field data and prepared the report.

Several projects that began in 1946 under the Missouri River basin program continued in the early part of the decade and were conducted primarily by Leonard and D.W. Berry. Missouri River basin funds generally were adequate for field work on one or two projects a year. Detailed work on one began as the other was finished. About 1949, a sizable increase in Missouri River basin activity and funds led to the establishment of field headquarters in Concordia, Salina, and Scott City.

The first Missouri River basin projects (and project chiefs in parentheses) were Kirwan (Leonard), St. Francis (Berry), and Prairie Dog Creek (Leonard). The mapping, data collection, and report for the Prairie Dog Creek project were integrated with the Norton County study made by J.C. Frye, the associate state geologist, to minimize the duplication of work. Observation wells were constructed, partly by test drilling, but mostly by jetting 3/4-inch pipe in all areas proposed for irrigation under the Missouri River basin program. Those areas included at least one project in each valley of rivers tributary to the Republican River, and also along the Republican River in north-central Kansas. The wells became an important part of the well network used to define and describe the occurrence and conditions of ground water for those areas. The test drilling crew of the State Geological Survey also drilled a number of test-hole cross-sections across each of those valleys as a part of detailed field work.

The first Missouri River basin project reports were largely descriptive and qualitative. A four-man office was set up at Scott City in 1950, however, to conduct a more comprehensive, quantitative study of ground water along the Ladder Creek area. That work was headed by E.A. Bradley, who was assisted by C.R. Johnson, K.L. Parish, and J.J. Schmidt.

Ground-water studies in the glaciated area of northeastern Kansas began about 1950, when a regional series of test holes was drilled by the State drilling crew. Those test holes provided the first evidence of the buried pre-glacial valley system and a thick (locally 400 feet) section of glacial deposits in that area. Subsequent events resulted in postponement of work in northeast Kansas after two county studies were completed.

Period 1953–57

By Charles W. Lane

The disastrous floods in the Kansas River basin in 1951 were followed, in 1952, by severe drought conditions that continued through the rest of the decade. These events strongly affected water-resources programs in Kansas in later years.

Legislation creating the Kansas Water Resources Board was passed about 1953. Although not a formal cooperator in the ground-water program, the Board's planning and coordination functions strongly influenced priorities for future ground-water investigations.

Missouri River basin program funds for ground-water investigations in Kansas declined sharply in 1953 as previously started investigations were completed, and G.C. Prescott and W.W. Wilson transferred from the District in 1954. During 1954, G.J. Stramel transferred from Michigan and C.W. Lane from Iowa to work on the cooperative program. The number of Kansas Geological Survey employees assigned to the program during 1953 and 1954 remained stable. Also in 1954, Dr. F.C. Foley, a former Branch employee, was appointed Director of the Kansas Geological Survey replacing Frye.

Summary studies of Kansas water resources and water-resources problems were made at this time (late 1954 and early 1955) by the newly organized Kansas Water Resources Board. Through adjustments in the Kansas Geological Survey cooperative program, all District personnel participated in the effort. The studies permitted a thorough review of the results of the Kansas ground-water program and were highly beneficial to the District staff newly assigned to the Kansas program.

During 1955 and 1956, the number of personnel, both Branch and State, remained stable. The county-studies program continued with ongoing investigations in northwestern, south-central, and eastern counties of Kansas.

Severe drought continued to plague the State. The drought conditions, coupled with rising grain prices and the ready availability of deep-well pumps and irrigation systems, resulted in a phenomenal expansion of irrigation with ground water, particularly in western and central Kansas. Increased municipal and industrial demand for water in the Wichita area of south-central Kansas during the period resulted in a rapid increase in ground-water withdrawals in the ''Equus Beds'' supplying that area.

The rapid expansion of ground-water use statewide and the problems associated with this development created pressures for the expansion of the Kansas ground-water program. The expansion began in 1957 as the decade drew to a close. During 1956, G.J. Stramel and C.R. Johnson, a part-time graduate student, resigned from the Branch. Shortly thereafter, R.H. King was employed as reports editor, graduate student L.E. Mack was employed part-time, and K.L. Walters and W.G. Hodson, employees of the Kansas Geological Survey assigned to the cooperative program, were employed by the District. Walters and Hodson were replaced on the cooperator's staff assigned to the program by new employees. Program emphasis at the close of the decade was directed to immediate problem areas in western, south-central, and extreme eastern Kansas.

QUALITY OF WATER BRANCH

Reviewed and expanded by Russell H. Langford

Beginning in 1949, an area office was established at Norton to conduct sediment investigations in northwestern Kansas, southwestern Nebraska, and eastern Colorado, as part of the Missouri River basin program. It was under the direction of regional engineer P.C. Benedict at Lincoln, Nebr. The staff at Norton ranged from three to nine persons and the office continued to function through the end of the decade. D.M. Culbertson was in charge until 1955, when he transferred to Lincoln to supervise a newly-established area office. M.L. Thompson, who had been stationed at St. Louis, Mo., succeeded Culbertson and remained through the balance of the decade, but with a diminished program. Other senior members of the staff included H.P. Guy (1951–55), C.D. Albert (1952–54), C.R. Collier (1949–52), and J.K. Hicks and B.E. Mape (1953–57).

Because the calculation of fluvial-sediment discharges was dependent not only on frequent ''around-the-clock'' sediment sampling but also on accurate water-discharge records, the Branch personnel worked closely with local personnel from the SW Branch. Those who collected sediment samples also carried and used stream-gaging equipment to make critical flow measurements during flood and other high-flow periods. Beginning in 1955, staff of the Norton office took over the collection of streamflow records in northwestern Kansas by assignment from the SW district. The ephemeral nature of many streams, together with ''shifting sandbed'' conditions, made it difficult to establish and maintain a rating needed in calculation of streamflow and of daily amounts of fluvial sediments that passed the gaging stations.

H.P. Guy recalls that ''the sandbed conditions of many streams in Kansas, Nebraska, and Colorado required considerable 'in-office' efforts to determine suitable shift values for the rating, not only on a daily basis, but also in the detailed computations within many days for sediment discharge computations. The lack of desired results in finding suitable shift values prompted some special field research, such as the installation of canvas ribbons in the bed of Bijou Creek near Wiggins, Colo. The results from the ribbons were far from satisfactory. The sandbed rating problems in this area and many others later led to the formation of a special research project at Ft. Collins, Colo., to study the flow characteristics and sediment movement of alluvial channels.''

The staff of the Lincoln Regional office was actively engaged in the investigation of surface-water quality and sediment characteristics of streams within the Missouri River basin in Kansas throughout the decade. In 1953, W.H. Durum prepared a report, ''Relationships of the Mineral Constituents in Solution to Streamflow, Saline River near Russell, Kansas,'' which was published in Transactions of the American Geophysical Union. The report demonstrated conclusively that the water changed from a sodium-chloride type at low flow to a calcium-bicarbonate type at high flow. The samples obtained by the staff of the Norton, Kans., office before, during, and after a runoff event were invaluable in documenting the changes in water quality with changes in the base flow-overland flow ratio. As a result of these studies, the methods of compositing water samples for chemical analysis were refined for the Saline River and for other rivers under investigation by personnel of the Lincoln office. A summary report (WSP 1651, 1964) on results of chemical quality and sediment investigations of the Saline River was later prepared by P.R. Jordan, B.F. Jones, and L.R. Petri.

W.H. Durum and R.A. Krieger of the Lincoln staff also worked with their counterparts in the GW Branch. Their findings on the chemical quality of ground water in Lincoln County, in the Ladder Creek area, and on the North Fork of the Solomon River are included in reports on each project published as Bulletins of the Kansas Geological Survey (nos. 95, 126, and 98, respectively). In addition, F.H. Rainwater participated with V.C. Fishel and J.K. Searcy in a study of water resources of the Kansas City area, published as USGS Circular 273 in 1953.

KENTUCKY

SURFACE WATER BRANCH

Reviewed by L.E. Carroon and F.T. Schaefer

The District staff increased from less than 15 persons in the late 1940's to nearly 25 at the end of the decade. Approximately two-thirds of the personnel were located at District headquarters in Louisville, initially in the Federal building in 1953, in the Commerce building at Third and Liberty Streets in 1954, and in the former Gibbs-Inmar building at 9th and Broadway Streets from 1955 through the remainder of the decade. Two area offices were maintained, one in Paducah with a staff that increased from two to four persons during the period, and another of about the same size at Williamsburg. In cooperation with the Ohio District, a two-man field headquarters was also used at Cincinnati, Ohio, from 1953 to near the end of the decade.

F.F. Schrader was district engineer, having been appointed to that position in 1946. He was the only member of the professional staff to remain at District headquarters during the entire decade. R.W. Pride was office engineer until May 1949, when he transferred to become assistant district engineer for Florida. He was succeeded by E.J. Kennedy who had been in charge of the Williamsburg area office. Kennedy left for the Kansas District in 1953 and R.E. Steacy, who had been on Navy duty, succeeded him. E.G. Barron was designated assistant district engineer from 1947 (when he arrived from the Illinois District) until F.T. Schaefer arrived from the Nebraska District in 1949. Both Barron and Schaefer transferred in mid-1954, the former to Ohio and the latter to become district engineer in Wisconsin.

Other principal assistants at District headquarters during the later 1940's included J.E. McCall, L.V. Page, and D.D. Dickstein. All three had left by the early 1950's and new transferees included J.H. Hartwell, L.E. Carroon, N.O. Thomas, C.H. Hannum, and C.H. Minehan. A.S. Curtis was in charge of the Paducah office during the period. The Williamsburg office was initially directed by Kennedy, then by Dickstein, C.V. Burns, and Minehan, in that order. C.G. Birch was stationed at Cincinnati. Mrs. I.A. Fraser, the district clerk, handled the bookkeeping for the GW District as well, because the headquarters staffs of both Districts occupied adjacent space. Ms. D.J. Deddins handled the secretarial work until 1950 when she was succeeded by Ms. D.A. Hayes.

The cooperative program with the State for nearly all of the decade was with the Kentucky Department of Economic Development which was created in 1949 as the Agricultural and Industrial Development Board (AIDB). The AIDB took over the cooperative program formerly conducted with the Highway Department, the Department having used flood records in the design of eight new highway bridges in 1948 and 1949 that were estimated to have cost more than $1 million. Cooperative assistance from the State geologist provided for the preparation of a bulletin giving information on the water resources of the State as well as the status of current water-resources investigations.

Carroon recalls (written commun., 1985) that "by the mid-1950's, the Highway Department had an internal requirement that all highway bridges planned to cost more than $100,000 should have an hydraulic-sufficiency report from the Geological Survey. Because of the need to replace many older bridges, the number of requested bridge-site reports was taxing the capacity of the District to produce them. No special funding was being provided by the Highway Department. Several of the reports produced resulted in design changes that saved the Highway Department many times the total cost of the District's cooperative program."

Of the other Federal agencies giving financial support, the Corps of Engineers was by far the largest. As stated by Schrader (response to a WRD Circular dated July 15, 1947), streamflow records, including copies of all rating curves and related information for practically all gaging stations in the State, were furnished to district offices of the Corps in Louisville, Ky., Nashville, Tenn., and Huntington, Ind. The data were used in the design of flood-control and flood-protection projects costing many millions of dollars, and also for navigation operations and for flood forecasting and routing on the Ohio River.

Support by the U.S. Soil Conservation Service also was substantial. Data were required for projects that included flood-control studies at Dawson Springs and for projects in Jefferson County. Flow records were also furnished to the Tennessee Valley Authority and to the Mississippi River Commission.

Daily discharge was determined at about 93 locations in streams at the beginning of the decade as reported in Volume IV of the WRD History. The number had increased to about 123 station sites by 1958, not including periodic measurements of flow from 31 springs. The collection of stream-temperature data began in 1949 (WRD Bull., Aug. 1950, p. 68–70). Steacy (written commun., 1981) noted that "because of flat river slopes, Kentucky was noted for the number of gaging stations with three-dimensional ratings" and that "at least one gaging station recorded negative flow at times."

Schrader reported (in response to a WRD Circular dated June 11, 1951) that a report on flood and drought frequencies was under preparation in cooperation with the AIDB, and that completion and publication (by AIDB) was scheduled for 1953 or 1954. A report summarizing streamflow, temperature, and chemical quality carried the same time and publication schedule.

GROUND WATER BRANCH

By Matthew I. Rorabaugh

The work program at the beginning of the decade consisted of monitoring water levels, water quality, pumpage, and recharge to the heavily-pumped aquifer at Louisville. It also continued the Louisville Water Company river-infiltration studies, the four-county Bluegrass project, and the new statewide reconnaissance project (Follansbee, v. IV).

In mid-1948, the Bluegrass project and the Louisville Water Company project were finished. Fiscal year 1949 was a crisis year: funds totaled $20,000, which included $2,000 of ground-water research funds to M.I. Rorabaugh; scientific papers from data collected during the Louisville Water Company infiltration tests were prepared and published by the American Society of Civil Engineers, International Association of Hydrological Sciences, and American Geophysical Union; and personnel in the District dropped to six. To stay alive, the District did drafting for, and furnished help to, other districts.

Many external events in the late 1940's influenced the water program. An article entitled "Thank God for Mississippi" dealt with Kentucky's schools which were rated 47th in the Nation, one notch better than last-place Mississippi. This report awakened the public to one problem. Post-war unemployment was another major problem. In the cities, there were lay-offs in war-related industries. Many workers from rural areas who went north to work during World War II came back home. Servicemen also returned. Many people converted furnaces from coal to gas when the price of coal made gas cheaper. Many coal miners were out of work.

In remote areas, domestic water supply was obtained from a dug well equipped with rope and bucket, and there was no indoor plumbing. Returning servicemen and workers who, for the first time, had experienced running water and other indoor plumbing were unhappy in their home environment.

Postwar movement of industry from the North to cheaper labor in the South brought many requests for water information to the District office, State agencies, and the State Chamber of Commerce. It soon became apparent that Kentucky was failing to attract new factories in some instances because of a lack of basic water-supply information. The Governor appointed a committee to study all phases of the problems. Ten subcommittees were formed to cover the status of and needs for education, agriculture, water resources, minerals, transportation, industry, health, and other areas of interest.

One of the results of this appraisal was the creation of the Agricultural and Industrial Development Board (AIDB) which had authority to cooperate with Federal agencies and to coordinate work of State agencies. The AIDB's name was later changed to Department of Economic Development.

In 1948, the AIDB, under executive director Phil Miles, began an aggressive program to make basic information available. A cooperative program with the Geological Survey's Topographic (now National Mapping) Division to map the entire State (800 quadrangles) was started. The Survey was then asked to propose a State-wide water-resources program. This proposal was reviewed by all members of the Governor's Committee and adjusted to meet suggestions of State and other Federal agencies.

The ground-water portion of the plan included detailed area studies of one or two quadrangles in each of the six physiographic regions; a reconnaissance of all counties in each region for geologic, water-level, water-use, and water-quality data (this permitted transfer of detailed information from the area studies to any area of the State); the establishment of a network of water-level and water-quality monitoring points; and special short-term studies to meet critical needs. This program began in July 1949. The start-up was slow because of difficulties in obtaining qualified employees and vehicles. Field headquarters were established at each of the detailed study areas, with staff being increased as people and vehicles became available. As detailed area studies were completed, those skilled in report preparation were transferred to other headquarters where they were most needed.

Field Headquarters and Staff

The following is a listing of the various field headquarters and the staff within them: Paintsville: J.A. Baker (1949–53), W.E. Price, Jr. (1951–55), and Chabot Kilburn (1954–55); Henderson: E.J. Harvey (1949–53), B.W. Maxwell (1951–55), and R.W. Duval (1952–57); Newport-Covington: Samuel Berman (1949–51), F.R. Hall (1950–56), W.N. Palmquist (1952–55), and Chabot Kilburn (1955–56); Hopkinsville: J.H. Kietzman (1949–51); Scottsville: W.B. Hopkins (1950–55) and R.F. Brown (1952–55); and Paducah: H.L. Pree, Jr. (1950–54), W.H. Walker (1951–53), T.W. Lambert (1952–57), and L.M. McCary (1953–57). As the planned program neared completion, some field headquarters were discontinued, and the program was reevaluated and effort directed to areas of developing problems.

Reports during this period were delayed during the review process and by the lack of funds for Survey publication. In order to meet the needs of the AIDB, data were furnished to them through open-file releases, hydrologic atlases, circulars, and as basic data. That the AIDB's program to encourage industrial development was

successful is demonstrated by the fact that about $2 billion worth of new commercial and industrial activities were located in Kentucky in 1953. Water-resources information was an important factor in many of these establishments. Although large industries were attracted to the larger cities, many small industries went to small towns where unemployment was high.

The District work was supervised by M.I. Rorabaugh, the engineer-in-charge who became district engineer in 1949. In 1954, Rorabaugh was succeeded by G.E. Hendrickson as acting district geologist. Hendrickson became district geologist in 1955. Principal assistants to Rorabaugh were E.H. Walker (1949–53) and G.E. Hendrickson (1953–54). Other personnel included Mary Grunder, district clerk; Edith Nichols, drafting; and Irene Fraser (SW) and Maxine Catlett (GW) of the combined fiscal section.

Reports of investigations of this decade number about 60 published by the Survey, 10 by cooperators, and 15 by technical journals. Cooperators were the city of Louisville, the Louisville Water Company, the Kentucky Geological Survey, the Jefferson County Planning and Zoning Commission, the Agricultural and Industrial Development Board, and the Department of Economic Development. The National Park Service supported studies at Mammoth Cave National Park.

QUALITY OF WATER BRANCH

By William L. Lamar

No branch personnel were stationed in Kentucky during the decade. The investigations were conducted by personnel from the regional laboratory in Columbus, Ohio.

In 1949, a systematic study of the quality of water of Kentucky began in cooperation with the Agricultural and Industrial Development Board (AIDB) of Kentucky. The study of the surface waters from 1949 to 1957 was comprehensive. A number of daily water-sampling stations for chemical quality were maintained. At other points, samples were collected at intervals during the year and at low- and high-water flows.

Suspended-sediment studies were begun in 1951. Daily-sampling stations were established for the measurement of suspended sediment and particle-size analysis. Samples were collected daily during low and normal flows and more frequently during rapidly changing water discharge. Some cross-section sampling was included. Three reports on the results of this study were published by the AIDB. All were of the subject "Quality of Surface Waters of Kentucky." The first, by W.L. Lamar and L.B. Laird, covered 1949–51. The second, by Lamar, R.A. Krieger, and C.R. Collier, was for 1951–53, and the third, by Collier and Krieger, covered 1953–58.

An interbranch study covered the effects of strip mining on the Beaver Creek watershed. The segment covered by the QW Branch included a study of the chemical characteristics as necessary to define the changes caused by mining. The sediment-yield rates and the movement of sediment within and out of the watershed were determined. The effects of the healing of the mined area on the chemical and physical characteristics of the streams were determined.

The study of the ground-water quality was made in cooperation with the GW Branch. Laird was a member of an interbranch team that studied and reported on the water resources of the Louisville area, Kentucky and Indiana (USGS Circular 276, 1953). Some chemical-quality analyses and (or) suspended-sediment examinations were made for other Federal agencies.

LOUISIANA

SURFACE WATER BRANCH

By Milton F. Cook and J. Wyatt Gambrell

The stream-gaging program was conducted by personnel located at the District headquarters in Baton Rouge and at an area office in Jonesboro. The District office was in the Geology building at Louisiana State University until late 1947, when it moved to 538 Florida Street. In fall 1951, it again moved to an apartment complex at 850 North 5th Street and on July 1, 1956, to space at 315 Main Street.

E.B. Rice was the district engineer at the beginning of the decade. He left in July 1947 for a similar post in Raleigh, N.C., and was succeeded by W.R. Eaton. Eaton left in September 1948 to be district engineer in Tennessee and was replaced by F.N. Hansen, who continued in charge through the remainder of the period. Other members of the senior staff during the first half of the decade were J.W. Gambrell, J.D. Shell, E.L. Hendricks, and J.S. Cragwall. During the latter half of the period, the top staff consisted of M.F. Cook, T.W. Weinheimer, L.V. Page, J.H. Holm, and W.J. Randolph. E.J. Taylor was in charge of the Jonesboro office, assisted by R.P. Smith who succeeded Taylor near the end of the period. In early 1957, plans were made to establish another area office at Many, and this office was opened just after the end of the decade with E.M. Miller in charge.

At the beginning of the period, 54 streamflow stations were operated as part of the cooperative program with the Louisiana Department of Public Works or in collaboration with the Corps of Engineers. Of these stations, 25 were equipped with water-stage recorders, and the

stage-measuring device at the others was a wire-weight or staff gage. Recorders were installed at 13 of these sites, which represented a continuation of a program to upgrade the gaging-station facilities started in the mid-1940's when nine recorders were installed.

In order to make the best use of available funds, all of the gaging-station structures built during the 1940's and 1950's were corrugated metal pipe stilling wells topped with wooden or metal "half shelters." These relatively economical structures contrasted sharply with the few "standard" concrete gages that had been built with Work Projects Administration funds in the late 1930's when the statewide cooperative program began in Louisiana. There was a marked increase in funds in the cooperative program in the late 1940's and early 1950's. Much of the increase was used to finance project-type investigations, but funds were available to increase the gaging-station network and to upgrade gaging-station facilities. At the end of the period, approximately 80 streamflow-measuring stations were being operated, most of them equipped with recorders.

Two major project studies were started in 1948: (1) an analysis of the water resources of southwestern Louisiana with emphasis on water supply for rice agriculture and (2) a study of floods in Louisiana with emphasis on flood frequency at highway stream crossings. Hendricks transferred to Baton Rouge in August 1948 to be in charge of the surface-water phase of the comprehensive study of water resources in the southwestern area. Water-Supply Paper 1364 (1956) was prepared to present results of this study, which was one of the first areal studies of water supply for a single crop.

Cragwall transferred to Baton Rouge in January 1949 to be in charge of the flood study for the State. This was a new program with the Louisiana Department of Highways and, in the next 3 years, sites were selected for 100 new crest-stage gages. Many bridge-site stream crossings were analyzed for hydraulic characteristics, and a flood-frequency report was prepared and published in 1952 by the Louisiana Department of Highways. In June 1952, Cragwall transferred to Washington, D.C., and, in September 1952, Hendricks transferred to Atlanta, Ga.

The outstanding hydrologic event of the decade was the historic flood in spring 1953. Heavy rains in March and April set the stage for rainfall of from 10 to 26 inches in southwestern Louisiana from May 11 through 19. Many highways thought to be above flood elevations were inundated and several were washed out. A considerable area of Lake Charles was flooded by the Calcasieu River, which received some overflow from the Sabine River. Indirect measurements of peak discharge at three sites indicated that the flood was a rare hydrologic event in terms of frequency of occurrence (greatest flood of record since at least 1886).

The wide acceptance of the two project studies by State cooperators resulted in increased support for areal studies. At the end of the decade, water-resources studies were started in eight parishes in northwestern Louisiana and the flood-analysis program was expanded with the Department of Highways.

GROUND WATER BRANCH

By Paul H. Jones and Rex R. Meyer

The District office, located in the Geology building of Louisiana State University in Baton Rouge during the decade, had a staff that varied from 3 to 10 persons during the period. Also maintained was a one-person field headquarters at Oakdale and, beginning in 1952, a larger establishment at Alexandria that had a staff of up to six persons.

P.H. Jones, who had been in the District since 1942, was in charge until 1952 when he transferred to become district geologist for Pennsylvania. He was succeeded by R.R. Meyer, who had been with the Maryland District and who continued in charge through the end of the decade. Other members of the senior staff included A.N. Turcan, Jr., who remained for the entire period; J.L. Poole (1954 on); J.R. Rollo (1955 on); and G.T. Cardwell (1955 on). In 1953, S.W. Fader was the head of the newly established Alexandria office. Roy Newcome, Jr., was also on the staff.

The 1947–52 period was one of rapid industrial growth in Louisiana, and the need for statewide information on ground-water conditions increased steadily. As many as 30 formal requests for information were received each month. Records were collected at many thousands of wells during this period; by 1952, the inventory of ground-water withdrawals included most industrial and public-supply wells and about 160 irrigation wells. The observation-well network covered all areas where pumping exceeded a few million gallons a day and included more than 300 wells, some 50 of which were equipped with automatic recorders. Many observation wells were located in the rice-farming area of southwestern Louisiana, and records collected during 1939–47 provided a basis for the comprehensive regional study in that part of the District that was begun in 1948 and completed in 1952 (WSP 1364, 1956). Water-level and pumpage records for wells in the Baton Rouge area, coupled with preliminary geologic and hydrologic studies in progress from 1940 to 1952, led to comprehensive studies begun in 1952 and published in 1955 (WSP 1296).

By 1952, the State Geological Survey had about 5,000 electric logs of oil-test wells in their files that showed at least part of the freshwater section. Through statewide

ground-water studies, the U.S. Geological Survey had collected several thousand driller's logs of water wells. A portable "Widco" electric logger was obtained in 1947. Pioneer studies in ground-water exploration using electric logs led to the preparation of the first map showing the maximum depth of occurrence of fresh ground water, which was published in 1950. Laboratory studies were made of the relation between hydraulic permeability of sandbed aquifers and the electrical resistivity "formation factor," and results were published in 1951. Local studies conducted using electric logs led to the development of new or improved municipal water supplies in several localities, including Kinder, Elton, Bernice, Oakdale, suburban Baton Rouge, and suburban New Orleans.

By mid-1952, projects were being completed and the staff dwindled to three members. The staff again increased in 1953 when the recharge effects of a proposed dam on Bayou Cocodrie needed to be determined. Congress approved the purchase by the Louisiana District of a truck-mounted power auger to obtain shallow subsurface data in the Cocodrie area. In addition, logs of 1,200 seismic boreholes were purchased for $1 per hole, which was the cost of reproducing the existing records.

In 1954, a series of studies was planned and initiated on a block of nine parishes in northwestern Louisiana. The final reports on these parishes included an evaluation of streamflow by the SW Branch staff. A similar study was started in East and West Carroll Parishes. In the Tallulah area, a study evaluated ground water as an alternative source of irrigation water for Roundaway Bayou. A series of wells was eventually drilled on the bayou's banks to maintain streamflow during dry periods. More importantly, the pumping test was one of the first in a semiconfined aquifer system.

The industries using ground water in the Baton Rouge area cooperated fully during the field-work phase of the study in 1952–53. After the publication of the report (WSP 1296, 1955), a Baton Rouge Industrial Water Users Group was established for the interchange of ideas and suggestions, and a review of the ground-water conditions by the Survey. The group still meets annually.

During the 1950's, State officials recognized the importance of Louisiana's large ground-water resources. It was also a period of improved relations with water-well contractors and water users.

QUALITY OF WATER BRANCH

By Burdge Irelan

At the beginning of the period, quality-of-water work for Louisiana was confined almost completely to analyses by the Texas laboratory staff of samples of water sent in from several military installations, with Fort Polk and Lake Charles Air Force Base being the prinicipal ones involved. Also, probably less than a dozen samples a year that were collected by the GW Branch staff in Louisiana were analyzed. About 1948, a comprehensive study of the availability and use of water in the rice-growing area of southwestern Louisiana was proposed. The quality-of-water phase of the study included complete chemical analyses of daily samples as 10-day composites on the three principal rivers of the study area (the Vermilion, Mermentau, and the Calcasieu); partial analyses of many samples collected on periodic tours of the area, including lakes, streams, and canals; and numerous samples of ground water collected by the GW Branch staff from wells used either for public supply or for rice irrigation. Results of the study, which lasted about 3 years, were published in WSP 1364 in 1956. Burdge Irelan coordinated the quality-of-water phase of the study and wrote the quality-of-water section of the Water-Supply Paper, but several of the Austin, Tex., staff were involved in the field work at various times.

Following completion of the rice investigation, the Louisiana Department of Public Works proposed a more systematic study of stream waters in all of Louisiana. Daily sampling stations were established on the large rivers of the State—the Mississippi, Arkansas, Ouachita, Red, Atchafalaya, and Pearl. Periodic samples were collected at other sites. Ground-water samples collected by the Survey's GW Branch personnel located at Baton Rouge were extended to include work at Baton Rouge, New Orleans, and other locations in the State.

At first, essentially all work on water quality was handled from Austin, Tex., but, a few months after the end of the decade, S.F. Kapustka transferred from the East to Baton Rouge to coordinate the work. Later, a chemical laboratory was set up in Baton Rouge. M.L. Eddards, Jr., was headquartered in Baton Rouge on a temporary appointment in October 1948, but transferred to the local SW District staff a year later.

MAINE

SURFACE WATER BRANCH

By Richard A. Morrill

At the beginning of the decade, the Maine District, which was housed in the State Capitol building, maintained a staff of four people. M.R. Stackpole continued as district engineer, having become the first chief of the Maine office in 1920. He retired in 1955 after supervising the basic-data surface-water network for 36 years. After retirement, Stackpole lived in Mount Dora, Fla., until his

death in 1980. Lura McLain served as district clerk during these years.

It was District policy to have two assistant engineers in charge of the collection, processing, and preparation of data for publication for two different areas of the State. G.S. Hayes and K.B. Young were each responsible for data collection and publication in one of the two areas of Maine for several years prior to 1947. Hayes transferred to the New Jersey District in 1946 and returned to Maine in 1956 as district engineer. Young transferred to Washington in 1949 and was not replaced until 1951. R.A. "Red" Morrill was hired to replace Hayes in 1946. H.L. Metcalf and I.A. Snow worked as engineers for short periods. R.E. Campbell transferred to Maine from Boston for a 2-year period, then transferred to Mineola, N.Y., in 1954. From 1954 to 1957, M.C. Morrill, an engineer, was hired to assist in the office.

The District staff operated nearly 50 gaging stations at which daily discharge was calculated and published annually. Its staff also made or received periodic readings of water levels of more than 30 reservoirs. Other District achievements during the decade included answering an average of 980 requests per year for information on water resources of the State; preparation of local data for the "Compilation of Records of Surface Waters of the United States through September 1950" with Morrill as project chief; preparation of flow-duration tables for all stations, which were then published in the biennial reports of the Maine Public Utilities Commission; and publication of an annual snow map, which involved making about 200 measurements of the water content of snow and compiling those data with data from other sources to show lines of equal water content of the snowpack as of March 1st of each year.

The programs in Maine were in cooperation with the Maine Public Utilities Commission and the annual cooperative State funds available were:

1948 - $8,500	1953 - $10,500
1949 - 9,000	1954 - 11,000
1950 - 10,000	1955 - 11,000
1951 - 10,000	1956 - 12,500
1952 - 10,000	1957 - 12,500

In addition to the cooperative funds listed above, a total of about $4,900 per year was allocated to the District from Federal program funds to cover partial costs of operating gaging stations near the Maine-New Hampshire border and along the U.S.-Canadian border.

GROUND WATER BRANCH

By O. Milton Hackett

Negotiations between State of Maine officials, O.M. Hackett, and J.E. Upson in 1956–57, assisted by G.S. Hayes, district engineer at Augusta for the SW Branch, led to a cooperative ground-water program with the Maine Public Utilities Commission beginning shortly after the end of the 1947–57 decade. G.C. Prescott, who had transferred from the headquarters staff in Washington, D.C., in September 1957, was placed in charge and was headquartered at Augusta. His first task was to complete a long-range plan for the program in Maine, and this became a blueprint for work lasting through the next decade. The first study under that plan, a reconnaissance of south coastal Maine, was also begun by Prescott.

QUALITY OF WATER BRANCH

By Felix H. Pauszek

Water-quality studies in Maine were conducted in the QW laboratory in Albany, N.Y., under the direction of F.H. Pauszek, district chemist for New York-New England. These studies were conducted in support of the cooperative programs established by the SW and GW Branches with State agencies. Water samples were collected by local SW and GW personnel.

INTERBRANCH ACTIVITY

By Joseph E. Upson, II

Maine was the scene of a unique interbranch investigation in summer 1951 to map the thickness, nature, and extent of unconsolidated deposits on the bedrock beneath the waters of Passamaquoddy Bay. It was largely, if not entirely, financed by the Corps of Engineers, Boston, Mass., district, in connection with the Corps' evaluation of tidal-power possibilities. The staff was carefully selected from all parts of the country. W.O. Smith, who was in charge, was from the Washington, D.C., office and was assisted by C.E. Mongan (then on loan from the Edo Corporation, New York City). J.E. Upson, who headed the geologic studies, came from the California District. A.I. Johnson and S.J. Spiegel were from Nebraska, and R.W. Stallman was also from Washington, D.C. C.E. Knox, from the District SW office in Boston, worked on vertical control for the soundings, no mean exercize in this area where sea level could change as rapidly as a foot in 15 minutes. For some, this was their first experience with Maine lobster, seaweed-roasted corn, and fresh blueberry pie. Sonar studies, in early stages of development by the Navy, were conducted by boat (a converted coastal salt-and-coal carrier) during intensive field work in June and July 1951. Data were analyzed and maps drawn in fall 1951 and in the early months of 1952 when a report was completed. Copies of

the report were sent to selected SW districts by WRD memo dated October 12, 1953. Aside from the report (USGS Open-File, 1952) to the Corps of Engineers, the only publication of findings was in a paper by J.E. Upson, W.O. Smith, and others that was published in the New York Academy of Sciences Transactions about 1952 or 1953.

MARYLAND

SURFACE WATER BRANCH

By Floyd F. LeFever

The College Park District had jurisdiction over programs in Maryland, Delaware, and the District of Columbia during the entire decade. Descriptions of activities in Delaware and the District of Columbia will be found under those headings. The headquarters staff, which was located in space provided by the University of Maryland, varied from about 10 to 18 persons. In 1950, an area office was established in Dover, Del. In the same year, another area office was established in Cumberland, with a staff of three or four persons.

V.R. Bennion was district engineer, having served in that capacity since 1945. In 1949, he left for a similar position in Iowa and was succeeded in September of that year by F.F. LeFever, who had been in charge of the Ellenville Subdistrict in New York. In February 1957 near the close of the decade, LeFever transferred to become district engineer for Nebraska and was succeeded in April 1957 by J.W. Odell, who had been assistant district engineer at the Salt Lake City, Utah, District. R.O.R. Martin was second in charge through 1948. In 1956, he joined the Branch headquarters staff. D.F. Dougherty was second in charge from 1949 until 1952 when he left for an assignment in Saudi Arabia. He returned in November 1953 and, in December of that year, transferred to the Virginia District. J.M. Darling, on the staff since 1949, was placed in charge of a Subdistrict office at College Park near the end of the decade. L.W. Lenfest, arriving from the Ithaca, N.Y., area office in 1950, served as office engineer until 1952 when he became the principal assistant. Mrs. M.R. Lowry was district clerk for the entire decade.

The Cumberland office was opened by L.A. Koffman who was succeeded by R.M. Beall in 1953. Beall moved to District headquarters in 1955, and was replaced by E.H. Mohler, Jr.

Tate Dalrymple, a specialist in highway runoff and member of the staff of the Branch chief, was headquartered at College Park from September 1946 to August 1947 to fill a new position set up to promote nationwide cooperative programs with State highway departments. In 1948, he held in College Park the first training school for WRD personnel working on highway programs. He also began a research project in Maryland to study the variation of peak discharges with size of drainage area for small basins.

Early in the decade, the use of fresh surface water in Maryland was reported (USGS Circular 114, 1951) to be "... about 400 million gallons per day (about 90 percent of it for Baltimore and Washington), plus about 500 million gallons per day ... of brackish water from Patapsco River for industrial use in Baltimore ...." Besides the two major metropolitan users, at least five other cities or counties needed knowledge of local surface-water resources for current use and future plans. The statewide pollution-control program, the need for water-rights legislation, and increasing use of surface water for supplemental irrigation required more data, especially on low flows.

The cooperative program with the State Roads Commission, which began late in fiscal year 1947, required data on peak discharges from small drainage areas. Floods in Maryland have resulted from such a wide range of hydrologic factors that maximums for the periods of record have occurred somewhere in the State for every month of the year. The program with the Corps of Engineers provided data for developing operating procedures for flood control and flow augmentation at Savage River Dam and for studying the potential for more storage in the Potomac Basin.

The primary program objective during the decade was to furnish basic data to meet the above needs. Analyses and report preparation were generally limited to SW sections of a series of interbranch county reports published by the State, preparation of bridge-site reports for the Roads Commission, and informal requests from various agencies. To complete State coverage, 21 stations were added to the network in fiscal years 1948 through 1950 through programs set up by Bennion with the State Geologist. General hydrologic coverage was then considered adequate. Additionally, small-area coverage was provided by about 10 stations and several crest-stage gages through the highway program. Other stations were built to meet special needs around the two metropolitan areas. A special research project for studying variations of peak discharge with size of drainage area for small basins set up around the beginning of the decade by Dalrymple was conducted by the College Park District personnel.

In 1954, a total of 81 gaging stations were in operation in Maryland. This figure included all eight mainstem Potomac River stations from Kitzmiller to Washington. Also, a partial-record station at Shepherdstown, W. Va., was used for flood records only. Maryland funds supported two of the three additional stations in Pennsylvania that were operated by the District. Graphs

of water temperatures were obtained at four stations. Three stations in the Cumberland area and the station on the Potomac River near Washington were equipped with Telemark instruments. The Federal-State cooperative work made up about 80 percent of the total program. The Department of Geology, Mines, and Water Resources (J.T. Singewald, Jr., director) accounted for about 85 percent of the total cooperative activity. Most of the remaining 15 percent was provided by State Roads Commission (R.H. McCain, chairman, and A.L. Grubb, chief, Bureau of Bridges), the City of Baltimore (J.S. Strohmeyer, water engineer), and the Washington Suburban Sanitary Commission. The Corps of Engineers provided funds for 15 stations. Maryland ranked fourth among all States in number of gaging stations per 1,000 square miles (table 1, pamphlet, "Report of Committee on Stream-Gaging Programs"). Median drainage-area size for the District's station network was less than 50 square miles as compared with 400 square miles for the country as a whole. The high density resulted mostly from two factors: (1) the addition of small-area stations through the highway program, and (2) expanded programs on the Eastern Shore where streams are tidal for most of their length, leaving only small upper portions to be gaged.

Many stations were new, but the District had some with unusually long records. These included the Potomac River gages at Chain Bridge near Washington estalished in 1891, upstream at Point of Rocks (1895), the North Branch Potomac River at Cumberland (1894), the Monocacy River at Ceresville Bridge (later at Jug Bridge, 1896), and the Patapsco River at Woodstock (1896).

A second major objective was the improvement of the quality and consistency of records. The two most effective steps toward this objective were the establishment of Subdistrict or area offices with responsibilities for both field and office work, and the introduction of improved computation procedures, especially for periods of ice effects.

The Dover, Del., Subdistrict office was assigned all 32 stations east of the Chesapeake Bay, including 19 in the 9 Eastern Shore Counties and 13 in Delaware. Because of the predominance of new and small-area stations, adequate servicing out of College Park was impossible, even after completion of the Bay Bridge in 1952 that reduced traveltime.

The Cumberland area office, located in the Post Office building, was assigned 20 stations, about half of which had to be serviced at or near the first of each month to provide current data to the Corps, Weather Bureau, and Upper Potomac River Commission , which represented major industrial and municipal entities in the region. Water temperatures were obtained for the Corps and State fishery interests, and six wells were monitored for the GW District. Evidence of the appreciation of this timely, wide-ranging service, and something of the excellent public relations it engendered, is recalled by Beall (written commun., 1982): "The Cumberland newspapers eagerly sought local water news items, to such an extent that an upper Potomac 'review' statement was prepared monthly during the open-water season, generalizing on the techical data provided by official distribution."

The need for improved and more careful streamflow-computation procedures was revealed when winter records for the 1949 water year (already computed before LeFever's arrival) were tested for interstation-flow consistency by means of basin studies and comparisons by semilog hydrographs. The inconsistencies found in the 1949 records were undoubtedly indicative of similar deficiencies in past years, but only the current year's records were revised. Because of the high station density throughout the State and especially along the Potomac mainstem, subsequent flow records were tested for consistency.

Personal Recollections

College Park proved to be an excellent assignment for a neophyte district engineer. Instead of the over-supervision which I had expected with such close proximity to National Headquarters, visits by such SW and WRD officials in my 7-year tenure were almost nil. Contacts were usually on my initiative. No doubt A.H. Horton benefited from similar circumstances after he moved his District staff from space at National Headquarters to College Park in 1940. When asked for his appraisal of the move, he is said to have exclaimed, "Now I'm free as a bird."

Other advantages included availability of Washington Headquarters technical personnel, especially flood specialists Dalrymple and M.A. Benson, for occasional 1-day visits. Also, I arranged several 1-day inspection trips for engineers in Washington on review detail. Two options were offered: (1) a trip to western Maryland or (2) a trip to the Eastern Shore and Delaware.

Soon after my arrival, I had the unique experience of carrying a payroll of nearly $1,000 in currency on an overnight trip to gage construction sites in western Maryland. To improve labor relations through prompt cash payments, Bennion (always an innovator and expeditor) had set up an account of alloted funds in a Riverdale bank from which he and (or) Martin were authorized to withdraw cash to meet weekly payrolls. W.B. Marshall II, a young construction engineer who was building two North Branch Potomac River stations simultaneously, had phoned in his payroll projections.

Unaccustomed to carrying that much money and fearing a holdup, I spent a restless night in the motel.

GROUND WATER BRANCH

By Gerald Meyer

The District office was located at Latrobe Hall, Johns Hopkins University, in Baltimore for the entire decade. It had jurisdiction over the Delaware program as well until 1954, when the Newark, Del., Subdistrict was given District status. The program in Delaware for the entire period is described under that State. The District headquarters personnel ranged from five to eight in number. An area office, maintained in Salisbury from 1949 to 1954, had a staff ranging from three to six.

R.R. Bennett, who had established the cooperative program in 1942, was district geologist until 1953 when he transferred to Washington, D.C., to serve as chief, ground-water research. He was succeeded by E.G. Otton who had transferred from a field headquarters in Lexington, Ky., in 1949. Other senior members of the headquarters staff included R.R. Meyer (until 1952); Gerald Meyer (from 1948); H.F. Ferguson (1949–55); J.W. Brookhart (until 1949); R.J. Dingman (1952–55); and Ms. C.A. Richardson for the entire decade.

The Salisbury area was under W.C. Rasmussen until 1954 when he moved to Newark, Del., to take charge of that newly created District. I.W. Marine, who joined the staff in 1951, moved to Newark in 1953. D.H. Boggess, who had begun investigations in the Salisbury area in January 1951, transferred to Newark in 1952. G.E. Andreason was on the staff from 1950 to 1953 when he resigned.

Except for minor allocations of Federal program funds, the Maryland activities were supported by the cooperative program with the Maryland Department of Geology, Mines, and Water Resources (Maryland Geological Survey prior to 1941 and after 1964). The District staff and that of the Maryland cooperator (abbreviated Md. Dept. GMWR in this summary) occupied adjacent space in Latrobe Hall, which invited a close working relation between the two organizations. Two State employees were assigned to the cooperative program, R.M. Overbeck (for essentially the entire decade) and T.H. Slaughter (1950–57), and each authored several county ground-water reports.

During the 6 years following initiation of the Maryland cooperative program that included the era of World War II, cooperative ground-water investigations were focused on the Baltimore industrial area and its water supply, with particular emphasis on saline-water intrusion phenomena that threatened the chemical quality of the bountiful ground-water supply. During 1947–57, however, the scope and magnitude of the investigative program broadened to include systematic areal coverage of ground-water resources of the 23 counties of the State. Statewide observation-well, spring-discharge, and water-sampling networks were established. The growing population of southern Maryland and the agricultural and municipal water needs of the Eastern Shore attracted first attention to the counties of these two regions. An investigation of Anne Arundel County, adjacent to Baltimore City on the east, was the first to be completed and published in 1949 (Md. Dept. GMWR Bull. 5, p. 28–143). Later studies covered the Piedmont, Valley and Ridge, and Appalachian regions of the State, whose rural counties, with their small populations and modest water demands, justified only secondary priority.

Collection of hydrologic and geologic data for these studies was aided immensely by the existence of Maryland's Water Resources Law of 1933 and the complementary Well Law of 1945. This law required that well drillers obtain a permit for each well, designate its location, and furnish a well log and construction data upon completion of the well.

The Baltimore industrial-area study was concluded about 1947, and a comprehensive report by R.R. Bennett and R.R. Meyer was published in 1952 (Md. Dept. GMWR Bull. 4). Its findings provided a sound technical basis for major water decisions with respect to pumpage and contamination management. This classic study also yielded numerous innovative scientific contributions. These included the first rigorous application of engineering flow-net analysis to a large, developed ground-water system; the design of a prototype of multiple-probe geophysical equipment for borehole logging and applications of these borehole findings to geological and ground-water interpretation; and original geochemical approaches to the identification of contaminant (saltwater) migration.

To their credit, the primary cooperating official, Dr. Joseph T. Singewald, Jr., and District Geologist Robert R. Bennett, provided an investigative climate conducive to research, and the Maryland ground-water program yielded a number of other important findings that have broad applications in hydrology. Development and applications of the borehole geophysical logger continued, and its success led to the establishment of a formal WRD research and logging-service facility for borehole geophysics in the Division. Delineation of the water-bearing characteristics of the crystalline rocks underlying the Piedmont region of the State enabled the siting of wells and well-construction design more in tune with the physical and hydraulic features of the crystalline-rock ground-water systems, providing well yields much greater than the modest rates earlier believed to be the maximum

possible (Md. Dept. GMWR Bull. 4, 14, 17, 22, and others). W.C. Rasmussen and G.E. Andreason conducted a quantitative measurement of the hydrologic budget of the Beaverdam Creek basin in the Salisbury area, Wicomico County, which provided an index to the magnitude of water influx, storage, and discharge that has applications to water studies and water management throughout much of the Coastal Plain region of the Atlantic coast (USGS WSP 1472, 1959). By the end of 1957, areal ground-water reports in manuscript or published form were completed for much of the State, and many of the hydrogeologic and geochemical phenomena important to good developmental and management practices statewide had been investigated.

MASSACHUSETTS

SURFACE WATER BRANCH

Condensed from documentation by D.J. Fogarty and G.H. Searles

The Boston District, as it was generally referred to, had jurisdiction over Branch activities in Massachusetts, New Hampshire, Rhode Island, and Vermont. These are described under each State. All personnel during the decade were assigned to District headquarters located in Boston's Post Office building. The District staff varied in number from more than 20 to about 30 persons during the decade.

H.B. Kinnison, district engineer since 1925, continued in that position until November 1956 when he was designated as the first Branch area chief for surface water for the Pacific Coast area. He held that post until his death in 1959. C.C. McDonald, in his memoir of Kinnison (*WRD Retirees* newsletter no. 19, p. 2) states that "he was a warm and friendly man, distinguished in bearing, unflappable, but modest." He "developed the 'Kinnison' cable for suspension of current meters . . ., refined the techniques for determining river discharge under backwater conditions," and pioneered [in collaboration with B.R. Colby] in the analysis "of flood frequencies and magnitude" which "received wide acceptance for the design of bridge openings, culverts, and spillways."

C.E. Knox, who had been on the District staff during 1936–41 and again since 1946, succeeded Kinnison as district engineer. Knox had served as second in charge before this time. G.K. Wood, who had been the office engineer of the District since 1942, continued as the third most senior professional member of the staff through the end of the decade. Mrs. E.C. (Crowley) Harbour served as district clerk until 1955 when she was succeeded by Ms. A.G. Gagnon.

Members of the staff who remained for all or nearly all of the period included J.V. Bagley, F.B. Cook, D.J. Fogarty, K.M. Kelley, G.H. Searles, and Ms. L.A. Swallow. Those present at the beginning but not at the end of the decade included E.L. Burke, W.S. Daniels, J.H. Hartwell, G.A. Miller, C.H. Minehan, A.M. Moore, W.P. Somers, and R.E. Steacy. R.M. Beall, H.A. Carlson, and L.V. Page were with the District for several years during mid-decade. Several who joined the staff at mid-decade and continued to the end of the period included C.G. Johnson, Jr., N.J. Roy, and J.W. Taylor.

D.J. Fogarty recalls (written commun., 1985) that one of the most noteworthy District achievements beginning in the late 1940's was the use of technical students from Northeastern University under a cooperative training arrangement wherein they would join the District staff for periods of from several weeks to several months at a time. Fogarty, who supervised many of them, states that they contributed significantly in both field and office and, by being assigned specific responsibilities, matured rapidly, and several joined the District after graduation.

Kinnison reported as of June 1951 that the station network in Massachusetts included 60 locations at which daily streamflow was calculated. Of these, 44 were funded under the cooperative program, 14 were supported with other Federal agency funds, and 2 were supported with allotments from the Federal program. By 1958, shortly after the end of the decade, program statistics show a total of 67 daily-streamflow stations, 25 of which were in cooperation with the Department of Public Works, 3 with the Water Resources Commission, 16 with the Metropolitan District Commission, and 9 with the Department of Public Health. The Corps of Engineers funded 11 stations. The contents of seven reservoirs were monitored daily as of 1951 as compared with periodic readings on nine reservoirs as of 1958. Periodic temperature readings were taken at 58 of the streamflow stations in 1951 and at 78 sites by 1958.

Among the floods that were measured, studied, and reported on during the decade were the "New Year" flood of 1949 (USGS Circular 155, 1952) and the floods of August and October 1955, which extended from New England to North Carolina and were documented in WSP 1420 (1960). G.K. Wood (career notes, 1963) supervised the preparation of the District's segment of WSP 1420 and also selected the sites for the indirect measurements. D.F. Farrell (career notes, 1955) tells of spending 2 months in the field and 1 month in the office making and computing indirect determinations of discharge. A drought occurred in New England in 1948–49 and was reported on by Knox (New England Water Works Journal, 1949, v. 63, no.3). Steacy mentions working on a "low-flow frequency study" (career statement, 1946–51).

The monthly water bulletins that were begun in 1941 (Follansbee, v. IV, p. 101) were continued during the decade. Mailed to several hundred various individuals and

companies and to municipal, State, and Federal agencies, the bulletins not only reported current streamflow conditions, but predicted flows for the next month based on streamflow records, ground-water elevations, snow-survey data, reservoir storage, and precipitation records. Fogarty was the bulletin editor during the decade. He recalls (oral commun., 1984) that the District was a "clearinghouse" for numerous public agencies and utilities who collected and sent in results of periodic measurements of their snow courses. At the end of the snow season, all of these data were summarized by the District, used in meetings of the Eastern Snow Conference, and published in the annual Conference Bulletin.

Studies of runoff from small drainage areas continued from the previous decade in cooperation with the Department of Public Works and led to a better use of hydrologic knowledge in highway design. Steacy mentions (career notes, 1946–51) working on an "expanded network" of such stations. The District's segment of the nationwide compilation of streamflow data through September 1950 was done under the leadership of Page and was published in WSP 1301 (1954).

Knox had a lead role in the preparation of maps and text depicting the runoff and water loss of New England streams during 1930–49. He also prepared a portion of a report on average annual runoff and precipitation for the New England-New York area, compiled jointly with the U.S. Weather Bureau, published as USGS HA-7 in 1955. The study was sponsored by the New England-New York Interagency Committee, which was established in 1950 by Presidential Order.

Knox spent a portion of summers 1948 and 1953 on detail to the Geologic Division, working with Chief Geologist W.H. Bradley on a determination of the effects of cutting a new entrance to Nantucket Bay (1948) and on a study of Sagadahoc Bay in Maine (1953). From September 1956 to June 1957, Knox was selected by the Survey to attend the graduate-level Water Resources Seminar at Harvard University.

In 1954, Wood, assisted by Swallow, prepared a 140-page instructional manual on computation of streamflow records. This was used extensively in the District and served as a model for a later manual in the Portland, Oreg., District.

GROUND WATER BRANCH

By O. Milton Hackett

The decade was a period of growth and diversification for the ground-water program in Massachusetts. At the onset, the program was small and beset with problems. That it existed at all may be credited mainly to the efforts of H.B. Kinnison, district engineer of the SW Branch at Boston. No single agency of Massachusetts was responsible for water resources, but Kinnison, who was highly respected in local engineering circles and strongly influential with the State agencies, was able to persuade the Massachusetts Department of Public Works (MDPW) to begin a small cooperative ground-water program in 1947. MDPW already had programs with the SW Branch and the Topographic and Geologic Divisions who supplied basic data that was clearly supportive of the MDPW missions for development and maintenance of highways and waterways. The benefit of ground-water studies to the MDPW was much less clear; its interest was marginal, and promised little opportunity for program expansion.

Other problems centered on the lack of trained personnel and the rapid turnover of personnel in the Boston office. While the lack of trained personnel resulted partly from the large expansion of the GW Branch after World War II, it was aggravated by the lack of antecedent ground-water activities in the Northeast and consequent lack of personnel, especially geologists, trained in problems particular to that region. The rapid turnover stemmed from an unusual tacit understanding at the local level that geologic mapping was solely the domain of the Geologic Division. This prevented ground-water geologists from mapping as needed for ground-water studies and from gaining necessary experience, which led to frustration and low morale.

Nevertheless, progress in the early 1950's was steady but slow. The program was under the general supervision of M.L. Brashears, Jr., district geologist for New York and New England, with headquarters on Long Island. H.N. Halberg was engineer-in-charge of the Boston office with responsibility for work in Massachusetts. The office was in the old Post Office building. Norma E. Lathrop was clerk, and professional staff included H.L. Pree, Jr., M.A. Pristrang, Aare Sinisala, T.A. Gorman, Walter McDonald, Jr., and E.A. Noble. The program consisted of a statewide network of observation wells, a statewide reconnaissance, and a study of the greater Boston area. Support for the reconnaissance was supplemented by funds from the New England-New York Interagency Commission and many of the data and results were incorporated in the reports of that commission in 1955.

In 1952, Brashears resigned to become a consultant, and J.E. Upson II from the California program replaced him as district geologist. About this time, training of young ground-water professionals in the post-World War II period was beginning to pay off and, in summer 1954, Upson was able to transfer O.M. Hackett from the Montana program and J.A. Baker from the Kentucky program to strengthen the Boston staff. H.N. Halberg was reassigned to a new segment of the Federal program for studying water supplies of urban areas, with headquarters

remaining in Boston, and Hackett was placed in charge of the Boston office.

Coincidentally and fortuitously at this time, concern with State water problems led the Commonwealth of Massachusetts to establish the Massachusetts Water Resources Commission. The interest of the commission provided an opportunity to expand and diversify the cooperative ground-water program, and formal cooperation with the Commission was begun in 1956 with new funding to supplement that from the MDPW. Also, at about this time, an agreement was reached with the Geologic Division, which gave personnel of the GW Branch freedom of action to conduct geologic field work as needed for ground-water studies.

In 1956, the Boston District of the GW Branch was established and Hackett was named district geologist with responsibility for activities in Massachusetts, Maine, and New Hampshire. The GW and SW District headquarters staffs were relocated to the Oliver building in 1957. Additions to the professional staff during 1954–57 were H.G. Healy and, for short periods, Richard Hecht.

Localities under study included the Lowell area, upper Ipswich River basin (Reading-Wilmington area), lower Ipswich River basin, Brockton-Pembroke area, Mattapoisett River basin, and Ware-Quaboag-Quinebaug River basins. The river-basin studies included input from the SW Branch staff. To meet the urgent needs of the State, the early results usually were open-filed in a series of basic-data reports, usually published by the State. These were supplemented later, when appropriate, in greater detail by Water-Supply Papers and Atlases in the Federal series published in the early 1960's.

QUALITY OF WATER BRANCH

By Felix H. Pauszek

Water-quality studies in Massachusetts were under the direction of F.H. Pauszek, district chemist for New York-New England, whose office was in Albany, N.Y. These studies were conducted in support of the cooperative programs established by the SW and GW Branch staffs with State agencies. Water samples were collected by local SW and GW personnel, and analyses were made in the water laboratory in Albany.

MICHIGAN

SURFACE WATER BRANCH

Condensed from documentation by A.D. Ash

The Michigan program, from its reactivation in 1941 until 1950, was administered by the Indiana-Michigan District with headquarters in Indianapolis, Ind. D.M. Corbett was district engineer. The work in Michigan was conducted from the three Subdistrict offices located in that State during 1947–50. A.D. Ash, engineer-in-charge of the principle Subdistrict office in Lansing, Mich., had the responsibility of acting as liaison officer between Corbett and the State and Federal cooperating officials in Michigan. As the program grew in size and complexity, caused in part by program commitments from the disastrous flood of April 1947, the need for a separate District was realized. The Michigan District was established and Ash was designated district engineer in December 1950 with headquarters in Lansing. In June 1951, S.W. Wiitala transferred from the Houghton Subdistrict to Lansing as assistant district engineer.

The Lansing office, a Subdistrict until 1950 and District headquarters thereafter, was located at 112 East Allegan Street in the Capitol Savings and Loan building during the entire decade. As a Subdistrict, it had jurisdiction over the program in the lower part of the Lower Peninsula. Dale Pettengill was principal assistant to Ash until he transferred to Grayling in 1949 and was succeeded (until 1951) by E.R. Buxton. The staff at Lansing grew from about 7 in 1948 to as many as 16 in 1955, and decreased to about 12 in 1957. It included Ms. M.P. Mahee and Ms. Lorraine Pomp, who were among the first WRD female employees to be directly associated with surface-water hydrology.

The Grayling Subdistrict office was located in the Fish Hatchery building that was owned and maintained by the Fish Division of the Conservation Department. The staff conducted the programs in the upper part of the Lower Peninsula comprised principally of the Muskegon, Pere Marquette, Manistee, Cheboygan, Thunder Bay, and Au Sable River basins. L.E. Widman was engineer-in-charge until 1949 when he was succeeded by Pettengill who remained in charge for the remainder of the decade. During this period, the staff size ranged from about two to five.

The Houghton Subdistrict office was located in the Community building, 100 Portage Street, until 1956, when it moved to a more central location at Escanaba in the newly completed State Office building that housed almost all of the Upper Peninsula State personnel. The move permitted day-to-day contact with the Upper Peninsula State cooperating officials. Office space was furnished by the State Geological Survey on a direct expenditure basis. The Houghton (Escanaba) office staff was responsible for the program in the Upper Peninsula. M.E. Noecker was engineer-in-charge until 1948 when he was succeeded by Wiitala from 1948 to 1951; L.G. Stearns from 1952 to 1953; F.G. Snyder III from 1953 to 1956; and R.L. Knutilla from 1956 to the end of the decade. Staff size ranged from about two to five during

this period. The engineer in charge of each Subdistrict office from 1947 to 1950 was responsible for all phases of the program in his area, including working up the discharge records. Each also administratively reported directly to the Indianapolis District office during that period.

During the decade, and particularly during the first half, the demand for information on lakes and streams increased greatly for several reasons. In the southern part of the Lower Peninsula, requests for flood protection were made to various agencies by residents and industries along most of the large rivers and many of their tributaries. In response, cooperating agencies requested that the USGS install additional streamflow stations and replace many nonrecording stations with recorders. Many of the streams were heavily contaminated with industrial wastes, and the expansion of the gaging-station network gave members of the Water Resources Commission information they needed for measures of abatement and control. Streams in the Northern Peninsula were subject to flash flooding and some were polluted from mine and factory wastes.

The major part of the expansion of the streamflow network was in the southern part of the State. S.B. Koks was in the Lansing office during the entire period and was assigned to construct and maintain the recording-gage structures. The number of stream-gaging stations in the District varied from 105 in 1948 to 143 in 1957, with a maximum of 147 in operation during 1954. About 44 percent of these stations were equipped with continuous recorders at the beginning of the decade, and reached 76 percent by 1957.

In the early 1940's, in cooperation with the Department of Conservation, a specific network of gages had been established to measure levels of certain lakes. In subsequent years, this network was made more flexible to provide a broad areal coverage of lakes to answer specific requests for data, and to obtain information on a large portion of Michigan's many lakes. Michigan's inland lakes, most of which are located in the upper part of the Lower Peninsula and in the Upper Peninsula, are probably the State's largest tourist attraction. The lake level and outflow- and inflow-measurement program was accelerated to meet the demand as the tourist indusry grew.

The number of lake gages, however, remained about constant during the decade, with considerable shifting after about 5 years of recording to obtain more areal coverage. There were 84 gages in 1948, of which 9 had continuous recorders; in 1957, there were 85, of which 16 had recorders. During the period, many discharge measurements were made also on outlet and inlet streams.

During April 1947, the lower part of the Lower Peninsula received extremely heavy rains, which caused the greatest floods since 1904 and the most destruction to property ever recorded. In the River Rouge basin, practically every bridge opening proved to be inadequate and sewerage outlets were inundated. (Follansbee, v. IV, p. 144, describes this flood and District efforts to measure floodflows.) After the April 1947 flood, the Saginaw Valley Regional Planning Commission asked the District to prepare a report on past floods in the Saginaw River basin, with particular attention to the 1947 flood, and contributed $5,000 towards its cost. The report was prepared mainly in the Indianapolis office and was transmitted to the commission in November 1947. The report, marked "provisional—subject to revision" and covering floods from 1873 to 1947, was never published, but a copy is on file at District headquarters in Lansing.

In 1950, in cooperation with the Department of Conservation, a study was begun of the Upper Rifle River basin in Ogemaw County in the Upper Peninsula, a 117-square-mile area with abundant springs, flowing wells, and cold-water streams. The investigation was both broad and comprehensive, covering all aspects of the hydrologic cycle, with the justification that the findings would give a better understanding of other river basins in the north country. F.G. Snyder III was assigned full-time to the project, with headquarters at Rose City, until he transferred to Houghton in 1953. The project was continued by personnel from the Grayling office. The report was published apparently by the State in 1971.

Beginning in 1954, District personnel participated in an interagency (Federal and State) study of four small agricultural watersheds in the Sloan-Deer Creek basins in southern Michigan to provide data needed for the design of drainage and water-control facilities. Findings were reported by Ash and others and published in 1958 as Water Resources Commission Report No. 1. The report was prepared primarily to document the effects of the April-through-May 1956 storm period.

C.O. Wisler, Ash's former hydraulics professor at the University of Michigan, became a part-time member of the District staff in 1952 with headquarters in Ann Arbor. He served as an advisor and consultant on the Upper Rifle basin study, was senior author of the Detroit area study (USGS Circular 183, 1952), and a coauthor of a similar investigation of the Grand Rapids area (USGS Circular 323, 1954).

The total funds available to the District increased from about $100,000 in fiscal year 1948 to $167,000 in mid-decade, and remained at nearly that level for the balance of the period. Nearly half the total was from Geological Survey appropriations, including the monies used to match State and municipal contributions. Other Federal agencies provided about 15 percent of the total budget, making annual allocations that varied from more than $8,000 to nearly $37,000 annually. State agencies collectively provided 40 percent of the total. The Conservation

Department furnished nearly four-fifths of the State's contribution, the State Highway Department about one-eighth, and the Water Resources Commission about one-tenth. About one-third of the Conservation Department's support was from monies provided by water utilities and local government units in lieu of separate cooperative agreements between the Survey and each of these public agencies.

The primary State cooperating officials during the decade included: M.P. Adams, executive secretary-engineer, Water Resources Commission; C.M. Ziegler, State Highway Commissioner; P.J. Hoffmaster (succeeded by G.E. Eddy in 1951), Director, Department of Conservation; G.E. Eddy (succeeded by W.L. Daoust), State Geologist; G.A. Walker, Chief, General Operations Division; F.A. Westerman, Chief, Fish and Fisheries Division; H.D. Ruhl, Chief, Game Division; and A.C. Elmer, Chief, Parks and Recreation Division. (The last four agencies were segments of the Department of Conservation.)

The basic programs were continued with the U.S. Fish and Wildlife Service in the Manistique River basin and with the Corps of Engineers, Duluth, Minn., district, in the Sturgeon River basin, both of which are in the Upper Peninsula. Cooperative studies were in progress in the southern peninsula with the Corps of Engineers, Milwaukee, Wis., district, in the Grand and Kalamazoo River Basins, and with the Federal Power Commission on the Kalamazoo River at Allegan and St. Joseph River at Mottville. Studies supported by the Detroit, Mich., district of the Corps of Engineers expanded substantially following the 1947 flood because of the need for additional data for flood-protection work.

In 1951, the Michigan Water Resources Division Council was established to coordinate the surface-, ground-, and quality-of-water programs in the State and to plan and present water-resources programs to cooperating officials. In January 1951, the first meeting of the Council was held and Ash was elected chairman. He also served as chairman in 1953, and from 1955 to 1959. The Council consisted mainly of key surface- and ground-water personnel. The small program of quality-of-water work that was conducted during the decade was through the QW Branch Regional office in Columbus, Ohio. The Council had no administrative jurisdiction as each Branch had its own administrative section.

GROUND WATER BRANCH

Condensed from documentation by J.G. Ferris and W.T. Stuart

The Branch maintained two separate headquarters in Michigan from 1947 to 1955, each reporting to the branch chief and engaged in separate program objectives. The Lansing headquarters, established in 1944 and designated as a District office in 1950, was located in space in the Capital Savings and Loan building, and was conducting statewide investigations largely in cooperation with State and local agencies. The other, a project office initially at Iron River and at Ishpeming from 1948 to 1955, was devoted to investigations of the hydrological factors involved in mine-drainage problems in Michigan, and later in a number of other States.

The District program had been under the supervision of J.G. Ferris since 1945. Ferris continued as district engineer until January 1957 when he joined the headquarters staff of the Branch. Beginning in 1955, however, he was also the regional staff advisor for the GW Branch for Indiana, Iowa, Kentucky, Minnesota, Ohio, Tennessee, and Wisconsin. Ferris also played an active role in the development and conduct of the ground-water short courses. Morris Deutsch, a member of the District staff since 1953, succeeded Ferris, becoming district geologist in 1957. District headquarters personnel ranged in number from about 6 to 13. Members of the headquarters staff during 1947–57 included E.C. Rhodehamel, L.A. Wood, E.A. Moulder, G.J. Stramel, Eugene Derragon, E.M. Burt, K.E. Vanlier, E.G. Crosthwaite, C.O. Morgan, and P.R. Giroux. Ted Thompson was assigned to a field headquarters at Grayling beginning in 1949.

The District program was conducted in cooperation with the Michigan Department of Conservation, of which the Michigan Geological Survey was a part. As reported by Ferris in 1951, the statewide cooperative program was comprised of three investigations: (1) comprehensive surveys defining the geologic and hydrologic features of areas where the ground-water resources were especially vital to the regional economy, (2) reconnaissance surveys of about 23 geographic units to determine the extent of ground-water development and to establish planning priorities for the areas that required comprehensive surveys, and (3) research in the development of aquifer-test techniques for on-site measurement of the hydraulic characteristics and flow constraints that are imposed by the complex boundary systems that typify aquifers in glacial terrains.

In the latter part of the decade, field studies of reported instances of ground-water contamination indicated that, in addition to accidental spills, contamination may result from surface or subsurface disposal and storage of either liquid or solid wastes, or by leachates from stockpiled materials. In addition to articles in technical journals, Deutsch summarized (WSP 1691, 1963) the reported instances of contamination and the extent of legal controls on ground-water contamination in Michigan.

Ferris also reported in 1951 that in the course of its current investigations, District staff made daily measurements

at 41 locations and periodic water-level (or artesian pressure) measurements at 188 locations. Periodic data on well discharge and both temperature and chemical quality of well waters were collected at selected locations. Driller's logs for water, gas, and oil wells and also records of foundation borings that were obtained in the course of the field surveys were released in a county bulletin series.

Two interbranch water-resources investigations were conducted and published early in the decade. One, for the Detroit area, by Wisler, G.S. Stramel, and L.B. Laird, was published as USGS Circular 183 in 1952. The other, for the Grand Rapids area by Stramel, Wisler, and Laird, is documented in Circular 323 (1954). The ground-water resources of the glacial deposits in the Bessemer area were documented by E.A. Brown and W.T. Stuart in Michigan Geological Survey (MGS) Program Report 14 in 1951.

The MGS published most of the District's reports of investigations made during the decade. These also included investigations in the Holland area by Deutsch, Burt, and K.E. Vanlier (Program Report 20, 1960); the hydrology and glacial geology of the Kalamazoo area by Deutsch, Vanlier, and P.R. Giroux (Program Report 23, 1960) and of southeastern Oakland County by Ferris and others (Program Report 16, 1954); and reconnaissances of Luce County (Vanlier; Program Report 21, 1959), Chippewa County (Vanlier and Deutsch; Program Report 17, 1958), and Mackinac County (Program Report 19, about 1960).

The project office at Iron River, which moved to Ishpeming in 1948, was under the direction of W.T. Stuart who had established the office in 1944 to use the expertise of ground-water hydrologists to solve problems of mine drainage and dewatering. This was a part of an earlier role assigned to the Survey, that of locating and evaluating ore reserves to meet the requirements of World War II and the postwar economy. Stuart reported directly to the branch chief and, beginning in 1952, also acted as branch advisor on mining-hydrology projects in other States. In 1955, the Ishpeming office closed when Stuart transferred to Arlington, Va., adjacent to Branch headquarters, so his experience could be used more conveniently in the guidance of mine-drainage studies in other states, including Pennsylvania, Alabama, Missouri, Nevada, Tennessee, Wisconsin, and Wyoming. Reference to these projects may be found under the States indicated. After 1955, the mine-drainage investigations in Michigan were conducted from Lansing under the cooperative statewide program.

The studies conducted from the Iron River headquarters required specialists from several Survey disciplines, including structural and glacial geologists from the Geologic Division and stream gagers from the SW Branch. Stuart, who was the only person headquartered at Iron River during the decade, was joined for periods by C.V. Theis, as well as by Max Noecker and S.W. Wiitala of the SW District. The primary study sites were the Mineral Hills and the Ice Lake areas where iron ore deposits were often flooded by water from the consolidated bedrock and the overlying glacial deposits. New hydraulic formulas were devised and successfully tested. The ground-water problems of the area are described by Stuart, Theis, and G.M. Stanley in MGS Technical Report no. 2 published in 1948.

The Marquette Iron Range investigation, conducted from Ishpeming, was similar in nature to the earlier studies at Iron River. The headquarters staff was larger, however; in addition to Stuart, included were two and three assignments by E.A. Brown, E.C. Rhodehamel and H.C. Boback. The mine-drainage problems in this 20-mile-long, steeply dipping range were caused not from lateral movement of water but rather from vertical percolation. The investigations were documented by Stuart, Brown, and Rhodehamel in MGS Technical Report no. 3 published in 1954.

QUALITY OF WATER BRANCH

By W.L. Lamar

No QW Branch personnel were stationed in Michigan during the decade. Members of the staff of the regional laboratory in Columbus, Ohio, fulfilled such minor program commitments as existed.

L.B. Laird was a member of the interbranch team that studied the water resources of the Detroit area and reported their findings in USGS Circular 183 published in 1952. Members of the same group conducted an investigation of the Grand Rapids area (USGS Circ. 323, 1954).

MINNESOTA

SURFACE WATER BRANCH

By David B. Anderson and Lowell C. Guetzkow

The District headquarters during the 1947–57 decade was located at 1427 Post Office building in St. Paul. The program was quite stable and the number of personnel employed varied little. The total staff in the District averaged about 14 and most were professional employees. They were assisted by a few especially competent engineering aids and three administrative and clerical employees. During summers, two or three extra men, usually students, were employed to assist with construction and station maintenance.

P.R. Speer was district engineer during the first half of the decade, having held that position since 1939

(Follansbee, v. III, p. 219). About May 1952, Speer was designated as a field representative of the special reports and investigations section of the branch chief's staff with headquarters at Chattanooga, Tenn. He was succeeded by L.R. Sawyer who had been in charge of the Subdistrict office at Carson City, Nev., under which the Nevada program was conducted. Sawyer served through the balance of the period. C.H. Prior was the principal assistant throughout the decade. E.H. Bekkedahl was in charge of field operations until 1950 when he transferred to the Montana District, at which time D.B. Anderson was placed in charge of field operations. When R.W. Lamson arrived from the South Carolina District in 1953, he took charge of field operations and Anderson became office engineer.

Anderson held this position until September 1955 when he transferred to the Nebraska District. L.E. Bidwell, who transferred from the Ohio District, replaced Anderson as office engineer and continued in this position through the rest of the decade. At the beginning of the period, Ms. Minnette Hullsiek was in charge of the clerical staff and maintained the District's financial records. She left Survey employment about 1952, and was succeeded by Ms. M.A. Bruchmann who continued in this position for the remainder of the period. L.C. Guetzkow, J.H. Hess, J.E. Johnson, and Bruchmann had been in the District since the early or mid-1940's. They, along with Prior, were the only personnel who remained in the District for the entire decade.

During the early part of the decade, all field trips originated in St. Paul, more than 400 miles from the most distant gaging stations in northwestern Minnesota. This situation was alleviated somewhat in December 1954 when a Subdistrict office was established jointly by the North Dakota and Minnesota Districts in Grand Forks, N. Dak. (Grand Forks is located on the west bank of the Red River which forms the boundary between Minnesota and North Dakota.) Personnel assigned to this office conducted the field work and computed discharge records for the Red River basin. Administrative and most of the operational control were from the North Dakota District headquarters in Bismarck, although more than half the financial support came from the Minnesota District.

Establishment of the Grand Forks Subdistrict solved some problems in shortening field trips, but it created other problems. It caused an awkward financial situation in the Minnesota District because charges were made some time after expenses were incurred. This gave the appearance of a healthy financial situation that often did not exist. Problems also occurred when a concerted effort of manpower was required, such as the collection of flood data in the field. (The writer of these comments is not aware of any other Subdistrict office which has been or is supported jointly by two different Districts. He doubts if it would be successful and does not recommend it, although interdistrict participation in a specific project seems quite feasible). G.M. Pike, who transferred from Bismarck to take charge of the Grand Forks Subdistrict office, did a commendable job working for two bosses and helped to minimize the inherent difficulties.

The surface-water program in Minnesota during the decade consisted mainly of operating the gaging-station network and computing discharge records that were published for about 115 to 130 gaging stations. Stage and reservoir records were computed for an additional 15 or 20 stations. Principal State cooperators who assisted in financing the data collection and computation effort were the Department of Conservation, Division of Waters, and the Iron Range Resources and Rehabilitation Commission. Other Federal agencies involved were the Corps of Engineers and the Department of State, which provided Waterways Treaty funds for the operation of the international gaging stations along the Minnesota-Canadian border.

A small amount of financing was also provided by the Federal Power Commission at a few gaging stations below hydroelectric plants. Funding in general was always austere, and it was difficult to conduct the scheduled work with the funds available, even though there were increases ($450 to $700 per year) in the funds provided for the operation of a typical gaging station during the decade. It was not until the later years of the decade that total funding for the District program approached or exceeded $100,000.

The scarcity of funds resulted in frugalities that caused some difficult experiences for stream gagers. For example, the District had a number of gaging stations that had to be measured by boat, even during subzero temperatures. The only boat owned by the District was a three-section sheet-metal craft that was assembled with a hinge arrangement where the sections joined. As the boat grew older, one stream gager had to bail while the other made the discharge measurement. The boat did have a safety device, two underseat flotation tanks; however, they leaked as much as the boat hull. Appeals for a new boat were to no avail.

The problem was finally solved, the hard way, when the boat sank while J.H. Hess was measuring the Mississipi River below the Coon Rapids Power Plant near Anoka. This was in January when the temperature was well below zero. Had he not been a rugged individual and a superb swimmer, Hess would not have survived. His problems were compounded by the fact that, when he reached the shore, he was confronted by a wall of ice, the result of the operation of the powerplant. His helper, who fortunately was on shore, thrust a tree branch down at him, and Joe crawled onto the bank where he was rapidly transformed into a block of ice. The powerplant

operator had viewed the proceedings, and he and Joe's helper dragged Joe into the powerplant where he gradually thawed out. A crew was sent out by the district engineer to recover the boat, but its members carefully stayed away from the site of the sinking. Needless to say, the sectional boat was not recovered and a new boat was finally purchased. On an earlier occasion, in October 1953, this writer sank the same boat while making a reconnaissance for a cableway site on the St. Louis River at Scanlon. Fortunately, at that time, temperatures were milder and there wasn't much distance to swim.

In addition to the collection and computation of routine streamflow records, the District staff conducted some other activities during the decade. Prior, assisted by Anderson, authored Minnesota's first flood-frequency report in 1949 entitled "Magnitude and Frequency of Floods in Minnesota," and published it as Minnesota Divison of Water Bulletin 1.

In the late 1940's and early 1950's, there was increasing interest in the development of the taconite industry. The three iron ranges of the State lie generally along a divide separating the Mississippi River, Hudson Bay, and the Great Lakes basins. As a consequence, streams are small and questions arose concerning the availability of adequate water to provide the considerable quantities necessary for the taconite-beneficiation process. Prior and others addressed this problem in a report published in 1951 as Minnesota Division of Waters Bulletin 5 entitled "Surface Water Supplies of the Mesabi Iron Range."

The hydrology of the Twin Cities metropolitan area is complex. It involves several interconnected ground-water aquifers and two major rivers, the Mississippi, which flows through the metropolitan area, and the Minnesota, which joins the Mississippi at Ft. Snelling in the southeastern part of the metropolitan area. In addition, numerous small streams flow into either the Mississippi or Minnesota Rivers within the metropolitan area. The population of the metropolitan area expanded greatly during the decade and comprised about one-half the population of the State. Numerous water problems, such as floods, adequate supply of potable water, waste disposal, and water quality, evolved. To address these problems, Prior, with ground-water hydrologist Robert Schneider and W.H. Durum, prepared a report entitled "Water Resources of the Minneapolis-St. Paul Area" (USGS Circ. 274, 1953).

Extensive spring snowmelt floods that occurred in three consecutive years (1950, 1951, and 1952) led to three flood reports: "Floods of 1950 in the Red River of the North and Winnipeg River Basins" (WSP 1137-B, 1952); "Floods of 1950 in the Upper Mississippi and Lake Superior Basins in Minnesota" (WSP 1137-G, 1953); and "Floods of 1952 in the Upper Mississippi and Red River of the North" (WSP 1260-C, 1955). Floodflows during 1951 were still being computed when the 1952 flood occurred and were incorporated in the WSP for that year. In the later years of the decade, much of the tabulation and collation required for the District's segment of the nationwide compilation of streamflow records through September 1950 were made by District personnel and the results were published in Water-Supply Papers 1307 (1958) and 1308 (1959).

At the beginning of the decade, Minnesota had the unenviable distinction of being one of the States most deficient in topographic-map coverage. Speer endeavored to get more State funds for a mapping program, and when he discovered Anderson personally knew the State legislator who was chairman of the Finance Committee, Anderson, too, found himself engaged in a minor lobbying effort to persuade the State Legislature to provide funds for a mapping program. This effort eventually bore fruit, but it was slow to develop. In the end, after the decade covered by this volume, all of the State was mapped. During the decade, Anderson computed drainage areas in a number of basins where areas had not yet been determined. In spring 1950, as the big floods in the Red River basin were winding down, Anderson made a trip to Winnipeg, Manitoba, Canada, to confer with personnel of the Canadian Water Resources Division, Department of Resources and Development, so that mutual agreement was reached on the location of drainage divides across the international boundary. Much of the area in the Red River basin in both Canada and the United States is very flat and divides are difficult to distinguish. During 1950–52, Anderson, Guetzkow, and Johnson were each on 3- or 4-month details to the Washington, D.C., office to review surface-water records. Johnson was the first engineering technician, nationwide, to receive such a detail.

GROUND WATER BRANCH

By Robert Schneider

Until 1950 when a District office was established in St. Paul, several localized investigations had been conducted in Minnesota by personnel of the Grand Forks District in North Dakota. Among the areas studied was Clay County in the Red River Valley, starting in 1946, in cooperation with the Minnesota Department of Conservation, Clay County, and the city of Moorhead (Follansbee, v. IV, p. 207). The investigation was completed in 1949 with a report on ground-water resources of the Fargo-Moorhead area, Cass County, N. Dak., and Clay County, Minn. On behalf of the U.S. National Guard Bureau, a study was conducted in 1948–49 of part of

the Camp Ripley Military Reservation, Morris County, in central Minnesota. In 1949–50, a third investigation was conducted in the vicinity of the city of Cloquet, Carlton County, in northeastern Minnesota in cooperation with that city and the State Department of Conservation.

The Minnesota District program was started under the cooperative agreement of July 1950 with the State Department of Conservation. This achievement certainly resulted from the efforts of many individuals; however, P.R. Speer, district engineer of the SW Branch since 1939, played a significant role in nurturing local interest in a statewide ground-water program.

Robert Schneider, formerly in the Memphis, Tenn., District, was appointed district geologist. He arrived in St. Paul in October 1950 and remained through the end of the decade. Schneider's efforts to organize the GW District office were aided in numerous ways by Speer, who gave generously of his time and the facilities of the SW District. In 1952, the GW District office moved to the Federal building in Minneapolis because of a shortage of space in St. Paul, but returned to the new Post Office building in St. Paul the following year.

The initial effort in the statewide program was concentrated on assembling the available ground-water data and identifying water-resources problems. The collection in the field of data on public ground-water supplies in the Red River valley region provided an opportunity to meet municipal water officials and others concerned with the adequacy of water resources, and to learn about existing or potential water problems.

The District activities expanded rapidly and, by the end of the decade, the full-time staff numbered 18. Senior staff members included B.A. Liesch, G.R. Schiner, R.D. Cotter, H.G. Rodis, J.W. Bingham, R.F. Norvitch, and J.E. Rogers.

The cooperative program with the State Department of Conservation included investigations in the following municipal-county areas: the city of Redwood Falls, Redwood County (Schiner and Schneider, WSP 1669-R, 1964); the city of Marshall, Lyon County (Rodis, WSP 1619-N, 1963); and the city of Worthington, Nobles County and part of Jackson County (Norvitch, WSP 1749, 1964). Matching funds were provided by the municipalities and were included in the Federal-State cooperative agreement.

Extensive ground-water investigations also were conducted, through a separate cooperative agreement with the Iron Range Resources and Rehabilitation Commission, in the Mesabi Range area of northeastern Minnesota and in Kittson, Marshall, and Roseau Counties in the northwestern part of the State. This agreement also included investigations by the SW and QW Branch staffs.

In addition to broadening the information base on water resources, the ground-water investigations yielded valuable hydrologic and geologic information of regional significance. The Lyon County study provided information on the occurrence of regional aquifers in buried meltwater channels of the flanks of the Des Moines glacier lobe, which occupied parts of central and southern Minnesota and Iowa (Schneider and Rodis, WSP 1539-F, 1961).

Temperature fluctuations of shallow ground water and adjacent lakes at Worthington suggested that thermometry could be used to determine if pumping induces lake recharge (Schneider, WSP 1544-B, 1962). Investigations of the Mesabi Range produced detailed maps showing depth to the top of the bedrock and data on the glacial stratigraphy that are useful in locating aquifers in glacial meltwater channels.

The Kittson-Marshall-Roseau County area, along with adjacent parts of North Dakota and Manitoba, Canada, is covered largely by fine-grained sediments of glacial Lake Agassiz. The investigation in that area produced information on the local and regional occurrences of aquifers in shore features of the lake and in underlying glaciofluvial formations.

In 1949, the Water Resources Councils were organized to coordinate activities of the three operating Branches. The Council membership in Minnesota included the SW and GW district chiefs and P.C. Benedict, who was in charge of the Missouri River basin water-quality program in Lincoln, Nebr. Representing Benedict at periodic Council meetings was B.C. Colby, who was conducting research on sediment-sampling equipment at the St. Anthony Falls Hydraulic Laboratory in Minneapolis, Minn.

As the program matured and the staff developed a broader knowledge of hydrologic and geologic conditions in the State, Survey data was able to help alleviate certain emergency problems. For example, in 1953, the water-supply well of the village of Watkins in Meeker County failed. Local efforts were made, without success, to replace it by tapping a more productive aquifer in the immediate village area, based on recommendations of a dowser. At the request of the State Department of Conservation, an examination was made of the surficial glacial deposits which indicated the presence of outwash channels about 5 miles to the west. After drilling some test holes and running a pumping test, it was suggested that an adequate supply could be obtained and piped into the village.

QUALITY OF WATER BRANCH

By R.H. Langford

In spring 1948, B.C. Colby transferred from Iowa City, Iowa, to the St. Anthony Falls Hydraulic Laboratory,

University of Minnesota, in Minneapolis to continue his leadership of an interagency project for the development of sediment-sampling equipment. At the time, agency participation was primarily between the Survey, the Corps of Engineers, and the Bureau of Reclamation. In 1956, the effort became more formally organized under sponsorship of the Subcommittee on Sedimentation of the Interagency Committee on Water Resources. The Branch staff increased from one to five persons during the final 2 years of the decade, and the development activity began to emphasize automatic equipment requiring reliance on such diverse fields as electronics, ultrasonics, and physics of light. Assignments of senior members of Colby's Branch staff were of short duration. They included R.A. Krieger (1948–49), G.M. Watts (1950), and C.O. Johnson (1952). Colby and the Branch members of his staff reported to P.C. Benedict, regional engineer, Lincoln, Nebr., during the entire period.

In the mid-1950's, the Lincoln Regional office staff began cooperation with the State, working closely with personnel of the St. Paul SW and GW District offices. The study involved determining the water resources of the Kittson-Marshall-Roseau Counties area of northwestern Minnesota. R.H. Langford was assigned to the project.

The work was financed through a cooperative program with the Iron Range Resources and Retabilitation Commission of the State. Daily records of chemical quality and temperature were obtained for several years on six streams draining the area, monthly water-quality data were collected at several sites on the Red River of the North, and extensive ground-water-quality data were collected throughout the three-county area. The results of the study were summarized in a 1955 USGS Open-File Report by J.R. Rapp, C.H. Prior, and R.H. Langford entitled "Progress Report on the Geology and Water Resources of Parts of Kittson, Marshall, and Roseau Counties, Minnesota."

Work in northwestern Minnesota then ended, and emphasis was shifted to the Iron Range area of the northeastern part of the State. Langford continued to lead the water-quality part of the studies there, and supervised the collection of daily water-quality and temperature records on streams draining the Mesabi and Vermilion Iron Ranges. Records of surface-water quality and temperature for both studies were published in the annual series of USGS Water-Supply Papers.

MISSISSIPPI

SURFACE WATER BRANCH

By Irving E. Anderson

The Mississippi District was barely 1 month old at the beginning of the decade. Prior to June 1947, it had been a part of the Alabama-Mississippi District with headquarters in Montgomery, Ala. Upon the retirement of D.H. Barber, the district engineer, Mississippi was split off and I.E. Anderson was named district engineer, a post he occupied during the entire period.

District Personnel

Alfonso Wilson was assistant district engineer until 1955 when he was succeeded by Winchell Smith. Other professional personnel were H.H. Hudson, W.H. Goines, H.H. Barnes, K.V. Wilson, J.E. Bowie, J.D. Shell, H.G. Golden, E.H. Boswell (who transferred to the GW Branch in 1953), V.D. Hemphill, Jr., I.L. Trotter, C.P. Humphreys, John Skelton, and B.J. Hall. Technical assistants included W.K. Bell, B.L. Neely, J.W. Hudson, and B.J. McCollum. On the clerical staff were B.E. Ellison, Jr., and R.F. Senseman. Goines and H.H. Hudson transferred to other districts during the period; Hemphill and Hall resigned. The staff averaged about eight professionals, three technical assistants, and two clerical employees during the period.

Finances

A modest cooperative program with the Mississippi State Geological Survey existed at the beginning of the decade. When the cooperative program transferred to the newly established Board of Water Commissioners in 1956, however, its magnitude increased nearly 90 percent. Other financial support at the beginning of the period came from Federal program funds and the Mobile, Ala., and Vicksburg, Miss., districts of the Corps of Engineers.

Many events during the 1950's led to the increased financing. In the regular cooperative program, it was the result of a more knowledgeable cooperating agency, the Board of Water Commissioners, and the increased use of water for rice irrigation in the delta area of northwest Mississippi. Threatened lawsuits against the State Highway Department charging that inadequate bridge openings were responsible for upstream flooding resulted in a major cooperative program with that Department. Small-stream flooding in Jackson and vicinity spearheaded a cooperative program with the city of Jackson. Heavy erosion in the Pigeonroost Creek basin in northern Mississippi led to substantial financing by the Agricultural Research Service and the Soil Conservation Service. Cooperative funding nearly tripled during the decade.

Programs

Although the funding in the District increased greatly, there was no significant increase in the operation of the

basic-data program; rather, the increase was in special investigational projects. The program with the State Highway Department consisted of five parts: (1) hydraulic analyses of bridge sites; (2) preparation of flood-frequency curves; (3) establishment of a crest-stage gage network on small streams; (4) determination of flood discharges, principally on small streams, by indirect determinations; and (5) studies of cross sections at selected sites to determine the extent of scour and fill. Crest-gage operation and determination of flood discharges were the principal components of the cooperative program with the city of Jackson. Also included was the development of flood profiles after major small-stream flooding.

Two special investigations were conducted in connection with rice irrigation. The major rice crop area was along Bogue Phalia. Irrigation water was being withdrawn from both the Bogue and ground-water sources and there was concern about overdevelopment. Also causing concern was the area around Lake Washington, a popular recreation site. Overdevelopment in this area would be at the expense of recreational interests. This investigation covered the complete hydrologic cycle, with all inflow into the lake from surface- and ground-water sources and all outflow being measured or calculated, including irrigation withdrawals and evaporation. All branches of the Water Resources Division except the QW Branch participated in the project.

The Pigeonroost Creek project was a joint SW-QW Branch endeavor designed to evaluate the movement of sand in Pigeonroost Creek and its tributaries. Another project during the period was the District's participation in the nationwide special compilation of surface-water records, 1888–1950.

The rapidly increasing population of the city of Jackson caused considerable concern about the future of Jackson's public water supply that came from the Pearl River. Consulting engineers were hired to study the feasibility of a dam and reservoir on Pearl River just upstream from Jackson. The District was, of course, called on to supply considerable hydrologic information. The dam was later built.

There had been discussion for many years of a slack-water route from the Gulf of Mexico as an alternative to traveling upstream on the Mississippi River. The route proposed was via the Alabama and Tombigbee Rivers and then downstream via the Tennessee River. (This Tombigbee Waterway project was eventually begun years later and opened to river traffic during the mid- to late-1980's.) The streamflow data collected in that part of the Tombigbee River basin in Mississippi during the decade helped in the planning and design of the project.

Other Activities

I.E. Anderson, the district engineer, chaired the Surface Water Subcommittee of the Mississippi Water Resources Commission established by the State Legislature in 1954. The findings of the Commission were published in 1955 in a report to the legislature entitled "Water for the Future." Anderson also served on a committee of the Jackson Chamber of Commerce charged with studying the city's public water supplies and its flood problems.

Reports

Numerous open-file reports were prepared during the period, principally hydraulic analyses of bridge sites for the State Highway Department. Five open-file reports also were prepared on severe local flooding in several areas of the State. The investigations of the Bogue Phalia area were released in an open-file report entitled "Rice Irrigation Potential of Bogue Phalia." Another report discussed the surface-water resources of Lauderdale County.

In addition to the annual publication of streamflow records in the Water-Supply Paper series, two formal reports were issued. "Surface Water of Mississippi" was published by the State Geological Survey. The other, "Effect of Irrigation Withdrawals on Stage of Lake Washington, Mississippi" (USGS WSP 1460-I), was published in 1961 and presented results of an investigation started in October 1956 and completed in September 1958.

GROUND WATER BRANCH

By Joseph W. Lang

Ground-water studies in Mississippi from June 1938 to mid-1947 were directed by several Branch geologists working in cooperation with the Mississippi Geological Survey (MGS), Dr. William C. Morse, director. The results were published in a series of USGS Water-Supply Papers and in MGS Bulletins, papers, and memorandums. Annual cooperative State funds available totaled $5,000 (Follansbee, v. IV, p. 203, 269–71).

These geologists were headquartered in space in the same building as the MGS at the University of Mississippi in Oxford. The cooperative program with the MGS was suspended in 1947 because of personnel problems and a strong desire of the State geologist to maintain control of the details of directing and managing the ground-water work.

W.O. George, on the staff of the Texas District from 1940–55, was detailed to Mississippi for one or more short periods during the early part of the 1947–57 decade. Because George had field experience as an oil geologist while stationed at Laurel, Miss., in the 1930's, he was asked to review with Dr. Morse the possibilities of

reestablishing a sound cooperative program in ground-water studies under George's supervision as district geologist, eventually to be headquartered in Jackson where the SW Branch District office was located.

In response to a National Headquarter's Circular dated July 1947, George prepared a summary of the status of ground-water reports in the process of publication, or being prepared for publication but still in manuscript form, by the MGS; the observations of water levels in key wells in the State; and the need for water-quality and pertinent ground-water studies, particularly in oil field areas "as a check against possible contamination" of ground-water reservoirs. The summary memorandum was signed "W.O. George, acting district geologist, Oxford, Miss." A similar memorandum about surface-water resources was submitted by I.E. Anderson, as district engineer (SW), Jackson, Miss.

George failed to reach a workable agreement and understanding with Dr. Morse about management of the cooperative ground-water studies and so he returned to the Texas District. The program was suspended late in 1947 and did not resume until July 1953.

In June 1947, a SW District was established in Mississippi under I.E. Anderson, with an office in the Millsaps building on West Capitol Street in Jackson. In 1952, a suite of offices was rented on the 3rd floor of the Century (Sanders) building on East Capitol Street near the historic Capitol building. This move was partly in anticipation of the planned reestablishment of a ground-water program, and the setting up of a GW District office to be located in Jackson. The sound thinking of C.G. Paulsen, A.N. Sayre, and J.W. Lang, as well as the efforts of Anderson who was well-regarded by key members of the State Legislature and local leaders, brought success, and the two water-resources districts were established in adjacent offices in Jackson. Another factor in the reactivation of the GW Branch was the serious, prolonged drought in 1952–53 that resulted in a shortage of irrigation water, and the onset of the rapid development of wells for irrigating large acreages of rice, cotton, and other agricultural crops in northwestern Mississippi. More knowledge was needed about the extent and storage characteristics of aquifers in view of the prospect of extensive ground-water development.

J.W. Lang, who had completed about 10 months of service as ground-water advisor in Iran in 1952, accepted the position of district geologist for Mississippi beginning in July 1953. The acceptance was contingent on the office being located in Jackson. Lang had also been stationed at San Antonio, Tex., as geologist-in-charge of the areal ground-water studies along the Balcones Fault Zone and Edwards Plateau (1950 to early 1952) involving, among other things, the interchange of surface and ground water.

In 1956, cooperation for both Branches was transferred by law from the Mississippi Geological Survey to the newly created Mississippi Board of Water Commissioners and increased funding was provided. Cooperative projects with other agencies were also being added in 1957.

The GW Branch staff, in addition to the district geologist, from July 1953 to July 1957 included the following personnel: Mrs. Amer Wilkinson (1953 on); E.J. Harvey (1953 on); E.H. Boswell (1953 on); W.F. Powell (1954–56); Grover Berry (1956 on); J.T. Callahan (1956 on); W.E. Wasson (1956 on); T.N. Shows (1956 on); William Chastain (1956 on); and P.E. Grantham (1957 on).

QUALITY OF WATER BRANCH

Program activities in Mississippi were under the jurisdiction of the Fayetteville, Ark., District. G.A. Billingsley, district chemist, reported, in response to a WRD Circular dated June 11, 1951, that periodic chemical-quality and temperature data were being collected under a Federal program allotment at two stream locations and 17 wells for inclusion in WSP 1299 (1952) giving nationwide coverage on the industrial utility of public water supplies. Water-quality data were also being obtained for another Federal agency at 14 locations and temperature data at 11 locations.

A program analysis for fiscal year 1958 indicates that water-quality data were collected periodically at seven stream locations under a cooperative program between the Board of Water Commissioners and the SW District, and at eight other stream sites and four observation wells as a part of the interbranch study of the Pascagoula River basin conducted in cooperation with the Jackson County Port Authority.

District chemist M.E. Schroeder, in his report for the first quarter of 1957, mentioned that plans were being formulated for the proposed Pigeonroost Creek sedimentation project, a joint QW-SW endeavor funded by the USDA's Agricultural Research Service. A project laboratory was established on the campus of the University of Mississippi at Oxford with R.F. Piest in charge. In March 1957, in connection with a sedimentation study with the U.S. Soil Conservation Service, a field headquarters was established at Holly Springs, with soil scientist C.A. Dunnam in charge.

MISSOURI

WATER RESOURCES DIVISION

H.C. Beckman probably had a greater variety of high-level responsibilities during the decade than any official

in the Division outside of the Washington, D.C., office. At the beginning of the decade, he carried the title of regional engineer for the Mississippi River basin, SW Branch. His responsibilities are described later under the activities of that Branch in Missouri.

About 1949, Beckman was reassigned to become a coordinator of the Survey's activities under the Missouri River basin (MRB) program. He coordinated interbranch activities as a representative of the CHE. He coordinated the MRB activities among the SW districts as a representative of the chief of the SW Branch. He attended meetings of the Interior Department's Field Committee for the MRB program as a representative of the Director. He also coordinated, for the Director, the interdivisional activities under the MRB program.

Such responsibilities included the difficult annual task of recommending allocations of funds from the Bureau of Reclamation, first among the Divisions of the Survey, then among the four Branches of the Water Resources Division, and finally among the participating districts of the SW Branch. Although competition for funds was great and recipients were often far from satisfied with their allotments, they valued Beckman's integrity and fairness.

In July 1957, Beckman was selected to be Division hydrologist for the newly created Midcontinent Area under the Division's 1956 plan of reorganization. He maintained his headquarters at Rolla for the entire decade in space adjacent to that used by the SW District staff.

SURFACE WATER BRANCH

District Activities

Condensed from documentation by E.A. Roemer, G.W. Edelen, Jr., and M.S. Peterson

The District, with headquarters at Rolla, had jurisdiction over the Missouri program except for those stations in the State that were handled by the St. Louis office, which was under the general supervision of Beckman during part of the decade. The Rolla headquarters, with a staff that varied in size from about 10 to 20, moved from the Missouri Geological Survey building on the campus of the Rolla School of Mines and Metallurgy to the Ramsey building in Rolla in 1945. It moved again in 1952 to a location at 900 Pine Street.

Additional personnel were stationed at other locations in the State to operate local segments of the statewide station network, especially where frequent discharge measurements were required. Such one-man field headquarters were maintained at Boonesville (all of the decade) to cover the central area, and at Rushville (until 1950) and Maryville (1947–48) for ready access to stations in the northwestern part of Missouri. The St. Joseph field headquarters was established about 1950 with a two-man staff, but was closed before the end of the decade.

H.C. Bolon was district engineer for the entire decade. E.A. Roemer and E.H. Sandhaus also were on the headquarters staff for those years. Other senior staff members present early in the decade included W.L. Doll (until 1948); G.W. Edelen, Jr., (until 1949); A.G. Hely (until October 1947); and J.K. Searcy (1947–54). Anthony Homyk, Jr., joined the staff in 1953 and M.S. Peterson in 1954. H.E. Moore was located at the Boonesville headquarters during the entire period and G.B. Riddle worked out of Rushville. C.H. Benson was in charge of the network operations out of St. Joseph during the early 1950's. Peterson was in charge of the cooperative highway program, and Roemer had a lead role in record computation and as flood specialist.

As the decade began, the District staff was busily engaged in measuring and compiling data on the record-breaking floods of June and July 1947. What was believed to be the most intense rainfall ever recorded in Missouri—12 inches in 42 minutes—occurred at Holt on June 22, 1947. Bolon (in reply to a WRD Circular dated July 15, 1947) stated that such data, collected under the cooperative program with the State, "are being used by State and Federal agencies to rebuild half a million dollars worth of highway bridges largely...in northern Missouri." Data were in demand also for flood-control studies and for the design of flood walls, levees, and navigation works.

The 1947 flood was followed by two other widespread events during the decade. The 1951 floodflows were carried by the Kansas River and its tributaries downstream into the Missouri River. In 1952, a major flood occurred in the upper Missouri River basin. Roemer (written commun., 1982) recalls that coverage of such floods was remarkably good, due in part to the pace set by district engineer Bolon. Bolon, a large and powerful man, seemed to enjoy the challenges, rigors, and physical endurance required in flood measurements and expected his staff to follow his example. The 1952 flood was followed by a dry period that became a severe drought by 1954. Rainfall increased gradually during 1955 and 1956, and by 1957 the drought was broken.

On July 24, 1951, Bolon reported that the District operated 68 gaging stations in cooperation with the State, 30 with financial support from the Corps of Engineers and other Federal agencies, 16 financed entirely by Federal funds, and 1 with funding from the Federal Power Commission's permittees and licensees, a total of 115. By 1958, this total had grown to 137 stations. Of these, 47 were supported under the cooperative program with the State Geological Survey, 14 in cooperation with the Missouri Highway Commission, and 52 with funds from the Corps of Engineers.

In addition to construction and operation of the stream-gaging program, a number of special investigations were conducted. The Kansas-Missouri flood records of July 1951 were documented (WSP 1139, 1952), and the magnitude and frequency of past floods in the State were analyzed (Searcy, Circ. 370, 1955). Low-water studies were conducted of the Gasconade River basin (Bolon, open-file, 1953) and the Meramec River basin (Roemer, open-file, 1953). A general description of the surface waters of Missouri was prepared (Bolon, v. 34, 2d ser., Missouri Geological Survey, 1952). Searcy was one of the authors of Circulars 216 and 273 that reported on interdistrict and interbranch investigations of the water resources of the St. Louis and Kansas City areas, respectively, early in the decade. Sandhaus was senior author of Report No. 23 of the State Geological Survey and Water Resources on the magnitude and frequency of floods in the State. Homyk and others compiled a report (published by the cooperator) that documented minimum spring flows measured during the 1954 drought and compared them with values given in a 1946 report on spring flows.

The St. Louis Office

Condensed from documentation by J.W. Odell

This office, a part of the Rolla District until 1946, was under the direction of H.C. Beckman at the beginning of the decade. In about 1949, when Beckman was reassigned as coordinator of Missouri River basin program activities for the Survey, the St. Louis office again became part of the Rolla District and remained so for the balance of the decade. The St. Louis staff varied in size from about four persons at the beginning to a maximum of 10 in 1953 and 1954. J.W. Odell was in charge until 1949 when he became engineer-in-charge of the Ithaca, N.Y., Subdistrict. He was succeeded by J.C. Berkenbosch, who had been with the Florida District, and who remained until 1954 when he resigned to participate in a family-owned business. He, in turn, was succeeded by R.H. Monroe who had been at Bismarck, N. Dak. Other senior staff members included G.N. Mesnier (until 1949), H.J. McDowell (1948–51), and F.R. Walsh (1951–55).

The St. Louis staff had as its primary responsibility the operation of four mainstem stations on the Mississippi River (Alton, Ill.; St. Louis, Mo.; Chester, Ill.; and Thebes, Ill.) plus auxiliary gages at Alton and Thebes. The office was established and continued through the decade to give particular attention not only to the measurement of the mainstem stations under the exacting accuracy standards set by the Corps of Engineers who provided the financial support, but also to make flow comparisons of Mississippi River records to assure consistency prior to publication. This was critical because of the relatively short distances between stations whose differences in discharges at times might not be greater than the limits of accuracy of calculated daily discharge at any one station.

Measurements on the mainstem stations were made daily during high water and weekly during low water. The frequency during the intermediate stages was determined largely from rates of channel shifting that were revealed by preceeding measurements. The Alton and Thebes stations required the determination of slope as well, because of backwaters from the Missouri (at Alton) and the Ohio (at Thebes) Rivers. Changes in the stage-discharge relation at the St. Louis and Chester stations were particularly rapid during the rising stages of floods.

The heavy-duty equipment required for the measurement of wide channels and great flood depths had, for the most part, been designed, built, and put to use prior to 1947. The handling of the 300-pound weights during flood measurements, however, taxed the strength and endurance of the stream gagers despite the use of geared-down winches with two cranks.

Early in the decade, the Corps requested the assistance of the St. Louis staff in a sampling program by which the sediment movement in the Mississippi River at St. Louis could be determined. Although the WRD had developed considerable experience in the measurement of sediment loads in smaller streams, it had little knowledge of sediment-sampling techniques on rivers of great depth. Odell, working closely with an engineer from the Corps' St. Louis district staff, developed the required methodology. The depth problem was resolved by using integrated samples in which as many as three sample bottles were used in each vertical. Fortunately, the sampling equipment that was developed by the interagency sediment laboratory at the University of Minnesota was adequate for such use, and the equipment was suspended from the same reels, cables, and weights used for current-meter measurements. The samples were turned over to the Corps for analysis. McDowell, who transferred from the California District at San Diego, had immediate supervision of the program.

GROUND WATER BRANCH

The only investigations known to be made by the GW Branch in Missouri during the decade were those conducted as part of the Missouri River basin program. The Arkansas District office had jurisdiction over WRD programs in the rest of the State.

QUALITY OF WATER BRANCH

By Russell H. Langford

Members of the staff of the Lincoln, Nebr., Regional office were engaged in extensive studies of the transport of sediment by the Mississippi River at St. Louis during the decade. A report, "Summary and Analysis of Sediment Records in Relation to St. Louis Harbor Sedimentation Problems," was later prepared by P.R. Jordan and released to the open file in 1968. W.H. Durum and F.H. Rainwater participated in preparing reports on the water resources of the St. Louis (Circ. 216, 1952) and Kansas City (Circ. 273, 1953) areas.

MONTANA

SURFACE WATER BRANCH

By Frank Stermitz

District headquarters remained in the Federal building in Helena during the decade, with between 15 and 20 members of the District staff located there. In the interests of better field coverage and economy, area and field offices were established. The area office in Billings opened in 1948, and generally three to five people were headquartered there. An area office opened at Kalispel in 1950 with two or three persons on duty. Two field headquarters also opened in 1950. The one at Fort Peck was usually manned by two people. The Bozeman field office was established for comprehensive surface-water information in conjunction with a ground-water study of the Gallatin Valley. Only one person was stationed there when it closed in 1953.

A.H. Tuttle, who became district engineer in 1938, held that position until his retirement in 1949. He was succeeded by Frank Stermitz who joined the District in 1936. Stermitz continued in charge throughout the period. C.S. Heidel, the other senior member of the staff, had been with the District from 1917. He was designated as the field representative of the CHE on matters pertaining to the division of the waters of the Milk and St. Mary Rivers between the United States and Canada. Funds for that activity were provided by the Department of State. Heidel continued in that capacity through the balance of the period, in quarters adjacent to the District office, and was assisted by engineers of the District.

At the close of the decade, the senior members of Stermitz's staff included W.A. Blenkarn and G.W. Buswell, who were employed in the District during the entire period. J.D. Goshorn rejoined the District in 1948 as engineer-in-charge of the Billings area office. His initial service in the District began in 1940, followed by military service and duty in the Indiana District. Goshorn moved to Helena in 1950 as assistant district engineer and completed the decade there. He was succeeded at the Billings office by E.H. Bekkedahl, another former employee in the District, who continued in charge of the Billings area through the decade. A.S. Sollid joined the Helena staff in 1948 after service with another Interior agency. He opened the Kalispell area office in 1950 and continued in charge through the period. C.D. Bue, a senior employee in the District, transferred to the reports section in Washington, D.C., in 1948 for better use of his editorial talents. V.K. Berwick and F.C. Boner joined the District's professional staff early in the decade and did an outstanding job in flood-specialist activities. B.A. Anderson, another professional employee, entered on duty in 1952. M.V. Johnson came to the District early in the period and served through the decade. V.J. Stermitz, who had been district clerk during the decade, died in 1956. W.M. Michels succeeded him. Technical assistants who made valued contributions to many phases of the work throughout the period were R.D. Schuller, O.J. Folsom, and Ms. F.C. Aagard.

During the early part of the decade, State cooperative funds were disbursed directly by the State upon submission and approval of claims. The State funds were generally used for seasonal and part-time employees, as well as for the initial employment of others until experience qualifications for acceptable Federal status prevailed. Credit for Federal service was later accepted on a case-by-case basis upon proof that such early service was wholly under the initiation and direction of the district engineer and his staff.

At the close of the decade, 184 daily and 50 partial stream discharge records were being collected. Information on contents of 36 reservoirs was being published, largely from data supplied by various State and Federal agencies and licensees of the Federal Power Commission. Collection of water-temperature data at all discharge stations was standard procedure. Near the middle of the decade, the number of daily-discharge stations increased by about 10 percent as the Missouri River basin program reached its maximum intensity. The activity of various Federal agencies in water-development projects later diminished.

The long advocated need for peak-flow data on intermittent streams for culvert design resulted in a cooperative program with the Montana Highway Commission for the installation and operation of 46 peak-flow stations in 1955. Berwick and Boner directed that phase and also served as flood specialists in this and other districts as temporary need arose. Cooperative programs related to stream relocations and ground-water studies sponsored by the Montana Fish and Game Department and the Montana Bureau of Mines and Geology were also initiated during

the decade. The adoption of the Yellowstone River Compact in 1953 led to the establishment of a few daily-discharge stations to supplement long-term records of the cooperative program with the Montana State Engineer's office. The adoption of the Compact was considered essential to the planning of storage projects by the Bureau of Reclamation and the Montana Water Conservation Board in the area near the Montana-Wyoming border. Construction of Yellowtail Reservoir on the Big Horn River began during the decade. The reputation of the impartiality of the Survey in providing hydrologic data for treaties and other matters led to the Compact provision that the Federal representative be a member of the Survey. The district engineer for Montana was selected for that role, and he also served as secretary of the Commission throughout the decade.

The increasing interest in the use of boundary waters in the United States and Canada promoted fuller investigations of streamflow, evaporation, and stream losses along the northern border. The Bureau of Reclamation sponsored new gaging stations on the Belly River and its tributaries, which rise in Glacier National Park and flow northward into Canada. These waters could not be used without an adverse environmental impact on Glacier National Park or on their flow through Canada, so these new installations were discontinued late in the decade.

The snow-survey program in the St. Mary River basin continued with the cooperation of the Department of State. Data from the program provided forecast information for irrigation planning of the U.S. portion of these waters in the Milk River basin of Montana. Snow surveys in the upper Missouri River basin, sponsored by the Corps of Engineers, continued with closer cooperation with the U.S. Soil Conservation Service in order to cut down on travel costs. The hydrologic investigations of Grinnell Glacier in Glacier National Park continued with similar assistance from various Federal agencies. Although useful data were obtained, preliminary correlation of the information indicated a ''lag period'' that might become more apparent later. The District's segment of the nationwide project to compile discharge records to 1950 was accomplished through the work of Buswell, Johnson, and Anderson.

Notable floods of 1948, 1950, 1952, and 1953 taxed the District's personnel capabilities, and flood specialists from other Districts were particularly helpful in making peak-flow determinations and in technical training. The reports of these floods were published in Water-Supply Papers 1080 (1949), 1137-I (1954), 1260-B (1955), and 1320-B (1957). Although previously-recorded maximum floodflows may not have been exceeded, documentation of both current and past data in a single report was appreciated. The documentation also instilled confidence in some historic peak stages founded on meager data. Among the historic peaks questioned by some Federal agencies were the 1894 peak of the Missouri River at Townsend, the 1916 peak of the South Fork Flathead River that affected the spillway design of Hungry Horse Reservoir, and the 1908 peak of the Missouri River at Fort Benton.

GROUND WATER BRANCH

By Frank A. Swenson

Ground-water studies by Survey personnel in Montana and northern Wyoming began, after a lapse of many years, in summer 1946 when F.A. Swenson, under the supervision of G.H. Taylor, regional engineer for Missouri River basin (MRB) program studies, conducted a study of the proposed Lower Marias irrigation project near Havre, Mont. Also, during summer 1946, Swenson conducted a study of the Heart Mountain project near Cody, Wyo. (See Wyoming for subsequent projects conducted by Swenson and staff in that State.)

In 1947, extensive test drilling was conducted on the buried valleys of the ancestral Missouri River on the Lower Marias project and in northeastern Montana. A statewide system of observation wells was established in Montana that spring. Swenson conducted a ground-water investigation of lands proposed for irrigation along the Missouri River valley in northeastern Montana and also the Paint Rock area near Manderson, Wyo.

In 1948, the MRB ground-water program in Montana and northern Wyoming was expanded with the establishment of a three-man District office in Billings, Mont., under Swenson and a suboffice in Riverton, Wyo. That summer, studies were conducted in the Helena valley and along the Yellowstone River between Miles City and Glendive.

In 1949, a suboffice was opened in Terry, with F.A. Kohout in charge of a study of the Yellowstone valley between Glendive and Sidney. A study of the Townsend valley-Crow Creek area was begun by H.W. Lorenz.

In 1950, E.A. Moulder and F.C. Koopman joined the District staff and, along with Kohout, began a detailed drainage investigation of the Buffalo Rapids irrigation project near Glendive. This was a new field of investigation for the Branch, and it was highly successful. The work was headquartered in the Terry field office. In summer 1950, the District held its first informal ground-water short course with J.G. Ferris from the Michigan District lecturing, and from this meeting on the banks of Whopup Creek on the Buffalo Rapids project, the national series of courses and the ground-water training program were developed. Also, R.G. McMurtrey joined the Survey in 1950 and worked with Lorenz on the Townsend valley study.

In 1951, a field headquarters opened at Bozeman for the study of the Gallatin valley. This study, designed to be as complete a hydrologic inventory of an area as had ever been made, considered ground water, surface water, precipitation, evapotranspiration, and other factors. O.M. Hackett transferred from the Riverton, Wyo., headquarters to head this study. McMurtrey transferred from the District office in Billings and John Rossier came from South Dakota to join the study team. Marvin Allison was a short-term employee on the study.

In spring 1952, district geologist Swenson took a 3-month assignment to India where he helped select the sites for 2,000 irrigation wells on the Gangetic plain. The Terry, Mont., suboffice closed, and E.A. Moulder, along with Mervin Klug and D.A. Morris, began a detailed drainage study of the lower Little Bighorn valley near Crow Agency, Mont. The suboffice for this study was located at Hardin at the north end of the study area.

F.N. Visher and W.L. Steinhilber were assigned to the Gallatin valley study to replace two men who had resigned in 1951 after only a short period on the job. F.C. Boner also was assigned to this project.

In 1953, the MRB program funding for ground-water studies was seriously restricted and active field investigations were ended in all districts except Montana. No new starts could be made, but the three studies underway were continued—the Gallatin valley, the lower Little Bighorn in Montana, and the Riverton project in Wyoming. At that time, the Corps of Engineers asked the District for assistance in locating water supplies for the series of radar bases being constructed along the northern border of Montana.

In 1954, MRB program funds were all but eliminated. All three above-mentioned studies were then completed, the suboffices closed, and all personnel except the district geologist transferred. The task of the review of lengthy and complex reports took much of the district geologist's time. The Corps of Engineers requested assistance in obtaining a large water supply for a Strategic Air Command base some 20 miles north of Glasgow, which included the drilling of test holes to depths exceeding 2,000 feet. This work was welcomed as it provided sufficient funds to carry the Montana District through the fiscal year. During the year, contacts were made and funds obtained to begin a cooperative ground-water program in Montana. The part of Wyoming formerly under the Billings, Mont., District office was placed under the Cheyenne, Wyo., District.

In 1955, McMurtrey transferred back to the Montana District and opened a two-man field headquarters in Missoula. R.L. Konizeski assisted on the cooperative study of the Bitterroot Valley and E.A. Zimmerman began a cooperative study of parts of Musselshell and Golden Valley Counties. He was assigned to the District office in Billings as were Q.F. Paulson and T.V. Zimmerman, who conducted a study of the Two Medicine irrigation project near Cut Bank using MRB program funds.

In 1956, D.C. Alverson and L.J. Hamilton were added to the District staff. Alverson began a MRB program study of the Ft. Belknap Indian Reservation, and Hamilton worked with Paulson on a study of the Hardin unit along the Bighorn valley below the Yellowtail Dam, which was under construction by the Bureau of Reclamation.

In 1957, a research program, financed by the Bonneville Power Administration, was begun for the purpose of forecasting low-water flows, derived from ground-water storage, in streams in the major valleys of western Montana. Study of the Deer Lodge Valley was begun by the three-man staff at the suboffice at Missoula. Also, in cooperation with the Montana Bureau of Mines and Geology, a study of Blaine County in northern Montana was begun. Under the MRB program, the studies were continued at the Ft. Belknap Indian Reservation and the Little Bighorn River valley near Hardin, Mont.

QUALITY OF WATER BRANCH

By Russell H. Langford and H.A. Swenson

The Branch had no permanent staff headquartered in Montana during the decade. Investigations in that part of the State lying in the Missouri River basin were assigned to members of the staff of the Regional office in Lincoln, Nebr., or to the Worland, Wyo., suboffice. The single exception to this procedure was the assignment of Louis Karhi, a geologist, who was stationed in Billings from January to July 1950, when he resigned.

For that portion of western Montana which was in the Columbia River basin, responsibility for water-quality activity centered in the Regional office at Salt Lake City, Utah. This continued until 1954 when the area was assigned to the newly established Portland District. (See discussion of District activities under Oregon.) From the beginning, the program was small and of a reconnaissance nature.

In 1955, cooperative financing with the Montana Bureau of Mines and Geology led to a joint (SW, GW, QW) project on appraisal of the water resources of the Bitterroot Valley, an area of about 300 square miles in southwestern Montana. Two reports emerged from this study. The State Bureau of Mines and Geology published Bulletin 9, "Preliminary Report on the Geology and Water Resources of the Bitterroot Valley, Montana" in 1959, by R.G. McMurtrey, R.L. Konizeski, Frank Stermitz, and H. A. Swenson. The final report, WSP 1889, was published in 1972 and authored by R.G. McMurtrey, R.L. Konizeski, M.V. Johnson, J.H. Bartells, and H.A. Swenson.

Also in the mid-1950's, a study of the geology and ground-water resources of part of east-central Montana was conducted in cooperation with the Montana Bureau of Mines and Geology. The report, on parts of Musselshell and Golden Valley Counties, was written by E.A. Zimmerman and R.H. Langford and was issued in 1956 as Information Circular 15 of the Bureau of Mines and Geology.

Throughout the decade, Branch scientists worked directly with their counterparts in the GW Branch investigating the chemical quality of ground water and preparing water-quality sections of reports published on ground-water resources of parts of Montana in the Missouri River basin. Chemical-quality-of-water sections for seven published Water-Supply Papers, two Circulars, and one Open-File Report on ground-water resources were prepared by scientists of the Lincoln office (primarily H.A. Swenson, but also R.A. Krieger, E.R. Jochens, W.H. Durum, and R.H. Langford). In addition, USGS Circular 170 (1952), which describes sediment and chemical-quality characteristics of surface water in the Powder River basin, was prepared by C.H. Hembree, B.R. Colby, H.A. Swenson, and J.R. Davis. Swenson later prepared a report on geochemistry of water in the Powder River basin for publication in Transactions of the American Geophysical Union (1953).

A summary of the entire Division program in Montana prepared in the Billings District office (GW) in 1956 indicated that the chemical quality of surface waters was being determined at eight locations under the support of the Missouri River basin program and at five other stations under the irrigation network program. The latter was financed by allocations from the Federal program. MRB program funds also were used in collecting sediment-discharge data at five locations.

TECHNICAL COORDINATION BRANCH

The Branch established a field headquarters in Billings in October 1947 from which soil and moisture conservation studies were conducted in Colorado, Montana, New Mexico, and Wyoming. The staff of from two to four persons was under the direction of K.R. Melin, who was assisted by R.F. Hadley; however, the entire activity was under H.V. Peterson, staff geologist, whose regional headquarters were transferred from Los Angeles, Calif., to Salt Lake City, Utah, in 1949. The Billings office closed in January 1955 and Melin transferred to Denver, Colo. Hadley had moved to Denver in October 1954. Program statistics available as of 1958 showed that the soil and moisture conservation studies in Montana were supported by an allotment of $17,000 from the Federal program, as well as $2,200 from the Bureau of Reclamation for work in the Missouri River basin.

NEBRASKA

SURFACE WATER BRANCH

By Elwood R. Leeson

By 1947, the Nebraska District already had felt the major impacts of the increased demands for timely surface-water data. These demands were created by the surge in planning for, and the implementation of, projects for the development and control of the surface-water resource within the State, and for the interstate administrative problems associated with the use of water from streams with multistate drainage.

In 1947, 22 streamflow stations that had been established during the previous 2 years under the Missouri River basin program were in operation. By 1957, the number had grown to 30.

Federal funding continued for operating the 18 stations needed for administering the Republican River Compact in effect since 1943 between the States of Colorado, Kansas, and Nebraska. The Compact station network remained stable from 1947 to 1957. Twelve of the stations in the network had previously been operated under Federal-State cooperation with the Nebraska Bureau of Irrigation (later reorganized as the Department of Water Resources). This transfer between programs reduced the number of stations in the cooperative program to 57, rising to 62 in 1951, and staying at about 72 by 1957. The funds, which were released by the transfer, were used primarily to increase the frequency of discharge measurements at existing stations having extremely unstable control conditions rather than for expansion of the network. Later funds were used to satisfy the need for data of greater accuracy. Additional stations were funded by miscellaneous cooperators, including Federal Power Commission permittees and licensees (about 10 stations) and the U.S. Army Corps of Engineers (growing from about 10 stations to about 30 during the course of the decade).

The 1947–57 decade was characterized not so much by a large expansion in the number of stream-gaging stations as by adequate financing to permit production on a timely basis of data having greater reliability. Thus, the overall total number of stations remained rather stable, 157 being reported in 1951 and 155 in 1958.

There was a growing need for special-purpose data, however, which could be collected on a periodic schedule, as well as for analytical studies that would permit the application of collected data to the solution of specific problems. To meet more adequately the demands of the U.S. Bureau of Public Roads for more sophisticated design data for federally-funded bridge construction, the State Department of Roads turned to the District for hydrologic expertise in flood-frequency analysis and for

sufficient knowledge in fluid mechanics to evaluate the hydraulic characteristics of bridge openings relative to flood discharges. The resulting cooperative program culminated with a report published by the State in 1955, "Floods in Nebraska, Magnitude and Frequency," by L.W. Furness, along with numerous site reports for use in resolving individual bridge-design problems. A network of almost 100 stations for the measurement of flood discharge from small drainage areas also was established under this program and operated during most of the decade. Operation of this network culminated in 1962 in USGS Circular 458, "Floods in Nebraska on Small Drainage Areas, Magnitude and Frequency," by E.W. Beckman and N.E. Hutchinson.

A network to immediately report flood stages and discharges to Corps of Engineers district offices in Omaha, Nebr., and Kansas City, Mo., and to the Weather Bureau River Forecast Center in Kansas City was maintained throughout the period to aid in their flood-control and forecasting activities. The District also initiated a program at 40 gaging stations for twice-daily determinations of water temperature. These data were collected at little additional cost above that for the usual station operation.

In an effort to improve the accuracy of determinations of maximum flood discharges other than by direct current-meter measurement, the District successfully proposed Federal program funding for a research project that included investigations of channel coefficients for streams with sandy beds (including variation of Manning's "n" values with stage or depth); accuracy and reliability of high-water marks recovered after a rise; extent of scour and fill; and the reliability with which data on scoured depths could be recovered by subsequent probing. The project ultimately resulted in WSP 1498-B, "Flow Characteristics of the Elkhorn River at Waterloo, Nebraska," by E.W. Beckman and L.W. Furness, published in 1962.

The District staff pioneered in the use of power equipment for the construction, operation, and maintenance of gaging stations. One unusual application was the use of a cement grout pump to stabilize the sandy streambed control section at a gaging station on a small stream. In another instance, the district engineer encouraged an engineering aid, Carl Falk, to work on an idea that Falk had for a power auger to drill holes in ice cover for winter discharge measurements. With the help of a small-town blacksmith, Falk built a crude looking machine which indeed would drill the desired holes with much greater dispatch than that achieved with the commonly used ice chisel. The drill was submitted to the Equipment Development Laboratory in Columbus, Ohio, for evaluation and possible refinement. The result was a more sophisticated machine that eventually became a stock equipment item. A later development from the laboratory was the "Pygmy" current meter that would readily pass through the limited-in-diameter hole that the drill could produce in the ice. Falk's career was cut short by his untimely death in the crash of a small private airplane during a violent thunderstorm in Illinois.

The total Federal staff of the District consisted of about 20 persons in 1947. This represented a substantial growth from the staff of four who began operations in Lincoln when Nebraska separated from the Denver District in 1941. By 1952, the staff had grown to 28, and it remained at about that level until 1957.

The Federal staff was augmented by a staff of about a dozen employees of the State Bureau of Irrigation, which was under the Office of the State Engineer who headed the Department of Roads and Irrigation. In later years, the Bureau of Irrigation became the independent Department of Water Resources headed by its own director. The State employees, called hydrographers, collected and computed discharge data for streams and canals that were used for the administration of water rights; they also conducted most of the stream-gaging activities for the Federal-State cooperative stations in the Platte River drainage in the western portion of the State. This work was conducted from an office in Bridgeport. Survey surveillance of these operations was originally provided by the assistant district engineer who spent about 1 week per month in the Bridgeport office. Near the end of 1947, a Survey employee was stationed full-time in Bridgeport to provide the overview of the stream-gaging activities that were the concern of the Survey.

The staffs of the area offices, at Cambridge for the Republican River basin and at Grand Island for the Loup River basin and the midstate portion of the Platte River basin, were about the same size. Staff varied in most years from four to six persons, and the offices were used during the entire decade. Field headquarters were maintained at Valentine (one person, 1948–53), at Ainsworth (one to three persons, 1952–56), and at Niobrara (one person, 1954–56).

D.D. Lewis was district engineer for practically the entire decade, having been appointed to the position in 1942. In February 1957, he became district engineer of Arizona and was succeeded by F.F. LeFever. E.R. Leeson was assistant district engineer from 1942 until 1952 when he left to become district engineer in Kansas. Other senior staff members at District headquarters in the early part of the decade included L.F. Hanks, C.V. Burns, G.E. Philipsen, R.E. Curtis, and F.T. Schaefer, who established the first sediment-sampling stations in Nebraska. Schaefer transferred to the Kentucky District in 1949 and, in 1954, became the district engineer in Wisconsin. Later in the decade, the top staff also included G.W. Caughran (who first came to the District in 1947

to head the area office in Bridgeport, moved to the District Office in 1949, and succeeded Leeson as assistant district engineer in 1952), L.W. Furness, E.W. Beckman, George Anthony, and I.L. Burmeister.

G.L. Whitaker, who was in charge of the Cambridge area during the decade, was assisted by A.E. Hulme until about 1950 and by P.N. Walker beginning in 1952. C.H. Carstens directed the Grand Island activities until 1952 when he was succeeded by J.E. Lind who, in turn, was succeeded in 1955 by A.F. Pendleton, Jr. As noted above, Caughran was the first to be stationed at the Bridgeport area office. He was followed by Anthony, Burns, Pendleton, D.B. Anderson, and G.G. Jamison. M.G. Zellars served at the Valentine field headquarters; D.W. Ericson and, later, E.K. Steele served at Ainsworth; and K.H. Calver served at Niobrara.

In 1948, R.E. Oltman, who had represented the TC Branch in Lincoln since 1946, transferred to the SW Branch to head a special reports unit in the District. He was assisted by H.J. Tracy. In 1950 or 1951, this unit was upgraded and took over interpretive surface water studies for the entire Missouri River basin. Designated as Office of the Staff Engineer, it was a field unit of the special reports and investigations staff section in the Washington, D.C., Headquarters. Tracy transferred to Atlanta, Ga., in 1952, and Oltman joined the Branch staff in Washington in 1955.

It seems appropriate also to mention a group of employees who all began their Survey careers as engineering aids with the Nebraska District from 1947 to 1957 and who, at the time of the preparation of this statement (July 1982), either have retired or are still on the active rolls after long and productive careers. Space will not allow individual discussion, but several of the persons whose names follow will appear in subsequent volumes of Survey history as occupying important supervisory, professional, or technical positions: J.A. Anderson, D.T. Hartley, L.L. Hull, J.D. Hungate, N.E. Hutchinson, Maynard Kubicek, C.R. Liggett, D.J. Pangburn, K.G. Polinoski, J.O. Rostvedt, and L.K. Thompson. Also holding important positions were M. Marjorie Gilbert, clerk-typist in the Cambridge office, and Josephine M. Eyen, clerk-stenographer in the Lincoln office, who advanced to positions of mathematics technicians in a career-long dedication to providing substantive contributions to the successes of the Nebraska SW District.

GROUND WATER BRANCH

By Ray Bentall, C.F. Keech, and H.A. Waite

The segment of the Missouri River basin (MRB) program assigned to the Branch continued to be directed from the Regional Headquarters located in the Rudge-Guenzel building (now called "The Atrium") in downtown Lincoln. G.H. Taylor, who had been designated regional engineer in 1946, served in that capacity throughout the decade. His MRB program headquarters staff grew to a maximum of 17 people in 1953, but was reduced to about half that size by the end of the period. Taylor conducted the program directly through newly established District offices in Billings, Mont., and Bismarck, N. Dak. (relocated to Huron, S. Dak., in 1952), and indirectly through previously established District offices in Cheyenne, Wyo.; Lincoln, Nebr.; Denver, Colo.; and Lawrence, Kans. The Billings and Bismarck (Huron) offices were funded wholly by the MRB program, and the other District offices were funded from the Federal-State cooperative program and supplemented by the MRB program.

Taylor's principal assistants at the beginning of the decade included G.A. Waring, H.F. Hayworth, and F.A. Swenson, but each transferred from the headquarters staff in 1948. Ray Bentall, who had been with the Nebraska District since 1945, transferred to the Regional staff in 1949 and served as second in charge through the balance of the decade. For various lengths of time during the decade, the Region maintained one- or two-man offices at nine locations in Nebraska—Ainsworth, Loup City, St. Paul, Fullerton, Grand Island, Holdrege, Edgar, McCook, and Superior. These offices were supervised from the Nebraska District.

At Taylor's insistence, each test hole and each water well inventoried or used for observation of water-level changes was assigned a number based on its location within the Bureau of Land Management land surveys. This inventory system, or modification of it, was adopted by several districts outside the basin because it made the retrieval of data easier.

In 1949, a hydrologic laboratory was established under the MRB program to conduct permeability, specific yield, and other tests of earth materials submitted from field offices. A.I. Johnson set up and operated the laboratory with the help of one or two assistants. Johnson reestablished the laboratory in Denver in 1954 to give nationwide service. In addition to providing testing services, the laboratory staff maintained and devised field equipment for rental to project chiefs. Laboratory staff were available also to operate the rental equipment and ensure that the samples that were collected were suitable for testing.

Even though the Bureau of Reclamation and other Federal agencies generally requested activities such as well inventory, water-level measurements, construction of water-table contour maps, and test drilling, Taylor required that all projects be described in formal geohydrologic reports. Virtually all of these reports were released first in mimeographed form for other agency use and for

review purposes within the Branch. Later, they were published as Geological Survey Water-Supply Papers, Circulars, or Hydrologic Atlases, or were turned over to District office cooperators for publication. Taylor's staff included several typists and draftsmen to reproduce manuscripts for review purposes and for publication.

On his visits to field offices, Taylor asked personnel to present a thorough account of their findings to date and generally gave valuable advice and direction for further activities. On several of his trips around the basin, Taylor was accompanied by one or two members of the Washington, D.C., WRD staff. In 1953, Taylor suffered a severe heart attack that limited subsequent visits to the field.

During the heyday of the MRB program, Taylor had all MRB staff assemble in Lincoln for an annual conference. He also had J.G. Ferris come to Lincoln to instruct selected MRB personnel on aquifer-testing techniques and in interpretation of test data. Moreover, he required all professional staff members to take advantage of the ground-water short courses. Such training was highly rewarding in that many of the attendees later headed districts or regions or occupied important positions at the National headquarters of the Division.

The ground-water program staff of the Nebraska District studied the resource in cooperation with the Conservation and Survey Division of the University of Nebraska. They also directed all Missouri River basin program ground-water studies with Nebraska, except three in the North Platte valley that were administered by the Wyoming District and one in the Republican River valley that was administered by the Kansas District. Federal-State programs and Federal-only programs supplemented each other. Federal-State programs consisted of drilling test holes at intervals of 3 miles along north-south lines 6 miles apart and of periodic measurement of water levels in a statewide network of observation wells. The subsurface geologic and hydrologic information thus obtained was invaluable for the areal project studies under the MRB program.

H.A. Waite was the district geologist until July 1952 when he transferred to the Utah District. He was succeeded by C.F. Keech. Professional staff under their direction at various times were W.K. Bach, Ray Bentall, Edward Bradley, D.W. Brown, J.G. Cronin, T.G. Newport, R.L. Schreurs, and R.T. Sniegocki. J.W. Nelson, who supervised test drilling, and F.G. Schnittker, who measured water levels, were long-time hydrologic aids in the District. In addition to Nelson, the drilling crew consisted of a geologist supplied by the Conservation and Survey Division and several seasonally-hired university students.

Reports produced during the decade included a compilation of all water-level measurements made in the State prior to 1954, annual compilations of water-level measurements made in subsequent years, and compilations of test-hole logs. Detailed geohydrologic studies were made in selected areas, and reports summarizing all geohydrologic information then available without significant additional fieldwork were produced in several other areas. Together, these reports described ground-water availability throughout much of the State. Many of these studies document water-table configurations prior to the mid-1950's and later increases in use of ground water for irrigation, and they now are valuable in evaluating the effects of those increases.

QUALITY OF WATER BRANCH

By R.H. Langford

In July 1951, the regional engineer, P.C. Benedict, reported that the basic-data network for Nebraska produced daily records of sediment discharge at 24 locations and periodic records at 28 locations; also daily and periodic records of surface-water chemical-quality at four sites and water temperature at 17 sites (these were apparently all financed under the Missouri River basin program). A later report in fiscal year 1958 shows a reduction for collecting sediment-discharge data to 10 daily and 8 periodic sites and that surface-water chemical-quality data were measured daily at six and periodically at five sites. Surface-water-temperature data were collected daily at 15 and periodically at 11 sites. The 1958 report indicated that network support had shifted to the Federal program as funds once received through the Bureau of Reclamation were now shifted to the USGS appropriation.

The July 1951 report also showed that a sizable number of project investigations were underway using Missouri River basin program monies. They included chemical-quality studies of water in the Loup River basin, the Dutch Flats area, Pumpkin Creek, the Platte-Republican divide, the Loup-Platte divide, the Bostwick unit, and the Prairie Creek unit. Studies of bed-load sedimentation were underway on the Niobrara and Middle Loup Rivers. The starting dates of these nine projects ranged from 1947 to 1950. The anticipated length of the studies varied from 1 to 7 years, with a median of 3 years.

Members of the Regional staff were authors of numerous reports, or segments thereof, dealing with the quality of Nebraska's water resources. Those listed in the "Water-Resources Investigations in Nebraska" folio, edition of 1978, included the following: F.H. Rainwater wrote the sections on chemical quality for ground-water reports on the Middle Loup division (WSP 1258, 1955) and the Prairie Creek unit (WSP 1327, 1955) of the lower

Platte River basin; Buffalo County and adjacent area (WSP 1358, 1956); the upper Niobrara (WSP 1368, 1956); Clay County (WSP 1468, 1959); and southern Sioux County (HA 6, 1956). R.A. Krieger did likewise on the Ainsworth unit, Cherry and Brown Counties (WSP 1371, 1957) and the Niobrara River and Ponca Creek basins (WSP 1460-G, 1959). H.A. Swenson wrote the chemical-quality section of WSP 1378 (1958) on the lower South Platte valley; E.R. Jochens on the lower Lodgepole Creek basin (WSP 1410, 1957); Robert Brennan on the Big Blue River basin (WSP 1474, 1959) and the Platte-Republican divide (WSP 1489, 1960); and R.H. Langford on the Loup River drainage basin (WSP 1493, 1960) and the Hallam Nuclear Power Facility (Bull. 1133-B, 1962).

Reports on fluvial sediments included those by R.B. Vice and E.F. Serr, III, on Middle Loup River near Dunning and Milburn (open-file, 1951); by B.R. Colby and C.H. Hembree on Niobrara River near Cody (WSP 1357, 1955); by D.W. Hubbell and D.Q. Matejka on Middle Loup River at Dunning (WSP 1476, 1959); and by J.C. Mundorff and P.R. Jordan on Whitehead watershed and reservoirs (Circ. 406, 1958). Considerable refinement in methodology and instrumentation was achieved by the Region's sediment specialists during the decade. Two such reports were identified in the Survey's segment of the Department's 1955 report (p. 164). One, WSP 1357 referred to above, presented improved and simplified computation techniques for computing the total sediment discharge of streams that included usually-unmeasured particles moving along the channel bed. The other (open-filed at the time) analyzed sediment sources and erosion processes from upland gully erosion in the Dry Creek basin. During summers 1953–56, J.C. Brice conducted field studies of erosion and deposition in the loess-mantled Great Plains of the Medicine Creek basin (PP 352-H, 1966).

NEVADA

SURFACE WATER BRANCH

By Hugh A. Shamberger

The writer served as deputy State Engineer from 1935 to 1942, when he became assistant State Engineer. During 1951, he became State Engineer and acted in that capacity until 1957 when he became Director of the newly formed Department of Conservation and Natural Resources. From 1935 to 1954, he represented the State in its cooperative program with the U.S. Geological Survey, as well as with some of the other Federal agencies dealing with land and water resources.

The cooperative stream-gaging program with the Survey started in 1913 and has been continuous since that time. Up until 1946, the stream-gaging work was supervised from the district engineer's office in Salt Lake City, which served both Utah and Nevada. During 1946, a Subdistrict office under the Salt Lake City District was established in Carson City, Nev., with L.R. Sawyer as engineer-in-charge. In 1952, C.H. Carstens replaced Sawyer, who had been appointed district engineer for Minnesota. The Subdistrict staff ranged from two to five persons during the decade.

By 1947, the stream-gaging program had been greatly increased with some 46 stream and reservoir stations in operation under the cooperative agreement with the State Engineer. A number of gaging stations were financed solely by the Survey and others by local agencies, making a total of 61. The State of California, Bureau of Reclamation, Corps of Engineers, and the Indian Service also contributed funds. By 1957, some 78 gaging stations were being operated, including some new and reestablished stations.

This progressive stream-gaging program was maintained during the ensuing years. The annual State appropriation for streamgaging increased from $1,500 for 1945 to $6,500 per year by the end of 1957.

Beginning in 1949, the Tucson, Ariz., District also maintained a field office in Nevada. It was located in Boulder City to facilitate the work in the middle reaches of the Colorado River and its tributaries. The staff, who varied in number from one to five, was under the direction of F.S. Anderson. [*Author's note*: We are grateful to Hugh A. Shamberger who kindly prepared this statement. A retiree of the State of Nevada, Mr. Shamberger is now (1982) a part-time member of the USGS staff in Carson City. He recalls with great pleasure his association with C.G. Paulsen, CHE. "Carl always attended the annual meetings of the Association of Western State Engineers and was extremely well liked. His talks before the Association were on an informal basis—never a prepared paper. He just chatted with us."]

GROUND WATER BRANCH

By Omar J. Loeltz

District headquarters remained at Carson City during the decade, having been established in 1945 when the statewide cooperative program became effective. In 1952, the office moved from its original location in the basement of the Ormsby County Courthouse to a newly completed State office building. T.W. Robinson, who transferred from Safford, Ariz., at the time the District was established, was district engineer until 1952 when he was designated staff engineer. He transferred to Menlo Park a year later. O.J. Loeltz, who had been senior staff assistant since 1946, succeeded Robinson and remained through the end of the decade. G.T. Malmberg was his principal assistant during the last year. D.J. Phoenix was on the staff until 1949, and J.L. Poole from 1949 to 1954. The headquarters staff varied in size from three to seven.

Two small field headquarters were used during portions of the decade. G.B. Maxey was stationed at Las Vegas from 1944 to October 1947 when he established and was in charge of the Ely headquarters. The Las Vegas office was again opened in 1954 by Malmberg, who transferred to the District headquarters in January 1957. T.E. Eakin succeeded Maxey at Ely in 1948 and joined the Carson City staff in 1949. The Ely headquarters, which varied from one to three persons, was manned by R.C. Perry from 1949 to 1953 when it was closed.

Ground-water investigations were financed for the most part by the continuation of a statewide cooperative program with the State Engineer that had begun in 1945. In 1957, the cooperative program was transferred to the newly established Department of Natural Resources. The primary cooperating official was Hugh Shamberger who was assistant State Engineer until 1951 when he became State Engineer and who, in 1957, was the first Director of the new Department. State funds available for matching by Federal funds were $40,000 for the biennium beginning July 1, 1947; $30,000 for 1949; $15,000 for 1951; $20,000 for 1953; and $30,000 for 1955. Wholly federally financed programs consisted of establishing and maintaining a network of observation wells; investigations for other Federal agencies were funded at about one-tenth the cooperative program level.

Development of ground water was expanding at a much increased rate at the beginning of the decade. The State encouraged development of its ground-water resources, but was committed to the principle of limiting development to a yield that could be sustained indefinitely. The legislature had enacted laws that permitted this principle to be carried out. The cooperative program was designed, therefore, first to investigate those areas where development was underway, then those areas where development was likely to begin, and finally the remaining areas. Concurrently with the area investigations, studies were also to be conducted to assist governmental entities in the development of ground-water supplies at particular sites.

Only in a few areas, such as Las Vegas Valley and Pahrump Valley where investigations had been underway since 1944, were sufficient data available for making quantitative studies. In most other areas, only qualitative studies were possible because of a lack of data and the economic infeasibility for obtaining needed data.

The qualitative studies commonly contained a ground-water budget in which estimates of recharge were based largely on the distribution of precipitation zones as shown on a statewide map that had been prepared by G.A. Hardman, Soil Conservation Service. Estimates of evapotranspiration from native vegetation (phreatophytes) were made by applying rates of consumptive use to the different species of plants as indicated by previous studies made by the Survey and other governmental agencies for a similar environment.

These qualitative studies were supplemented by additional studies as the development of ground water in a given area increased substantially. Such a supplemental study was begun in July 1954 to update the large amount of data that had become available for Las Vegas Valley since the publication in 1948 of the first study of that area made under the cooperative program. The State needed to know within closer limits how much ground water could be withdrawn on a perennial basis. The difference between the ever increasing demand and the perennial supply of ground water would have to be made up by importing Colorado River water from Lake Mead.

During the decade, some phase of ground-water occurrence and movement was investigated in nearly every part of the State. Near the end of the decade, studies were in progress in seven areas. The results of three site studies were available as duplicated reports and seven site studies as typewritten reports. A few of the completed studies of 21 valleys or areas were duplicated, but most were published in the series of State of Nevada Water Resources Bulletins. A study of Smith Valley was published as WSP 1228 in 1954. More detailed information on areas investigated can be found in biennial reports of the State Engineer.

New Hampshire

SURFACE WATER BRANCH

The New Hampshire program was under the jurisdiction of the Boston, Mass., District which maintained no field headquarters in New Hampshire during the decade. The primary activity was the operation of a network of stream-gaging stations. H.B. Kinnison, district engineer, reported in 1951 that 44 stations were in operation from which daily discharge was calculated and published. Of these, two were funded by the Federal program, 27 by the cooperative program, and 15 with funds transferred by other Federal agencies. D.J. Fogarty (written commun., 1985) reported that four additional stations in New Hampshire (on the Androscoggin and Saco Rivers) were operated by Maine District personnel with funds from the New Hampshire cooperative program. This arrangement was logical because these rivers drained into the Atlantic Ocean through Maine and the Maine District staff also operated additional stations downstream.

Program data available for fiscal year 1958, shortly after the end of the decade, showed a total of 48 stations, 6 supported by allocations from the Federal program, 32 operated in cooperation with the New Hampshire Water Resources Board, and 10 with funds transferred by the Corps of Engineers. Periodic water temperatures were taken at 46 of these stations. Reservoir stages, later

converted to reservoir content, were collected periodically at 14 locations. The water content of snow was measured at six locations. New Hampshire streams were included in several special studies by staff of the Boston District, which covered New England, but none were reported to have been prepared exclusively for New Hampshire.

GROUND WATER BRANCH

By O. Milton Hackett

In New Hampshire, negotiations by J.E. Upson, assisted by H.B. Kinnison, led to a cooperative ground-water program with the State Water Board beginning in 1953. At that time, E.A. Bradley was reassigned from Wyoming to begin a quantitative ground-water study of the New Hampshire seacoast region from field headquarters at Durham. The Durham headquarters, initially a part of the New York-New England District under Upson at Long Island, became a part of the newly formed Boston District in 1956. Upon completion of the seacoast study in 1957, Bradley was reassigned to the international program for work in Iraq, and J.M. Weigle began a study of the lower Merrimack River valley from field headquarters at Concord. This project was interrupted in 1959 because of a lack of funds from the State, but was resumed in the early part of 1961.

QUALITY OF WATER BRANCH

Water-quality studies in New Hampshire were under the direction of F.H. Pauszek, district chemist, New York-New England, Albany, N.Y. These studies were conducted in support of the cooperative programs established by the SW and GW Branches with State agencies. Water samples were collected by local SW and GW personnel, and analyses were made in the QW laboratory in Albany.

New Jersey

SURFACE WATER BRANCH

Condensed from documentation by G.S. Hayes

The District office, located in the Federal building in Trenton during the entire decade, had a staff that varied in size from 7 to 11. No field headquarters were used.

O.W. Hartwell, district engineer since 1921, retired in October 1956 and was succeeded by D.F. Dougherty who had been second in charge of the Virginia District. Otto Lauterhahn, whose association with the District also dated back to 1921, retired in 1956. E.G. Miller, who began his Survey career in the District in 1938, continued through the end of the decade. G.S. Hayes, who transferred from the Maine District in 1946, assisted Hartwell in District administration during the 1950's until he left in January 1956 to take charge of the Maine District. A.C. Lendo, who left the District staff in 1946 for duty in Georgia, returned in 1953. W.T. Sittner was on the District rolls until 1953. R.H. Tice arrived in 1956 from Virginia and began serving part-time also as flood specialist for the floods section of the Branch Chief's staff. J.A. Bettendorf, from the Wisconsin District, joined the staff in 1956. M.R. Stackpole transferred from the Connecticut District in 1953 and returned to Connecticut in 1955. J.M. Ludlow, who joined the staff in 1942, continued through the period. E.L. Beaumont, who entered on duty in 1946, transferred to Florida's Miami Subdistrict in 1956. The District clerk stenographer, Helen Stidworthy, on the staff since 1936, resigned in 1956 and was succeeded by Dorothy Kozak.

The District entered the decade with a backlog of office and fieldwork that stemmed from personnel shortages associated with the war years. Streamflow records processed up to the publication stage were nearly 3 years in arrears at the beginning of the period. Little maintenance had been accomplished for some time on the gage structures and controls. With the addition of several hydrologic field assistants and engineers, this condition was gradually alleviated and, during the last few years of the decade, more normal work schedules prevailed. The use of technical assistants for both field and office activities expanded greatly during the decade and was found to be advantageous.

Nearly all of the District program was in cooperation with the Division of Water Policy and Supply, a segment of the New Jersey Department of Conservation and Economic Development. Smaller cooperative programs were with the North Jersey District Water Supply Commission and the Passaic Valley Water Commission.

Hartwell reported, in response to a WRD Circular dated June 11, 1951, that the District currently operated 74 stream-gaging stations at which daily discharges were computed. Seventy of the stations were supported under the cooperative program with the State Department of Conservation and Economic Development, two were funded under the Federal program, and the remaining two from funds transferred from other USDI agencies. The cooperative program also included the collection of daily stages of two lakes. The station network, as reported for fiscal year 1958, showed no appreciable change in size except the addition of about 30 streamflow sites at which periodic measurements of discharge were made.

Urban and industrial development along the tidal reach of the Delaware River created the need for better information regarding tidal-flow characteristics and the

extent of freshwater inflows from local tributaries and adjacent bodies of ground water. In cooperation with the Philadelphia, Pa., district of the Corps of Engineers and the New Jersey Department of Conservation and Economic Development, personnel of the District conducted a series of continuous-flow measurements during 1955–57. E.G. Miller reported the findings in WSP 1586-C (1962), which provided a hydraulic base for a concurrent study of the salinity of the Delaware Estuary (WSP 1586-B, 1962) described under the Pennsylvania QW activities. The New Jersey segment of the nationwide compilation of summaries of streamflow records through 1950 was published in WSP 1302 (1960).

During the period, a Supreme Court decision allocated water use of the Delaware River. The Montague gaging station was designated as the control point, which created considerable work at that location. A minimum allowable flow at the Trenton gaging station was set also, and a Stevens long-distance recorder was located in the District office to have the flow continuously monitored at that point.

From the early 1950's and extending through the end of the decade, the District participated in an interbranch research project to evaluate the effect on ground-water recharge of the State's policy of controlled burning in pine forests. GW Branch staff directed the project in cooperation with the State. SW District staff selected and measured the runoff from two areas, one on the unburned control area and the other from a test-burn area.

In 1953, a study was begun to evaluate municipal problems created by the flooding of Stoney Brook at Princeton. The study included the establishment of a gaging station and an artificial structure in the downstream channel that controlled the stage-discharge relation. The theoretical (calculated) rating was found to be within 5 percent of that determined by actual current-meter measurements over the entire range.

GROUND WATER BRANCH

By Solomon M. Lang

District headquarters was located in the Federal building in Trenton for essentially all of the decade, having moved from the Trenton Trust building in the late 1940's. The number of personnel at headquarters increased from three to as many as 12 by the end of the period. Only one field headquarters was used, which was established in late 1950 at Seabrook.

H.C. Barksdale, who had begun his Survey career in the District in 1924, was appointed district engineer in 1939 and continued in that position until April 8, 1957, when he transferred to the newly established Atlantic Coast Area Headquarters at Rosslyn, Va., to become its branch area chief. Barksdale had begun serving as a staff engineer in addition to his District responsibilities as early as 1952, however, and, by 1954, his role involved one of consultation and advice on the scientific aspects of ground-water investigations in North Carolina, Pennsylvania, Virginia, and West Virginia. Allen Sinnott, who had been serving as district geologist for Virginia, succeeded Barksdale as chief of the New Jersey District.

Senior members of Barksdale's staff at the beginning of the decade included G.D. DeBuchananne, who began his Survey career in the District in 1942 and transferred to Knoxville, Tenn., in 1948. J.M. Birdsall was recruited for the District in 1943 and transferred to the Branch headquarters staff in 1952. S.M. Lang entered on duty in 1949 and moved to the Providence, R.I., Subdistrict staff in 1955. Irwin Remson joined the headquarters staff on graduation in 1949 but, in 1950, he transferred to Seabrook where, assisted by G.S. Fox, he assumed charge of the study of the effects of land-management practices on ground-water supplies. E.C. Rhodehamel arrived from the Michigan District in 1951. G.S. Hilton began his career in New Jersey in 1950 and moved to Sacramento, Calif., in 1956. J.E. Reseneau and P.R. Seaber joined the staff in 1949.

The decade was one of major growth in ground-water activities in the State. At the beginning of the decade, funding for the ground-water program, all from the Federal-State cooperative program, was about $10,000 and supported a staff of three. Activities consisted largely of monitoring conditions in "critical areas" of the State where ground water was the principal source of supply. The critical areas were primarily along the Atlantic coastline, where saltwater encroachment was a major concern and where each of the principal resort communities had its own ground-water supply, and along the lower Delaware River, where increasing ground-water development for commercial and industrial activities posed problems of overdraft, excessive drawdown, and interference between supplies.

Toward the end of the decade, funding increased to about $200,000 and there was a staff of 12. The concerns were somewhat the same, but the degree of interest in ground water was much higher because of major increases in water requirements for municipal, industrial, and recreational use, as well as for irrigation in the agricultural areas of southern New Jersey. The principal source of funds continued to be the Federal-State cooperative program with the New Jersey Department of Conservation and Economic Development, Division of Water Policy and Supply. The funding covered two principal groups of activities. One was the continuation of general ground-water investigations in New Jersey, and involved qualitative evaluations of conditions in the various counties of the State. As sufficient data were accumulated, periodic

progress reports were released to document existing conditions. The other group involved interstate investigations in both New Jersey and Pennsylvania along the lower Delaware River. Planned products included a series of county reports and a joint report covering the entire interstate area.

Another dimension was added to the ground-water program in New Jersey in the early 1950's when Federal funding was received to establish an office at Seabrook, N.J., for research of the effects of land-management practices on ground water, and a three-party cooperative program was developed between the Survey, the State Division of Water Policy and Supply, and Rutgers University to research the ecology and hydrology of the Pine Barrens region of the State. Ground-water research conducted in the New Jersey District established an important precedent for the Water Resources Division because it demonstrated the highly technical interplay between professionals as research went on side-by-side with general investigative studies.

The ground-water program in New Jersey during the 1947–57 decade produced a number of significant results that had far-reaching impact on WRD activities nationwide. For example, the research program in the Pine Barrens involved aquifer testing in a small, highly-instrumented test area that led to a better understanding of the complex geology and hydrology of the Atlantic Coastal Plain. A three-dimensional picture of ground-water flow illustrated how water moves on both local and regional scales, replenishing aquifers and contributing to base flow of streams both locally and at points far distant from where recharge initially occurs. Further understanding of the hydrologic complexities of the Coastal Plain resulted from the interstate project funded under the Federal-State cooperative program. Several deep test wells were drilled as part of the project which provided important information about the location, extent, thickness, and hydrologic characteristics of the principal water-bearing formations in southern New Jersey. The wells also contributed to a better understanding of the regional movement of ground water and an indication of the approximate position of the freshwater-saltwater contact in the water-bearing formations.

The general ground-water monitoring activities in the State also contributed key information about regional water movement. Not only did the water levels show the status of ground-water storage, they also indicated the ground-water gradients that control the movement of water. The records were instrumental in defining areas of recharge to the various aquifers, directions of water movement, and areas of discharge. Some of the earliest ground-water records in the Nation were collected in New Jersey. These studies, coupled with the records from the 1947–57 decade, provided the base from which the interpretations of ground-water occurrence and availability were possible and were reported in a series of county reports.

The research at Seabrook, N.J., saw some of the earliest pioneering efforts to relate land-management practices to ground-water hydrology. Insight was gained into the physical and hydrologic factors associated with interception, infiltration, percolation, soil-moisture storage, and unsaturated flow and their relation to ground-water recharge. Results of research indicated that, although the effect of land-management practices on ground water was dependent on geology, topography, soils, and climate of an area, these practices could have significant impacts on the accumulation and depletion of ground water.

In summary, the ground-water program in New Jersey experienced rapid growth and diversification during the decade. The program assumed a significance that transcended State boundaries because of the high level of professionalism of the District staff who produced greater knowledge about the geology and ground-water occurrence in the major physiographic provinces of the Eastern United States. The many and significant reports resulting from hydrologic monitoring, areal studies, and research activities have played a key role in the management decisions relative to the development of the water resources in New Jersey.

QUALITY OF WATER BRANCH

By Norman H. Beamer and David McCartney

The limited program in New Jersey was conducted by the staff of the Pennsylvania District. Among the major projects was a study of the flow and salinity characteristics of the tidal reaches of the Delaware River. This study was conducted jointly with SW District personnel. Observations began in 1955 and continued through the end of the decade in cooperation with the New Jersey Department of Conservation and Economic Development, Division of Water Policy and Supply (CED-WPS), and the Philadelphia district of the Corps of Engineers. Findings were published as WSP 1586-C by E.G. Miller in 1962.

In the mid-1950's, an investigation of the sources and movement of sediment in the Stoney Brook basin was begun to provide a base for a water-quality appraisal and for use in resolving current dredging problems in an all-purpose lake owned by Princeton University. Malcolm Crooks, Director of the Stoney Brook Watershed Association (SBWA), provided skilled advice in setting up the project, and J.P. Eiler of the District staff supervised the project and reported on its findings. An index station, for which daily records of fluvial sediment were published, was established in January 1956 and continued

in operation through the decade. Funding was provided by the SBWA, and Princeton University through the CED-WPS.

New Jersey had a potentially serious ground-water problem in the coastal areas where continued heavy pumping could cause saltwater intrusion. A well-sampling program was established in which wells from Asbury Park to Cape May were sampled. The District laboratory personnel made the many hundreds of analyses of chloride and conductance that were required annually. In addition, there were regular GW Branch water-quality, rainwater, and hurricane-rainwater sampling programs.

The Trenton GW District transferred an average of $8,000 per year to the Pennsylvania District for analytical services. In 1957, the cost of a complete analysis was $45. The cost of a chloride analysis was $2 and the cost of a conductance determination was $1.

Between 1955 and 1957, personnel of the District and Trenton SW District participated in continuous monitoring of water discharge and specific conductance of the water throughout several tidal cycles on the Delaware River at the Burlington-Bristol Bridge and the Delaware Memorial Bridge below Trenton. The study was made in cooperation with the Corps of Engineers and the CED-WPS. The findings, reported by E.G. Miller (WSP 1586-C, 1962), showed that a correlation existed between velocity at a fixed point in a cross-section of the river and the mean velocity in the cross-section. The correlation, applicable also to specific conductance, gave a measure of the salinity caused by saltwater moving upstream. Specific conductance readings were greatly helped by the use of the first battery-operated specific-conductance recorder in such a study.

Near the end of the decade, the Delaware and Raritan Canal, a diversion of the Delaware River, was under study in cooperation with the State. A composite record of chemical-water quality was collected from February to September 1956, followed by sampling at 14 other locations on the canal.

Cooperation with the CED-WPS developed slowly during the decade, largely because its funds available for cooperation were almost entirely used by the older, well-established programs with the SW and GW Branches. Chief Engineer (and primary cooperating official) George Shanklin expressed his feeling years later at the time of his retirement that "water quality was New Jersey's number 1 problem."

New Mexico

SURFACE WATER BRANCH

Condensed from documentation by R.E. Cook, William Dein, L.J. Reiland, and J.C. Schaefer

District Headquarters, with a staff that fluctuated in size from 10 to 17, was located at the Federal Courthouse in Santa Fe during the entire decade. A Subdistrict office in Albuquerque, located at the University of New Mexico during the latter part of the period, grew from a one-man headquarters to a staff of seven or eight at the end of the decade. Of the numerous field headquarters, none was used continuously from 1947 to 1957. The largest (four persons), at Carlsbad, was used from 1952 on. Another, at Socorro, was established in 1950 and was a base for between two and four persons. One or two persons were located at the Roswell headquarters until it closed in 1949, and a similar number were stationed at Las Vegas from 1949 to 1955. One-man posts were used at Gila (1951 on); Silver City (1947–49); Taos (1951–53); Tucumcari (1953 on); and Virden (1949–50). The intermittent use of a field headquarters at Durango, Colo., was needed to efficiently handle stream gaging and maintenance in the San Juan basin.

Berkely Johnson, district engineer since 1931 when the District was established, continued in the position until his retirement in 1955 after which he worked on a part-time basis. Johnson also served as the U.S. representative and chairman of the Pecos River, Canadian River, and Rio Grande Compact Commissions and continued these roles until 1969. He was succeeded as district engineer by W.T. Miller, who joined the Santa Fe staff as assistant district engineer in 1948. Miller continued in charge through the end of the decade. R.E. Cook was the only member of the staff to remain throughout the decade. Other senior headquarters staff members as of January 1948 included E.L. Barrows (assistant district engineer until 1948), G.L. Oakland, and L.J. Reiland. As of July 1, 1957, the top staff included Cook, H.J. McDowell, Reiland, C.R. Sieber, and L.A. Wiard. Oakland was in charge of the Subdistrict at Albuquerque and S.O. Decker at Carlsbad. J.N. Fitch headed the work program at Socorro and R.F. McCauley at Roswell. T.E. Yates worked out of Silver City (and later Virden and Gila) at about the same time R.H. Beeler was at Las Vegas and E.E. Cerny was at Tucumcari.

The growth of the stream-gaging program during the decade reflected the increasing demands for water. New lands were being irrigated. Industrial, municipal, and domestic water use expanded. Water for recreation took on a greater importance with new flood detention or storage reservoirs designed to assure some permanent pools.

The State Highway Department, having begun its support of four gaging stations for bridge-site studies in 1942, increased the program with the addition of 146 crest-stage stations. Some of these were equipped with weekly recorders so that any substantial flow would start the mechanism and hopefully record duration of flow as well as stage; however, most flood crests were determined by indirect measurements using high-water marks. Wiard

compiled a flood-frequency study (Circular 464, 1962) that made it possible to generate a synthetic flood peak almost anywhere in the State. The only flood that occurred during the decade that caused loss of life and appreciable property damage was on the Rio Felix, a tributary of the Pecos River, in 1954.

The Corps of Engineers support for the stream-gaging program was related in part to the severe flood damage in locations on floodplains and in the dry beds of arroyos subject to rapid development. Flow data were used by the Corps for the planning and design of new flood-control structures and for the operation of Conchos Reservoir, a flood control and irrigation facility under the Tucumcari project.

The typical gaging station, supported with funds from the Bureau of Reclamation, operated for about 7 years, after which the funds were used for flow records at a new site. Data were used not only for the study of a transmountain diversion proposal and the Heron Reservoir, but also for the determination of water lost to existing stands of saltcedar mainly in the Pecos and Rio Grande valleys. A 1936–38 water-use study had shown that a thick stand of saltcedar could use up to 7 feet (depth) of water annually. The diversion of such water to beneficial irrigation was an attractive alternative. The Bureau also had District personnel collect flow data on sand-channel streams as an aid to composite studies of gains, losses, and water use.

The Fish and Wildlife Service supported four gaging stations in connection with their Bosque del Apache Refuge. Their primary objective was to determine flows into and out of the refuge. Variable backwater at some of these stations made flow computation a difficult task.

Many records had to be processed and furnished on both a calendar-year and water-year basis. This added to the workload because some of the records had to be reworked when all supporting data became available. Resulting revisions often meant more work for the cooperators as well. Many records had to be worked concurrently. R.E. Cook recalls his urging (unsuccessfully) that the added efforts required in current computations be recognized in cooperative negotiations by an increase of 20 to 25 percent over normal station costs.

Adequate stage-discharge ratings depended on "flood chasing." Using all alerts and maintaining a state of readiness, high-flow measurements were often obtained on flash floodflows. High-water marks were flagged for indirect measurements, the accuracy of which was gradually upgraded.

Progressively, records increased in accuracy after artificial controls were installed in the shifting beds. Considerable study was given to self-cleaning types for sand-and-gravel channels with migrating bedloads. Some were standard types, such as Parshall flumes and weirs. Heaters in gage wells were increasingly used to get better records of stage during winter. Some low-flow measurements were made with portable Parshall flumes, others by quantitative determination. Many seepage runs were made on the Pecos River, usually from Anton Chico (or Santa Rosa) to Malaga. These measurements were compiled and published. Accurate streamflow data continued to be needed in the administration of the Rio Grande, Pecos River, Canadian River, and Costilla Creek Compacts. Because low-water channels meandered widely within the main channels, as many as four gage wells had to be placed on bridge crossings at some stations.

The number of active discharge stations during the decade varied considerably. Many stations were discontinued and funds allocated to new sites. The initial network totaled about 162. In 1957, there were 173, including 10 reservoir-stage stations. Some furnished records were reviewed and published.

The District had its full share of unusual events that placed stresses of various types on the program or personnel or both. In February 1950, a "hedge-hopping" light plane hit and destroyed the cableway on the Rio Grande at Bernalillo. With the cable acting as a bowstring, the plane was deposited on a sandbar and the pilot walked away. Expenses incurred to repair the damage could not be collected. Another time, an overloaded truck caused the collapse of a span of steel bridge on Rio Chama near Park View, destroying the gage structure in the process.

Because District finances were rarely stable, construction or rehabilitation could not be scheduled well in advance. Funding was typically meager for 10 or 11 months, followed by supplemental monies; this at times required highly unseasonal construction work. Reiland and Cook poured concrete in December and January at zero temperatures and also constructed a gage on the Rio Grande near Cerro during spring runoff. Using the new cableway made from a "temporary" cable salvaged from a mine, Reiland measured the flow with his feet dangling in the water. It is also recalled that, despite the uncertain District finances, District Engineer Johnson never ran short of money.

GROUND WATER BRANCH

By Clyde S. Conover

District headquarters, in Albuquerque throughout the decade, was initially in the Rosenwald building. About 1948, it moved to the Bass building, along with the District laboratory of the QW Branch and an area office of the SW Branch. The building was jointly occupied with the U.S. Bureau of Reclamation. Accordingly, close working relations developed among the Branches and the Bureau.

In 1953, the WRD offices moved to the new Geology building at the University of New Mexico. An area office of the fuels section of the Geologic Division also was in the building and close contact was maintained with C.B. Read and his staff.

C.V. Theis was district geologist for the GW Branch until November 1951. C.S. Conover, nominally in charge during Theis' absences, was formally designated assistant in August 1949 and district engineer through the end of the decade. Theis initially was involved in a variety of non-District investigations, particularly the hydrologic aspect of iron mining in Michigan that began in 1954, and the emerging program with the Atomic Energy Commission (AEC). In 1951, he was assigned full-time as WRD's coordinator of work for the AEC and for Federal program activities relative to radioactivity of water resources.

An administrative services section was created early in the decade to provide support to the District offices of the three branches. The section was first located at the SW District headquarters at Santa Fe, and then moved to Albuquerque when space in the Geology building became available. R.E. Gay, section chief, moved to Albuquerque from Santa Fe. J.E. Marquez took over as head of the section in early 1957 after Gay transferred to Denver.

The period was a decade of growth for the Branch in New Mexico. The total number of personnel increased from 7 in 1947 to 44 in 1957, while the professional personnel increased from 4 to 28. Total funds increased from $24,250 to about $300,000 in 1957, which included about $15,000 transferred to the QW and SW Branches for participating in various investigations. The prime cooperator was the State Engineer of New Mexico whose program grew from $13,000 to about $150,000 per year. Other cooperators were the Elephant Butte Irrigation District, the State Bureau of Mines and Mineral Resources, the Pecos River Commission, and a few counties. Investigations were also supported by other Federal agencies, including the AEC, the U.S. Army Corps of Engineers, the Bureau of Reclamation, the Bureau of Indian Affairs, the National Park Service, and the Forest Service. Federal program funds were small, amounting to about $3,000 in 1957, which included about $2,000 for an evaluation of the saline-water resources of New Mexico. The report on saline water in New Mexico by J.W. Hood and L.R. Kister, Jr., was published in 1962 as WSP 1601.

In 1947, a joint cooperative program with the State Bureau of Mines and Mineral Resources (BMMR) and the State Engineer was arranged. The objective was to evaluate and prepare reports on the geology and ground-water resources of various counties. The first report, on eastern Colfax County, was prepared by R.L. Griggs who was headquartered at Raton during the period of field work. Griggs transferred to Albuquerque in 1948 to complete the report, which was published in 1948 by the BMMR as Ground-Water Report 1. This study was initiated in 1946 in cooperation with Colfax County in part to solve a water shortage at Raton and at the airport. The work was integrated with the fuels section of the Survey in preparing a geologic map of the county and with the QW and SW Branches. Griggs began a study of San Miguel County about 1948. G.E. Hendrickson finalized the report following the assignment of Griggs in 1946 to the Los Alamos water-supply investigation. The report on San Miguel County was published in 1951 as BMMR Ground-Water Report 2. Hendrickson transferred to Carlsbad in 1948 to complete the Eddy County study begun in 1947 by R.S. Jones. Hendrickson transferred to Albuquerque in 1949 to finalize the report that was published in 1942 as BMMR Ground-Water Report 3.

Jones began a study in 1949 on northeastern Socorro County. The work was taken over by Zane Spiegel, and the report was published in 1955 as BMMR Ground-Water Report 4. R.E. Smith began work in Albuquerque in 1949 and was assigned to take over the Torrance County investigation that was started in 1948. Smith authored the subsequent report that was published in 1957 as BMMR Ground-Water Report 5.

The drought of 1946 and the severe drought of 1950–51 caused record-low flows in the Santa Fe River, the source of Santa Fe's water supply. As a result of the periodic droughts and the desire of the BMMR to expand its participation in water- and mineral-resources studies, additional funds were obtained from the legislature. Accordingly, a multi-disciplinary team was set up by the BMMR to evaluate the water and mineral resources of the Santa Fe area. E.L. Barrows analyzed the data on precipitation and streamflow. Zane Spiegel transferred to Santa Fe and began the evaluation of ground-water resources in 1951. The study showed (WSP 1525, 1963) that ground water was available to supplement the Santa Fe River source, which, with increasing demand for water, would be inadequate in most years.

C.F. Berkstresser transferred to Tucumcari in 1953 to start the study of Quay County. Field work was completed, and Berkstresser transferred to Albuquerque in 1955. The county-wide study was an outgrowth of Tucumcari's shortage of water and its application to the State Engineer and the Bureau of Reclamation for water from the Tucumcari Canal, which diverted irrigation water from Conchas Reservoir. Before any consideration could be made to allocate surface water, a determination of a deficiency in the ground-water supply being used by Tucumcari was required. Accordingly, the Survey was asked to look into the matter. The water shortage was critical and Spiegel and Conover made a rush trip to

Tucumcari in 1952 to conduct a reconnaissance. They determined that wells in the current wellfield were sanded up and most of the pumps were not producing water; however, water in the old wellfield, which had been abandoned years before, had apparently recovered and offered a potential supplemental supply. These facts were reported at a meeting of the City Commission with the conclusion, however, that an investigation was needed to evaluate the quantity of ground water that could be developed on a long-term basis. Unfortunately, the only outcome was a "thank you" at the meeting.

Alfred Clebsch transferred to Santa Rosa in 1954 from the Geologic Division in Washington, D.C., to start the study of Guadalupe County. Following completion of field work, he transferred to Albuquerque in 1956 to complete the report. Clebsch prepared a supplemental report for the WRD Bulletin published in 1958 on the effect of solution and collapse of limestone on ground-water movement.

F.D. Trauger was assigned to investigate the ground-water resources of Grant County in 1954 and transferred to Silver City. Upon completion of field work, he transferred back to Albuquerque in 1956. I.J. Winograd assisted Trauger near the end of the study to obtain training in field investigations. While at Silver City, Trauger was successful in locating a ground-water supply for the town of Central, which was in dire straits. Central had obtained a governmental loan to develop a water system and a well. The well had been drilled but was dry. Trauger evaluated the conditions and selected a location, far removed from the dry well, that produced water. He was able to locate an area for a new wellfield for Silver City, which eased a perennial shortage of water that Silver City had experienced for many years. He also prepared a report for the Forest Service on availability of ground water at proposed well sites in Gila National Forest, and in Sierra and Catron Counties.

Conover returned from military furlough in January 1946 and, among other duties, took over much of the continuing program, with the State Engineer, to evaluate the ground-water resources. In 1947, he was also assigned to evaluate the ground-water conditions in the Rincon and Messilla Valleys. Drought conditions in the Rio Grande basin had reduced the surface-water supply to the Rio Grande project so that rationing of water from the Elephant Butte Reservoir was imminent. The Elephant Butte Irrigation District, the cooperator, needed to know whether ground water could be developed for irrigation to supplement the surface-water supply. Results of the study, published as WSP 1230 in 1954 (the first Water-Supply Paper on ground water in New Mexico since 1933), showed that adequate quantities of ground water were available. The ground water pumped was not a new or additional source of water, however, but rather borrowed from future surface-water supplies. The study made a significant contribution to conjunctive management of surface and ground water and, in part, pointed the way to later declarations by the State Engineer that surface and ground water in the alluvial valleys were one supply. Another outgrowth of the study was a chart prepared to show the effects of ground-water pumping on a drain or stream in the Rincon and Messilla Valleys, which later was modified with the help of Theis to make it universally applicable and published as WSP 1545-C in 1964.

Expansion of Los Alamos required an assessment of sources and permanency of water supplies developed hurriedly during World War II. Theis in 1949 arranged for an investigation of the potential water supply in the Valles Caldera west of Los Alamos. The resultant report by Conover, Theis, and Griggs (WSP 1619-Y, 1963) showed that ground-water supplies were available but that development would reduce the flow of Jemez Creek, the water supply of the Jemez Indians. Accordingly, emphasis on locating a water supply was shifted to the Los Alamos and Guaje Canyon areas east of Los Alamos. Conover conducted the pumping tests on the Los Alamos Canyon wellfield in 1950 and prepared a report with Theis (WSP 1619-I, 1962), which indicated that the supply was substantial, that water levels would decline about 100 feet in 40 years, and that space between wells should be greater and they should be drilled deeper. Subsequently, Conover conducted a pumping test and evaluated the water supply, the effect of planned pumping, and well spacing in the projected Guaje Canyon wellfield. One critical technical problem at Los Alamos was that of measuring, recording, and portraying the deep ($\pm$1,000 feet) water levels in pumped wells. Conover devised automatic air-line recording gages and a system of processing the records from the pumped wells. The program emphasis with Los Alamos gradually shifted from water supply to evaluating the potential migration of radioactive waste from the solid, low-level radioactive-waste sites. A number of individuals were involved in that program during the decade, including J.E. Weir from about 1952 through 1957 and J.F. Waldron from about 1953 to 1956.

The program with the New Mexico State Engineer, the principal cooperator, consisted of two main endeavors: (1) the continuing annual evaluation of the status of ground water in the various declared and undeclared ground-water basins, and (2) investigations of the water problems in various parts of the State. Practically all reports produced were printed by the State Engineer in his Technical Report (SETR) series. By the end of the decade, annual assessments and reports were being produced in about 20 heavily developed ground-water areas consisting in part of a network of nearly 2,000 observation wells. A necessary part of the quantitative evaluation of ground-water resources entailed annual appraisals of the amount of

pumpage and the development of a ''well-location'' numbering system based on the township-range-section land-grid. One facet of the program was the evaluation of the effects of pumping in northern Lea County. Information gathered by Conover and discussed with personnel of the State Engineer's office formed the basis for the allocation of water rights by townships for a 40-year term. The Internal Revenue Service later accepted the concept of a depletion allowance for ground-water mining of areas of the High Plains. As part of the subsequent evaluation of water in storage in the Ogallala Formation in Lea County, W.E. Hale and Alexander Nicholson prepared three maps in 1953 showing the bottom, the water table, and the saturated thickness of the Ogallala Formation. As an outgrowth of the investigation of storage depletion in the High Plains area of New Mexico, Conover devised a graphical scale for determining drawdowns from a mass array of wells. A paper on the use of the scales was jointly authored with H.O. Reeder.

L.J. Bjorkland and W.S. Motts transferred to Carlsbad in 1953 to evaluate the water resources of the Carlsbad area, to determine the sources of water to Carlsbad Springs, and to portray the geology of the Capitan Reef. The results of the study, released in 1959, were used by the State Engineer in allocating water rights to the city of Carlsbad and the Carlsbad Irrigation District. Bjorkland also prepared a report on ground-water resources of the Crow Flats area in Otero County (SETR-8). Bjorkland transferred to Albuquerque in 1956 and, along with B.W. Maxwell, evaluated ground-water conditions in the Albuquerque area (SETR-21). A study of the source of Rattlesnake Springs, the water supply for Carlsbad Caverns, was conducted by Hale for the National Park Service (SETR-3), and the information developed was later used in court to determine the water rights for Carlsbad Caverns.

The continuing deficiency of water in the Pecos Valley resulted in a number of studies to improve the water supply and quality. One study of much interest, conducted in cooperation with the Pecos River Commission, was the feasibility of diverting the saline springflow at Malaga Bend on the Pecos River to a nearby depression. This study was conducted by Hale and C.R. Cox and later supported as a research study by the Bureau of Reclamation. Their report was prepared in 1954. The toll taken of water used by phreatophytes (saltcedar) in the Pecos Valley resulted in studies of the use of water by saltcedar in the McMillan delta for the purpose of salvaging the lost water. The study for the Bureau of Reclamation and the Pecos River Commission was conducted by Hale. A preliminary assessment, ''Factors for Consideration in a Study of Salvage of Water Used by Phreatophytes,'' was prepared by Conover and Theis in 1951 (published in 1962 by the State Engineer). The report was part of a report by the Salt Cedar Interagency Task Force to the Salt Cedar Interagency Council established in 1950, which consisted of representatives of the office of the New Mexico State Engineer and of the Departments of the Army, Agriculture, and Interior. The assessment concluded that the most probable success for water salvage was the removal of water from the saltcedar rather than removal of the saltcedar.

The perennial question of the source of Major Johnson Springs and the relation to leakage from Lake McMillan prompted a long-term analysis of the geology and ground-water conditions of the area between Lake McMillan and Carlsbad Springs on the Pecos River, which was begun by Hale and Cox in the early 1950's. J.W. Hood prepared a report (WSP 1539-M, 1963) on the occurrence of saline-ground water near Roswell. R.W. Mower, Hood, and others prepared an appraisal (WSP 1659, 1964) of potential ground-water salvage along the Pecos River, between Acme and Artesia. Motts evaluated the recharge potential from the Rio Penasco to the Roswell artesian basin. R.T. Bean evaluated the geology of the Roswell artesian basin and its relation to the Hondo Reservoir (SETR-9). W.A. Mourant in 1957 completed a reconnaissance of water resources in the upper part of the Sacramento River Canyon, Otero County. The concern and interest in use of water by saltcedar in the Pecos Valley prompted a study near the end of the decade of ground-water conditions in the delta area of the Elephant Butte reservoir on the Rio Grande between Truth or Consequences and Las Palomas, by Cox and Reeder.

A study of nonthermal flowing wells south of Hot Springs, Sierra County, started in 1945 by C.R. Murray, was concluded in 1948 (SETR-10). The study of the Grants-Bluewater area, Valencia County, started in 1954 by Murray, was continued by Conover and then by E.D. Gordon (SETR-20). I.J. Winograd completed reports on ground water in the vicinity of Taos Junction, Tres Piedras, and No Agua, Taos and Rio Arriba Counties, in 1955; on ground water in the Fort Union area, Mora County, in 1956; and on ground water and geology of Sunshine Valley, western Taos County, published as SETR-12. S.W. West transferred to Gallup in 1955 to begin a study of the ground-water resources of the area. West transferred to Albuquerque in 1956 on completion of the field work. Reeder began an investigation in 1948 of the ground-water resources of the Amimas Valley in Hidalgo County. The information (SETR-11) was used by the State Engineer in declaring the area a ground-water basin and establishing water rights. Beginning about 1956, G.C. Doty evaluated the ground-water conditions in the Playas Valley, Hidalgo County (SETR-15).

A program with the Corps of Engineers was initiated in the early 1950's to evaluate the water resources of the

White Sands Proving Ground in the Tularosa Valley in south-central New Mexico. Water supply at the headquarters just east of the Organ Mountains was seriously deficient even though a large number of fairly shallow wells had been drilled over the years. E.H. Herrick was assigned to investigate the area, and a decision was made to drill a large capacity, deep test well at a selected location well away from the existing wells. This source was later supplemented by another well, and the reliability of the supply was assured. Subsequently, water shortages at Alamagordo Air Force Base were evaluated by Hood, and a report on ground water in the vicinity of Boles wellfield was released in 1956. The potential for a supplemental supply for the Alamagordo Air Force Base and for the city of Alamagordo from the Three Rivers area was evaluated by Herrick and Hood. Miscellaneous studies of the potential for ground-water supplies in the northern part of the White Sands Integrated Range were conducted by Herrick and others. Results of the various ground-water investigations in the Tularosa Valley were summarized in a report by Conover and others in 1955 published in the New Mexico Geological Society Sixth Field Conference report, and by Herrick and others in a report on ''Ground-Water Resources of the Tularosa Valley and Adjoining Areas'' in 1960.

QUALITY OF WATER BRANCH

Condensed from documentation by J.D. Hem, F.C. Ames, and J.R. Avrett

The District, with headquarters in Albuquerque throughout the decade, was initially under C.S. Howard who transferred there from the Washington, D.C., headquarters staff in 1942. Howard was responsible for all Branch programs west of the Mississippi River except those in the Missouri River basin and in the States of Arkansas and Texas. In 1948, Howard moved to Salt Lake City, Utah, where he established a Regional headquarters. He was succeeded as district chemist in Albuquerque by J.D. Hem who had joined the District staff in 1945. In 1953, Hem transferred to Denver, Colo., where he established a research laboratory. He was succeeded by J.M. Stow who continued as district chemist through the end of the decade.

Hem states that, at the beginning of the decade, the District staff was located in a small building provided, rent free, by the Bureau of Indian Affairs, which owned an old red brick residence in front of it at 723 North Second Street (written commun., 1984). By 1948, when the Rio Grande sediment studies began, the space had become inadequate and, in 1950, the facility moved to 918 Park Avenue, Southwest, in the downtown area of the city in quarters shared with the GW Branch. The final move of the decade was in 1953, when all WRD personnel in Albuquerque and the local staff of the Geologic Division's Fuels Branch were consolidated in space on the second floor of the new Geology building on the campus of the University of New Mexico. Hem further recalls that, at the new location, the District was able to afford laboratory furniture designed and constructed for such use. Previously, laboratory benches had been improvised from unfinished household furniture, plywood, and transite, using the carpentry and artistic skills of the laboratory staff.

In 1949, F.C. Ames transferred from the SW Branch and joined the District staff in Albuquerque. B.R. Colby and George Porterfield came in 1955 to assist Ames. A recognized authority in the field of sedimentation, Ames had represented the Survey on the recently completed interagency study of the sedimentation of Lake Mead. In his new assignment, he advised and assisted all western districts, as a representative of the branch chief, in the planning and execution of sediment investigations. Ames continued in this role until the close of the decade, when (April 1957) he was designated branch area chief, Rocky Mountain area, with headquarters in Denver.

The District headquarters staff was composed of about a dozen individuals at the beginning of the decade. The number grew to a maximum of about 35 by 1955 and dropped to less than 30 by the end of the period. Many of the personnel worked part-time and were engaged in laboratory activities. Among the senior professional members of the staff were W.G. Bratschi, who remained during essentially all of the decade, and J.R. Avrett and D.Q. Matejka, who arrived in 1954. J.L. Kunkler opened a field headquarters at Tucumcari in 1949 in which from two to three persons were located until near the end of the decade. Kunkler transferred to Albuquerque in 1952 and was succeeded by Fred Mintoya. The Tucumcari staff operated a network of sediment-discharge stations in eastern New Mexico and conducted chemical-quality studies to assist the Bureau of Reclamation in solving problems related to its new Tucumcari project. In 1955, M.H. Biederman and T.E. Diaz established a second New Mexico field headquarters at Fairview for operation of sediment stations in the northern part of the State. The Tucumcari and Fairview facilities included small laboratories to determine sediment concentrations. Among those who began their careers with the Branch in Albuquerque during the period were J.K. Culbertson, L.S. Hughes, and J.L. Hatchett.

The District maintained active programs in both New Mexico and Arizona and that portion of Colorado within the Rio Grande and Arkansas drainage basins. The network of stations in New Mexico where water data were collected as of July 1951 is identified in the District's response to a WRD Circular dated June 11, 1954. Chemical-water quality was determined on a daily basis at 12 stream and other open channels and periodically at

20 other locations, including 11 springs. Water temperatures were recorded daily at 10 and periodically at an additional three points. Daily suspended-sediment discharge was measured at 21 stream-channel stations. A somewhat similar report made in March 1958, shortly after the end of the decade, shows about the same number of daily chemical-quality and suspended-sediment discharge records, but a large increase (to nearly 60) in periodic records. Daily water-temperature collection sites about doubled and periodic readings were made at nearly 60 points. Chemical-quality analyses of periodic water samples from about 150 observation wells were shown as of 1958.

The data-collection program was accomplished largely in cooperation with the Interstate Streams Commission (ISSC) of New Mexico and with Colfax County. The ISSC continued as the major cooperator through the end of the decade according to program statistics as of March 1958. Federal program funds were used for studies of the San Juan River, in the Colorado River basin, and of the Rio Grande. As of 1958, the Federal program allotment supported about 50 percent of the New Mexico program. Major cooperating agencies, in addition to the ISSC, included the Pecos River Commission, the State Engineer, and the State Bureau of Mines. Five other Federal agencies also supported the program as of 1958, the two largest being the Atomic Energy Commission and the Bureau of Reclamation.

Among the projects conducted or participated in by the District staff was the investigation, in conjunction with the GW Branch, of ways to improve the water supply in the Pecos Valley by diverting saline springflow in the Malaga Bend area. Hatchett had a lead role in the District's participation in the Navajo Indian Reservation study in Arizona and New Mexico from about 1951 to 1955 (Circ. 308, 1954). In 1952, Hem reported on the water quality in the Conchos Reservoir (WSP 1110-C, 1952). His article, entitled "Geochemistry of Groundwater," was published in Economic Geology in 1950. Hem served as instructor in the new field of geochemistry of ground water at the GW short courses beginning in 1952. Lecture notes and the journal article were the nucleus of his later "Study and Interpretation of the Chemical Characteristics of Natural Water" (WSP 1473, 1959).

New York

SURFACE WATER BRANCH

By Margaret E. Woods

The New York District, one of the largest in the country, maintained a total staff that varied from more than 30 near the beginning of the decade to nearly 60 near the end of the period. The small four-person headquarters staff was located in the Federal building in Albany. Also at the headquarters location was the Albany area office, which operated the closer gaging stations. Three other area offices were maintained during the period, the largest being at Ithaca, one nearly as large at Ellenville, and a smaller one on Long Island.

A.W. Harrington was district chief throughout the decade, having held that position since 1922. The assistant district chief was H.W. Fear, who joined the District initially in 1914 and returned in 1938. (Biographic memoirs for Harrington and Fear are in *WRD Retirees* newsletters numbers 12 and 32, respectively.) A.O. Waananen, who began service with the District in 1944 and had most recently served as assistant to the district chief for technical studies, left in 1948 to join the headquarters staff of the TC Branch. Miss A.D. Buchanan, district clerk since 1922, held that position until 1952, when she become a WAE. Following her retirement in 1954, Miss Buchanan received the USDI Distinguished Service Award. She was succeeded as district clerk by Ms. L.R. Teres. C.C. Covert, district chief at Albany until 1922, died suddenly on December 11, 1950, at age 79. (Following his resignation in 1922, Mr. Covert had been associated with W. & L.E. Gurley, manufacturers of surveying instruments.)

The Albany area office was headed by C.H. Hardison until 1950 when he joined the staff of the branch chief in Washington, D.C. He was succeeded by L.A. Wiard, who had moved from the Ithaca area office in 1946 and who continued in charge until his transfer to the New Mexico District in 1955. W.E. Forrest, who had been in the Ellenville area office since 1952, then took charge. Other members of the staff for much or all of the period included O.P. Hunt, Bernard Dunn (who also operated the one-man field station at Port Jervis for a year), A.R. Leonard, T.J. Buchanan, and D.F. Farrell.

The Ithaca area office was under J.J. Molloy until 1949 when he was designated assistant district chief for Pennsylvania. J.W. Odell, who transferred from St. Louis in 1949, was then in charge until 1950 when he was reassigned as assistant district chief for Utah. C.W. Reck moved from the Ellenville office to take charge, but in 1952 left to study at Harvard University and in 1953 transferred to the staff of the branch chief in Washington, D.C. C.L. Whitaker, who transferred from Mineola, was in charge for the rest of the decade. Others serving in Ithaca during the period included L.B. Yarger, J.E. Wagar, Philip Pfannebecker, John Shen, D.H. Ahrens, S.D. Schiavo, and C.R. Wagner. Hollister Johnson, who had transferred to the Washington headquarters in 1943 as a flood specialist, returned to the District in 1952 and served in Ithaca until his retirement in December 1952.

(A biographic memoir for Johnson is in *WRD Retirees* newsletter no. 7.)

F.F. LeFever was in charge of the Ellenville office until 1949 when he was designated district chief for Maryland and Delaware. Reck was his immediate successor, followed by G.R. Ayer who transferred from the Ithaca office in 1950. Other members of the staff who remained for several years included R.E. Campbell, R.M. Comegys, W.K. Dein, W.E. Forrest, C.G. Johnson, Jr., C.W. Reck, R.M. Sawyer, and W.A. White.

The Long Island and Westchester County activities were conducted from an area office in Jamaica until 1949 when both SW and GW offices moved to Mineola, a location closer to the center of the investigational work. H.D. Brice continued in charge until 1951 when he joined the Albany headquarters. He was succeeded by C.L. Whitaker who had transferred from the Albany area office in 1947. When Whitaker was designated engineer-in-charge at Ithaca in 1952, he was succeeded by R.M. Sawyer from the Ellenville area office. E.J. Pluhowski and G.S. Craig, Jr., were among the staff members during the 1950's.

Two new units were established at the Albany headquarters during the period. Both were independent units with District-wide responsibilities. The hydrologic unit was set up in March 1948 to investigate and report on floods, droughts, bridge-site hydraulics, and flood frequency and duration, and to conduct other interpretive investigations. Over the period, the unit staff also contributed to research on indirect methods of determining peak flows, as well as to the methodology of flood reporting. After June 1949, the unit was under the direction of D.B. Bogart who had been in charge of the Miami, Fla., office. In 1951, he was designated flood specialist (part-time) for the technical standards section of the Branch. Other members of the staff included F.H. Ruggles, from 1948, and Jacob Davidian, from 1950, both remaining until their transfers to the research staff in Atlanta, Ga., in 1956 and 1953, respectively. Other members included J.P. Monis, B.J. Frederick, and J.R. Crippen, all three of whom joined the Survey in 1951.

The second new unit was the records unit, established in 1951. Its purpose was participation in the nationwide compilation of records through 1950, to conduct special studies of streamflow data, and development of a network of classified gaging stations. Brice, who had served in Albany from 1941 to 1944, returned there from the Long Island office in 1951 as assistant to the district chief for hydrologic studies and as engineer-in-charge of the records unit.

The guidelines for the stream-gaging program in New York instituted by Harrington in previous periods continued in force: To operate a network of permanent gaging stations on a sound cooperative financial basis, to produce professional work of the highest possible quality, and to plan investigative programs that would meet the present and probable future needs of State and Federal agencies for water-resources information. (See "Recollections—After Thirty Years" by A.W. Harrington, reprinted in *WRD Retirees* newsletter no. 39.) Harrington personally reviewed all streamflow records before they were sent to the Washington office for publication, a task that required more and more time as the number of records increased to some 230 before the close of the period. In addition, Harrington was a member of the Survey committee appointed in 1952 to develop guidelines for future policy on streamflow records.

In addition to his handling much of the administrative work, Fear directed, and was largely responsible for, the District's active and successful recruiting program. He continued to represent the USDI on the College-Federal Agency Council organized in 1946 by the regional Civil Service office and served as its vice-chairman. It is worth noting that, at this relatively early date, the subprofessional staff included two women, Ms. M.E. Woods, engineering technician in the Ithaca office, and Ms. E.L. Kirchner, mathematical aid in the Albany office.

The program of lectures and demonstrations of field techniques to engineering students that began in the 1920's expanded to include more colleges and, with interbranch participation, provided a broad range of information on hydrology. The demonstration program acquired a new dimension when the U.S. Military Academy at West Point requested not only demonstrations and lectures, but also the preparation of study guides to be used in a new course on the theory and practice of stream gaging, with emphasis on its application under combat conditions. Ayer, in charge of the Ellenville office, collaborated with the Mechanics Department at West Point in preparing the guides, and provided professional advice and assistance in designing the new course that became part of the West Point curriculum in 1953. In January 1954, Ayer received a Superior Accomplishment Award from the USDI for his work on this project.

In 1949, Harrington instituted a program of District-wide personnel conferences that consisted of three quarterly conferences of supervisory personnel and an annual convocation. The convocation became an interbranch affair, with attendees from Branch headquarters and surrounding Districts. These conferences not only provided a forum for the communication of technical and other information, they were highly successful in sustaining an ambience of unified cooperative effort throughout all the Branch offices in the State.

A monthly publication, "Gage House Gossip," started in 1942, continued throughout the period, and became

interbranch in scope. The success of the *Gossip* in enhancing morale was recognized in 1951 in a letter from CHE C.G. Paulsen in which he stated that "even though I have never had the good fortune of having been an actual member of the Albany District, the comments, personal notes, editorials, and news items that emanate from the Gossip make a person feel that he is an integral part of the Survey family in Albany." Cover designs by Ms. E.L. Kirchner and other artistically talented members of the Branch districts added to the appeal of the *Gossip*.

Cooperation

The Federal-State cooperative program was the chief source of funding. The State Department of Public Works, as in the previous period, was the principal State cooperating agency.

Cooperative programs with all the other State, county, municipal, and regulatory agencies that were in effect in the 1946–47 fiscal year continued throughout the present period. These agencies were the State Department of Conservation; the State Department of Law; the Nassau County Department of Public Works; the Suffolk County Board of Supervisors; the Suffolk County Water Authority; the Westchester County Department of Public Works; the New York City Board of Water Supply; the New York City Department of Water Supply, Gas, and Electricity; the cities of Albany and Auburn; the village of Lancaster; the Black River Regulating District; and the Hudson River Regulating District. Funding under these programs increased substantially during the period, usually in response to both the rising costs of operation and to the need for additional streamflow data.

Because the stream-gaging program had become an integral part of the State's operations well before 1950, the major expansion of the program took place largely in cooperation with the State Department of Public Works (DPW). Cooperative funding with the DPW increased more than threefold during the period. The DPW also provided continuous funding for special investigations relative to floods and droughts, beginning in 1949; studies of runoff from small drainage areas, beginning in 1954; and hydrology relative to highway design, beginning in 1956.

In 1956, a cooperative program was arranged with the State Department of Health to collect data for studies relative to the abatement of surface-water pollution. The Dutchess County Board of Supervisors in 1956 initiated a cooperative program to supply data for the design and operation of flood-control structures. On a smaller scale, cooperation began with the village of Nyack around mid-decade to furnish data required in the operation of municipal reservoirs, and with the Oswegatchie River Commission for regulatory purposes. Cooperative arrangements with the Corps of Engineers, in effect in 1947, continued and expanded throughout the period, as did investigations of streamflow in connection with power developments under license from the Federal Power Commission.

Two new Federal cooperative investigations began during the period. One, which started in 1948, was with the Atomic Energy Commission (AEC) for an investigation of the surface-water resources required for the satisfactory operation of AEC installations in upstate New York and for investigations of potential surface-water contamination from radioactive wastes. The other new program, which began in 1955, was with the U.S. Soil Conservation Service for hydrologic evaluation of small streams.

Floods and Droughts

Cloudbursts and unusual meteorological conditions produced floods in one or more areas of the State in practically every year during the period. Only record-breaking floods will be mentioned here. All floods were investigated, indirect measurements of peak discharges were made when warranted, and memorandums or other reports were prepared. In June 1954, a flash flood on Depot Creek at Sidney Center in the eastern Susquehanna River basin set a new maximum known rate of runoff for the State, 2,770 cubic feet per second per square mile. Data on a number of minor floods are included in WSP 1137-I (1955) and most of the more extensive floods have been reported in other Survey publications. A flood during December 1948–January 1949 broke previous records at several stations in northern and eastern New York; a report on this flood was published in USGS Circular 155 (1952). Another severe flood that caused extensive damage and that set new peak stages was caused by heavy rainfall in the Callicoon area in August 1947 and was reported on by Hollister Johnson. In November 1950 and again in March 1951, heavy precipitation caused new peak discharges at several stations in the upper Delaware River and lower Hudson River basins; data on these floods were reported in WSP 1227-C (1958). In August and October 1955, two disastrous floods again occurred within a short time span in the Delaware River and lower Hudson River basins as a result of tropical storms along the Eastern Seaboard. The highest monthly precipitation of record for the State, 25.27 inches, was registered at West Shokan in Ulster County (lower Hudson River basin) during October 1955. Considerable damage occurred and new peak stages were recorded along streams on Long Island and in lower Westchester County from the October storm. Investigations of the August and October floods in the several Districts affected

were coordinated by D.B. Bogart, and the results published in WSP 1420 in 1960. A tropical storm in 1954 caused considerable damage in western and central New York, but a more severe flood in those regions came in March 1956, when heavy rain and snowmelt combined to bring widespread flooding and to set new maximums at most of the stations in the area, some of which had over 40 years of record.

Dry periods from deficient rainfall occurred one or more times in nearly every year. Typically, such periods were short-lived and had only local effects. In 1949, however, a prolonged period of low precipitation resulted in a critical water shortage for New York City, which at the time was largely dependent on water supplies from the lower Hudson River basin and Long Island. One of several steps taken to alleviate the crisis was to accelerate the development of supplies from the upper Delaware River, which had been delayed by World War II and court action. At the request of the Branch headquarters, a special report was prepared in 1950 for President Truman's Water Policy Commission on the water situation and water development of the Delaware River basin by Branch districts in each of the four States concerned with the river. The first water to be diverted from the Delaware River basin into the New York City water-supply system was impounded in Neversink Reservoir in June 1953. In 1952, New York City had appealed to the U.S. Supreme Court for permission to divert more supplies from the upper Delaware River than were originally agreed to; this petition was granted in 1954. Because three other States would be affected, the Court decreed that a Water Master be appointed to assure the Court that New York City met the stipulations of the decree, one of the first such appointments in the East. C.G. Paulsen, CHE, served as Delaware River Master for the remainder of the period, assisted by W.V. Iorns, who transferred from the TC Branch at Tulsa, Okla., to Milford, Pa., in April 1955 as staff engineer.

The 1949 drought likewise revealed the potential for serious deficiencies in water supplies for heavily industrialized, upstate metropolitan areas. This threat aroused acute interest in minimum streamflows. A program of miscellaneous measurements at a network of low-flow sites on ungaged streams was begun in 1951. In 1954, an areal small-streams program was set up, in cooperation with the State Department of Public Works, under which special investigations for specific areas as well as for general hydrologic purposes were conducted. Memorandum reports were prepared on all periods of critically low flows.

Special Investigations

The study of the effects of reforestation on streamflow, begun in 1932, continued through the period. A progress report was prepared in 1949 by G.R. Ayer, project chief, and published as a District report in cooperation with the State Department of Conservation. One major finding of the study was that, although total annual runoff on the partially reforested areas was significantly lowered, peak flows were lower only during the dormant season. This report on one of the first empirical investigations of the effects of reforestation on runoff created an exceptional amount of interest among agencies and universities in the United States, Canada, Western Europe, India, and Africa. Donald Outlaw, a graduate student at Pennsylvania State College, used the data for a doctoral dissertation, which was published as an Open-File report (1954). Early in 1957, plans were made with the State Department of Conservation for a second progress report.

Another continuing investigation was a program, begun in 1942 for Suffolk County, to provide data for planning for water-supply development. In 1953, Brice completed an Open-File report on this project that included, besides all available streamflow records, duration data for each major stream as well as the results of periodic flow measurements at a network of ungaged sites. In recognition of this work, Brice received the Charles Evans Hughes Award in May 1953 from the Capital District Chapter of the American Society of Public Administration for "outstanding accomplishment in one's chosen field, far and beyond regular requirements."

The New York Cooperative Snow Survey, begun in winter 1937–38 and coordinated by the hydrologic unit after 1949, continued and expanded. Records made available promptly through monthly or more frequent reports were of immediate use to over 100 cooperators in connection with water storage and release, flood-warning systems, water-supply forecasts, and—in at least 1 year—protection of wildlife. In 1948, a year of unusual snow depths, data on snow courses were used to support legislation providing for the statewide feeding of deer. The Eastern Snow Conference, organized in 1940, held annual meetings that were attended by Federal and State officials and representatives of private agencies throughout the Northeast. District personnel who held the position of Conference Secretary during the decade were H.W. Fear, later D.B. Bogart, and finally G.R. Ayer.

Throughout the period, the Interstate Commission on the Delaware River continued to use streamflow records of the headwaters of the river to develop plans for the regulation, use, and conservation of water resources, and for abatement of stream pollution in the highly industrialized lower Delaware River valley. Beginning in 1951, local personnel of the three branches conducted a joint study of radioactive-waste disposal at the Knolls Atomic Power Laboratory near Schenectady. This study included the development of techniques and equipment needed to trace the path of radioactive phosphorus that might be introduced accidentally into a stream. An open-file report

on the results of this investigation was prepared for the AEC. The SW Branch portion of the joint investigation was under the direction of Ruggles, who subsequently was designated coordinator of all studies for the AEC in New York.

Under the sponsorship of the Water Utilization Committee of the Branch headquarters, water-use studies were conducted jointly with the GW Branch in the industrialized areas of upstate New York. Two reports were published during the period, USGS Circulars 173 (1951) and 246 (1953).

A New England-New York Interagency Council was formed in 1951 to coordinate and report on investigations of the material resources in the region. Data from numerous special studies of surface-water conditions in New York and their potential for development are included in the general reports of this agency, one of which was a Hydrologic Investigation Atlas, HA-7 (1955).

Major special studies for cooperating agencies during the period also included "A Determination of Rates of Disposal of Storm-Water Runoff by Infiltration Through Seepage Basins to Ground-Water Reservoirs in Nassau County" (part of a joint surface and ground-water investigation of recharge rates), and "Joint Surface Water-Ground Water Studies of the Geology and Hydrology of Proposed Sites for AEC Installations." In addition to these and other nonroutine investigations, nearly all of the work of the hydrologic unit, and to a large extent of the records unit as noted earlier, consisted of special and complex studies of streamflow for a variety of purposes. (Prepared with assistance from D.B. Bogart, H.D. Brice, G.R. Ayer, and J.W. Hood.)

GROUND WATER BRANCH

By Joseph E. Upson, II

The New York-New England District had jurisdiction over programs in New England as well as in New York for nearly all of the decade. District headquarters remained on Long Island, but moved from the Post Office building in Jamaica to space at 239 Old Country Road in Mineola in 1949. The headquarters staff varied from about 12 to 17 employees, most of whom were assigned to the several area offices and field headquarters. The largest of the area offices was at Albany, N.Y., and staffed with from 8 to 12 people during the period. From one to four additional persons were headquartered at Upton on Long Island (later Brookhaven National Laboratory). The out-of-state Subdistrict offices included area offices at Boston, Mass.; Providence, R.I.; and Middletown, Conn. Field headquarters were located at Durham, N.H., and East Barre, Vt., for parts of the decade. Activities outside of New York State are described under the headings for the particular State.

M.L. Brashears, Jr., who had been with the District since 1936, was district geologist. In 1952, he resigned to join former Branch employee R.M. Leggette in a consulting firm known as Leggette and Brashears. Brashears was succeeded by J.E. Upson II, who had been serving as assistant district geologist for California. In February 1957, Upson was designated as a representative of the branch area chief to work on the interrelationships of geologic events and sea-water encroachment, and to provide assistance in geologic field interpretations for investigations in other States of the Northeast. N.J. Lusczynski was the only member of the senior staff to serve at District headquarters for the entire decade. C.M. Roberts left in 1948 to join the staff of the PC Branch, Washington, D.C. N.M. Perlmutter and L.R. Wistoff joined the staff in 1948. Others who served for extended but shorter periods include H.D. Wilson, Theodore Arnow, J.J. Geraghty, J.F. Hoffman, Jr., W.V. Swarzenski, and H.G. Healy.

E.S. Asselstine was in charge of the Albany area office until 1955, when he was succeeded by R.C. Heath who had been assistant district chief for Florida. E.S. Simpson was on the staff until 1955. I.G. Grossman entered on duty in 1949, and F.K. Mack in 1951. Wallace deLaguna transferred from Jamaica in 1949 to take charge at the Upton field headquarters, and remained there until 1954 when he was placed in charge of the project at Oak Ridge, Tenn. M.A. Warren was second in charge, having transferred from Santa Barbara, Calif., in 1950. He left in 1954 to take charge of the Savannah, Ga., Subdistrict. L.A. Weiss remained until the Upton office closed in 1955.

The work in Massachusetts was conducted from the Boston office, which was a subdistrict of the New York-New England District until it was designated a District in 1956. The new District also assumed responsibility for the programs in Maine and New Hampshire. The staff ranged in size from four to six persons until about the end of the decade when additional people were assigned. H.N. Halberg was in charge until 1954, when he was succeeded by O.M. Hackett who had transferred from Bozeman, Mont. H.L. Pree, Jr., and L.M. Page, Jr., were each assigned for 2 or 3 years in the latter 1940's; J.A. Baker, R.J. Hecht, and H.G. Healey during the latter part of the period. Mrs. N.E. Lathrop joined the staff early in the decade, the beginning of a lengthy career as district clerk.

The work in New York during the decade held to the pattern established in the 1940's, with the main thrust of Albany office personnel being county-by-county appraisals of the occurrence and availability of ground water. These proceeded fairly well along a planned schedule. Most of the counties were in the eastern, more populous parts of the State. There was a steady shift in personnel from numerous part-time employees on more

or less routine observations to predominantly better trained geologists and engineers engaged in more analytical and research investigations.

Concurrently, occasioned by the national interest in the development of nuclear power, more specific and directed studies were financed by the AEC. One of these studies was at the Knolls Atomic Power Laboratory near Schenectady, where multidiscipline work was conducted by Simpson, F.H. Ruggles, and W.A. Beetem. Simpson also worked on a site at nearby West Milton. These were among the early studies by the Survey dealing with the rate and direction of movement of potential radioactive contamination, both in streams and ground water.

Asselstine gave direction of the upstate program to Heath in 1956. Asselstine then began to work with W.T. Stuart on a study of water drainage from coal mines in the Pennsylvania anthracite region.

On Long Island, previous work had pretty well outlined the basic geologic framework and the major aspect of ground-water recharge and discharge. A large backlog of water-level measurements and chemical analyses had been built up, and the time was ripe for more intensive investigations. When water-supply wells in southwestern Nassau County began to show some increase in chloride concentrations, attention shifted to more comprehensive studies of water movement in the deeper aquifers. Accompanied by the drilling of deep "outpost" wells made possible by increased funding from the Nassau County Department of Public Works, Lusczynski, Perlmutter, and Geraghty, and later Swarzenski, determined the location of the saltwater wedge along the base of the Magothy aquifer and made detailed analyses of water movement along the saltwater-freshwater interface. It was determined, among other things, that the rate of movement of the saltwater was very slow. A similar detailed study was begun in northwest Nassau County, and another one in the south part of Suffolk County by the staff of the Upton office. As in upstate New York, the investigations relative to water supply and preservation of the resource were accompanied in mid-decade by an intensive study at the Brookhaven National Laboratory in central Suffolk County. This was financed by the AEC, and again dealt with the rate and direction of water movement, which would be of critical importance in the event of a loss of radioactive contaminants to the environment. deLaguna and later Warren led these studies.

QUALITY OF WATER BRANCH

By Felix H. Pauszek

Prior to 1951–52, the only water-quality investigations conducted in New York by Branch personnel were as part of the nationwide program to evaluate the industrial utility of public water supplies (WSP 658, 1934, which was superseded by WSP's 1299 and 1300, both published in 1954). Thereafter the investigations were expanded from 1951 to 1957 in cooperation with the AEC, the General Electric Corporation (the prime AEC contractor), and the New York State Department of Commerce. Some data on the water quality of ground water were obtained and fluvial-sediment studies were also conducted.

The AEC was interested in the movement of pollutants, radioactivity, and general water quality of the Mohawk River at Schenectady and of Glowegee Creek at West Milton. The Bureau of Industrial Development, New York State Department of Commerce, needed information on the quality of surface water as sources of water supply to promote industrial activity in the State. The information was also useful in locating new sources of water for public supplies and agriculture. The work for the AEC was confined to the Mohawk River and its tributaries; to satisfy the needs of the New York State Department of Commerce, basin studies were conducted statewide.

The scope of the program consisted of the collection of daily samples at key points on the Mohawk River mainstem. Monthly or less frequent samples were collected basinwide. Subsequently, chemical analyses were made for the major pollutants calcium, magnesium, iron, manganese, sulfate, nitrate, fluoride, chloride, alkalinity, and acidity. At the time of sample collection, temperature measurements were made.

The quality of surface waters varied considerably throughout the State. Because of oil-field operations in Pennsylvania, excessive amounts of sodium chloride were found in samples from the section of the Allegheny River flowing through the southwestern part of New York. Drainage from underlying limestone beds added to the calcium and magnesium content of the water. Similarly, the chemical quality of the Genesee River deteriorated as it flowed northward from its origin in Pennsylvania into Lake Ontario, near Rochester. The Susquehanna River has its headwaters near Cooperstown. Although there were fluxuations in the water quality of its major tributaries, the Cohoction and Chemung Rivers, water from the Susquehanna River generally was satisfactory. The same applied to water from the Mohawk River and its tributaries. All of the water from the mainstem and (or) the tributaries could be made satisfactory with adequate treatment. Results of the water-quality studies of surface waters in New York State during 1951–57 appeared in the following reports published by the cooperator: W.H. Beetem, 1953, "Chemical Quality of Water Resources of the Conewango Creek Basin, 1951–52;" F.H. Pauszek, 1956, "Chemical Quality of Water Resources in the Allegheny and Chemung River Basins;" and F.H. Pauszek, 1959, "Chemical Quality

of Water Resources in the Allegheny, Genesee, and Susquehanna River Basins, New York, 1953-56."

The laboratory work was initially conducted in a field office set up near Saratoga Springs by W.A. Beetem in 1951. Later, the work was conducted in the District laboratory established by F.H. Pauszek in the Federal building in Albany. Personnel making the analyses were Beetem, J.A. Shaughnessy, D. Tanski, A.L. Mattingly, R. Doyle, and G. Caneri. Initially the studies were under the direction of W.F. White, in charge of the projects office, Washington, D.C. Beetem was in charge of the field office near Saratoga Springs in 1951. A year later, the direction shifted to Pauszek, also of the projects office, who was placed in charge of projects in New York and New England. In 1954, Pauszek transferred to Albany to establish a District office and laboratory. He continued as district chemist through the end of the decade.

North Carolina

SURFACE WATER BRANCH

By Robert E. Fish and Henry C. Riggs

The program, as measured by the number of personnel in the District, more than doubled in size during the decade. The staff of about 17 at the beginning increased to about 40 by 1957. Somewhat more than one-half were in District headquarters in Raleigh. Located in the Education building initially, they moved to the Capital Club building about 1947 and then to the Federal building in 1954.

The largest Subdistrict office was in Asheville, which had been the District headquarters until 1943 (Follansbee, v. IV, p. 117). From five to 11 members of the staff were located there during the decade, engaged primarily in the collection and processing of streamflow data. The operation of the stations in the extreme western part of the State was accomplished by one or two men headquartered at Bryson City and who reported to the Asheville office. The remainder of the District staff worked out of Statesville, which had become a headquarters late in the previous period (Follansbee, v. IV, p. 117). These hydrographers operated the station network in the center of the Piedmont region.

J.L. Lamson was acting district engineer as the decade opened, E.D. Burchard having retired on April 30, 1947, after directing the District activities since 1924. E.B. Rice, who succeeded Burchard and who had been district chief for Louisiana, arrived in Raleigh in July 1947. Lamson continued as second in charge. H.A. Taylor and E.G. Wollin were also on the District headquarters staff during the decade. Other senior headquarters staff members at the beginning included E.B. Hodges and R.H. Peck. Those on the rolls in the final years included R.E. Fish (who was named assistant district engineer in 1954), H.G. Hinson, and G.C. Goddard. H.C. Riggs, who transferred to Raleigh in 1952, was in 1954 designated part-time staff engineer for the technical standards section in the office of the branch chief. He transferred to the branch chief's office in the mid-1956 for duty with the research section. Ms. M.V. Harrington was district clerk throughout the decade and was named chief of the administrative services section for all local branches when that section was established in 1953. She reported to the WRD Council in the latter assignment.

W.R. Eaton, in charge of the Asheville office, left in July 1947 to succeed Rice in Louisiana. A.G. Goodwin took the position vacated by Eaton and continued in charge until 1956 when he was designated field staff officer of the branch chief to oversee that portion of the nationwide special compilation of streamflow records that were in the South Atlantic Slope and eastern Gulf of Mexico basins (WSP 1304, 1960). Goodwin remained in Asheville under this assignment.

T.G. Johnson, who had arrived from the Florida District in 1949, succeeded Goodwin as subdistrict chief. Miss Mary Armstrong served as subdistrict clerk (later mathematical aid) during the period. Other senior personnel serving at Asheville during portions of the period were E.L. Burke and R.J. Smith. P.G. Ford, in charge at Bryson City, moved to Asheville early in the period. H.A. Carlson succeeded Ford in Bryson City and was in turn succeeded by Burke. Those in charge at Statesville were Hodges until 1952; R.J. Smith until 1954; J.R. Carter until 1956; and E.G. Wollin during the balance of the period.

Cooperation

The principal cooperator was the North Carolina Department of Conservation and Development. Other State and local cooperators included the Stream Sanitation Committee of the State Board of Health; the State Highway Commission; the State Board of Water Commission; the cities of Burlington, Greensboro, and Asheville; and the town of Waynesville. The District also provided streamflow information for the Tennessee Valley Authority, the U.S. Army Corps of Engineers, and the U.S. Soil Conservation Service. These cooperative efforts carried the regular gaging station network as the backbone of the District and the special projects to follow.

Special Projects

In the late 1940's, the State looked for industrial growth and asked the Survey for hydrologic information at many

locations for which data were often not available through the existing stream-gaging network. The needed areal-network coverage was largely satisfied by Rice and Lamson siting 100 partial-record stations throughout the State. Financing was accomplished by increasing the regular station cost by some 20 percent. The program led to a more intense inventory of water resources, provided for the needs of the State, and enhanced the Survey's profile with the cooperators.

Near the beginning of the 1950's, North Carolina passed a stream-pollution-control law whose administration required the collection of partial-record low-flow data at a great many sites throughout the State. This activity continued throughout the 1950's under the direction of Fish and Goddard. Low-flow measurements were used by the State Health Department to establish a stream-classification system, to compute pollution loads in streams, and to reach decisions on requests to discharge wastes to specific streams.

The streamflow measurements at the partial-record stations, when correlated with records of regular stations, opened the way for the estimation of streamflow characteristics statewide, for low-flow frequency, duration, maximum periods of deficient flow, and storage required. Two Water-Supply Papers reported the results for gaging stations and partial-record sites, "Water Resources of the Neuse River Basin, N.C." (WSP 1414, 1957) by Billingsley and others, and "Water Resources of the Yadkin-Pee Dee River Basin, N.C." (WSP 1415, 1957) by Fish and others. An Open-File report, "Surface-Water Supply of Eastern and Central North Carolina," by Rice depicted streamflow characteristics. Another WSP on "Water-Supply Characteristics of North Carolina Streams" was then in preparation by Goddard, giving statewide coverage by use of representative sites. (The report was later published in 1963 as WSP 1761.)

Cooperation with the State Highway and Public Works Commission was begun in order to furnish flood information needed for the design of bridge and culvert waterways. The first part of this project was to establish a statewide network of crest-stage gages that were to operate long enough to define the flood-frequency characteristics at those sites. In the meantime, similar characteristics at the regular gaging stations were defined and used to develop tentative relations for estimating flood-frequency characteristics at ungaged sites in the State. This analytical work is described in an Open-File report (1955) by Riggs entitled "Floods in North Carolina, Magnitude and Frequency." Operation of the crest-stage gage network continued well beyond the end of the decade.

Unusual Hydrologic Events

The drought of the early 1950's produced the lowest minimum flows in 30 or more years on many streams, although the annual mean flows were not particularly deficient. The need for minimum-flow information statewide was well recognized by personnel of the Raleigh low-flow unit, and the drought periods offered opportunities to gather such information. By October 1954, flows receded to extremely low figures. Personnel of the unit and several from other units were dispatched to all points of the compass with instructions to look at the streams at every highway crossing en route, and to measure or estimate flows or note "no flow" at each site. After several days of the inventory, Hurricane Hazel swept through the central area of the State and the associated torrential rains abruptly ended the low flows. Cliff Smith, who had measured low flows near Greensboro, phoned Raleigh to say that rain was pouring down by bucketfuls.

The Greensboro area officials had been especially watchful of the dwindling water supplies and had called in a rainmaker. The subsequent downpour from Hazel rapidly refilled reservoirs—their floodgates were opened, and the rainmaker was sent packing. Survey personnel, who had gathered a wealth of valuable data on minimum flows, turned to high-water measurements.

During 1955, Hurricanes Connie and Diane and a widespread thunderstorm battered the eastern half of the State. Later in September, the third hurricane of the season, Ione, passed through the Coastal Plain of North Carolina. Rainfalls of up to 16 inches associated with this hurricane fell on land already saturated by the earlier September storms. The resulting floods were most severe near the coast. Inshore winds greatly increased the flood stages in coastal towns and adjacent lands. Major damages from flooding were reported in Morehead City, New Bern, Washington, and Belhaven (WSP 1420, 1960). During August and September, Maysville received some 50 inches of rain, the equivalent of an average year's total precipitation.

These several storms produced moderate to extreme floods. The engineers obtained flood measurements to check the stage-discharge ratings at regular stations and to define ratings at the crest-stage gages. The Raleigh office sent out as many as 13 field parties. The two men remaining in the office collected buckets and moved desks to handle the roof leaks. The field men encountered some difficulties, but no major ones. One engineer checked his suitcase at a hotel but couldn't get back for 2 days—he worked in his damp clothes. Another had a circuitous route of about 100 miles daily to visit four stations. Although the fourth site was near his starting point, he was blocked by a flooded road and had to retrace the 100 miles. Some worked around the clock.

In July 1956, J.D. Simmons encountered a real downpour near Robbins. He had been working his way back to Raleigh from a low-flow trip. Stopping for coffee, he asked why so many people were heading for town. The

waitress answered that a car had been driven into Bear Creek. Having come from a low-flow trip, he didn't think her answer seemed likely, but he found that the storm had indeed flooded the bridge and its approaches. Bear Creek crested near dawn. In the pre-dawn, the drivers of two cars drove into the flooded approach to the bridge and several lives were lost. When the stage receded sufficiently for Simmons to set up his equipment, he could hardly get on the bridge because of the crowd of people. After measuring the discharge, he scouted miscellaneous-rainfall catches. He located a test-tube raingage set in a hole bored in a fencepost. He wisely asked the farmer where he had obtained the raingage and learned many had been distributed by a local feed store. At the store, he obtained a list of recipients, visited them, and found observations sufficient to draw an isohyetal map. The reports of up to 13½ inches of rain helped define the area of most severe flooding. A millpond dam constructed before the Civil War overtopped for the first time, but it did not fail. Hinson prepared an informal report on the rainfall, runoff, and damages.

Until 1956, the office computations, interpretive studies, and reports were completed manually by personnel of the Raleigh units of basic records, floods, and hydrology (covering 70 percent of the State), and Asheville and Statesville Subdistrict offices. After that date, Rice introduced automation by having the first discharge records punched on tape. Under direction of Lamson, the compilation unit reviewed, revised as necessary, and compiled for publication all regular station records from the earliest ones to 1950.

Rice was responsible for fostering the outstanding progress of the District. His attention to all facets of the organization and his warm cooperation with personnel and State officials deserve note. He offered responsibilities to heads of units and field offices and was pleased that they accepted the challenges and fulfilled their assignments. His cooperation with the State was productive for the SW Branch and, in some measure, enhanced programs for other Branches.

GROUND WATER BRANCH

Condensed from documentation by H.E. LeGrand and M.J. Mundorff

The District continued to have jurisdiction over the programs in both North and South Carolina until 1952 when a separate District was established for South Carolina. Program activities for South Carolina for the entire decade are described under the heading for that State. North Carolina District headquarters remained in Raleigh for the entire period, first in the Education building (a State office building) and, after 1954, in the Federal building. The District staff, which varied in size from two to four, were all headquartered at Raleigh.

M.J. Mundorff, in charge of the District since August 1941, was designated district geologist for Washington in 1949. He was succeeded by H.E. LeGrand, who had been on the staff of the Georgia District, and continued as district geologist through the end of the decade. G.E. Siple, a senior member of the staff during the first half of the decade, was assigned largely to the South Carolina work. He spent winter 1947–48 on a detail to the Tennessee District and in 1952 was named district geologist for South Carolina. Ms. M.M. Reid joined the staff in 1952, as did P.M. Brown and R.G. Schipf during 1953. Schipf resigned in 1955.

The program during the decade was in cooperation with the State Geological Survey, which was a part of the North Carolina Department of Conservation and Development. The portion of State funds that were matched by the Survey were less than $10,000 at the beginning and funding increased only moderately through 1957. The long-range plan was to cover the State with a series of reconnaissance studies, each including an area of seven or eight counties. Program emphasis was on finding quantities of ground water with special attention to well yields. No aquifers were in danger of overproduction. Studies in the Coastal Plain gave attention to the potential for salt-water encroachment. Funds were inadequate for financing the collection of original hydrologic records, so, when and where available without cost, field personnel gathered information from other sources. This required many temporary diversions of effort from established projects, while workers visited even remote paths of the State for such purposes.

The specific projects completed or underway during the decade included those listed below. The reports were usually published as Bulletins by the North Carolina Division of Mineral Resources (MR) or the Division of Water Resources and Engineering (WRE): (1) A study of the Charlotte area, the report which set a pattern for several subsequent reports on igneous and metamorphic rocks (MR Bull. 63); (2) a study of the six-county ''Statesville area'' in the Piedmont province (MR Bull. 68); (3) investigations of the Washington and New Bern-Wilmington areas in the Coastal Plain; (4) studies of ground water in the North Carolina portions of the Little Tennessee and Hiwassee River basins (a WRE Bull.), the Roanoke and Tar River basins (a WRE Bull.), and the French Broad River basin (a WRE Bull.); (5) research by LeGrand on solution depressions in diorite showing the significance of solution subsidence as an erosional process in igneous and metamorphic rocks (American Journal of Science); and (6) a popular layman report by LeGrand on the ground-water resources of North Carolina for the MR which

became a "best seller" used extensively in the public schools.

QUALITY OF WATER BRANCH

By Felix H. Pauszek

During the decade, the Raleigh District had jurisdiction over not only the North Carolina program, but also Branch activities in South Carolina, Georgia (until 1953), and Tennessee (1953 on). Activities are described separately under the State headings.

The period saw an expansion of quality-of-water activities in North Carolina. As far back as 1906, the Geological Survey had begun a study of the quality of surface water in the United States, including North Carolina. The program included several large rivers, such as the Cape Fear and Neuse Rivers. The results of that study were published in 1909 in WSP 236. From 1925 to 1927, additional data were collected and published by the North Carolina Department of Conservation and Development (NCDCD) as Economic Paper 61. In 1943, the need for information on water quality increased, and a cooperative program was established with the NCDCD. In 1945, the program was expanded further to include the study of public water supplies in cooperation with the North Carolina State Board of Health.

Since 1943 and continuing through 1947–57, an additional geographic segment of the State's water resources was studied each year for its mineral content, and evaluated on the basis of geology, streamflow, and man-made influences. Quality-of-water data were obtained in the Tennessee, French Broad, Broad, Catawba, New, Yadkin, Cape Fear, Neuse, and Tar River basins. The data were published by the NCDCD under the title "Chemical Character of Surface Water of North Carolina" as annual volumes of Bulletin 52. Among them were volume 4, 1947–48, by F.H. Pauszek and B.F. Joyner; volume 5, 1948–49, by Pauszek; volume 6, 1949–50, by Pauszek and K.F. Harris; and volume 7, 1950–51, by Pauszek.

The data were also published by the U.S. Geological Survey in its annual Water-Supply Papers series: WSP 1102, 1947; WSP 1132, 1948; WSP 1162, 1949; WSP 1186, 1950; WSP 1197, 1951; and WSP 1250, 1952. Data on selected public water supplies were published in WSP 1299, "The Industrial Utility of Public Water Supplies in the United States, Part 1, States East of the Mississippi River" (1954) by E.W. Lohr and S.K. Love.

Generally, the mineral content of most surface water in North Carolina was satisfactory for most domestic and industrial uses or, if the requirement was more stringent, some treatment would be necessary. In the coastal areas within the tidal reaches, a high salt content would prohibit use of the water. Concentrations of iron and color in some waters would have to be removed in order for it to be used for domestic and industrial purposes. Other dissolved constituents were well within the acceptable limit for water supplies.

In addition to the aforementioned investigations, a salinity study of the lower Cape Fear River near Wilmington was conducted to determine water quality under tidal conditions. Results from this study and the increased water-supply requirements, because of municipal and industrial growth in the Coastal Plain, prompted similar investigations in other North Carolina tidal estuaries in 1954. A sediment study supported by Federal program funds was begun in 1951 in the Yadkin River basin. Beginning in 1954, studies of fluvial sediment transport and factors affecting trap efficiency of flood-detention reservoirs were begun in the Piedmont Plateau in North Carolina for the U.S. Soil Conservation Service. An expanded cooperative program by the GW Branch to determine the sources and availability of ground-water in North Carolina included the determination of its water quality as well. The chemical quality of public water supplies was determined. The Armed Forces provided financial support to analyze supplies that served military installations.

The collection of water samples and chemical analyses were made in accordance with methods regularly used by the USGS. From 1943 to 1945, laboratory work was conducted in facilities furnished by North Carolina State University (then North Carolina State College). In 1946, laboratory space was furnished by the North Carolina Department of Hygiene. In 1952, the laboratory moved into commercial space on Oberlin Road in Raleigh. Finally, in 1954, consolidated space for all branches was obtained in the Century building (old Post Office building) on Fayetteville Street.

The District program was under the supervision of district chemists W.L. Lamar, 1943–48; F.H. Pauszek, 1948–52; and G.A. Billingsley, 1953–57. Laboratory work was conducted by the following Survey chemists and engineers: B.F. Joyner, K.F. Harris, H.B. Wilder, Ms. S.A. Phillips, T.H. Woodard, R.L. McAvoy, and H.O. Reeder; and state chemists E. Holloman, C.B. Pickering, and E.J. Phibbs, Jr.

DIVISION-LEVEL ACTIVITIES

An Administrative Services Section was established in 1953 under the jurisdiction of the WRD Council to conduct accounting and other "housekeeping" activities for each of the three District offices. The work of the section was greatly helped after 1954 when the headquarters staffs

of the districts were all located in adjacent space in the Federal building.

Ms. M.V. Harrington, district clerk (SW) for the earlier years of the decade, was reassigned to head the section. Others on the staff were Mrs. R.D. Harrison, who transferred from the QW District staff, and Ms. M.L. Ellis.

North Dakota

SURFACE WATER BRANCH

By John A. McCabe

District headquarters, which was located in the Eltinge building at 202½ Third Street in Bismarck during the entire decade, grew from approximately 8 to 12 persons during the late 1940's and remained about that size. The District had charge of programs for South Dakota as well, which are covered under the heading for that State. Total personnel located in North Dakota almost doubled during the period, with about 10 persons on the rolls in 1947. A field office with from two to three persons was maintained at Dickinson throughout the decade. Another, at Grand Forks, was established in 1953, and its staff increased from two to five persons by 1957. A one-man field office at Williston was used from 1949 to 1955. The work in South Dakota was under an area office at Pierre and is described under that State.

R.E. Marsh was district engineer at the beginning of the period, having assumed that position when the Bismarck District, consisting of the States of North and South Dakota, was created in 1944 (Follansbee, v. IV, p. 158). Marsh was designated district engineer for Alaska in 1948 and was succeeded by H.M. Erskine, who had been in charge of the West Virginia District. Erskine continued in that position for the balance of the decade. F.B. Sessums joined the District in 1946, having moved from the Subdistrict office in Pierre. He served as assistant district chief until 1952, when he took charge of the Fort Worth Subdistrict in Texas. He was succeeded by R.H. Monroe who, in turn, was succeeded by J.B. Shjeflo in 1954. H.C. McCreery was a member of the senior staff throughout the period, as were J.A. McCabe from 1948 to 1957 and K.B. Nelson from 1947 to 1954.

R.B. Vice was in charge of the Dickinson field office until 1948, when he transferred to the QW Branch with headquarters at Lincoln, Nebr. He was succeeded by E.J. Tripp, who remained there until he transferred to the Santa Fe headquarters of the New Mexico District in 1951. J.B. Shjeflo was in charge from that time until 1954, when the supervisory role was assigned to E.E. Schroeder. G.M. Pike had charge of the field headquarters at Grand Forks and L.W. Bethke conducted the work out of Williston.

The North Dakota Water Conservation Commission continued to be the principal State cooperator during the period. The North Dakota Highway Department cooperated in the measurement of flood discharges from small areas using crest-stage gages, the findings being published in "Floods in North and South Dakota, Frequency and Magnitude" by J.A. McCabe and O.A. Crosby. The South Dakota Department of Highways also cooperated in this report. Federal cooperation continued through the Missouri River basin program and also with the Corps of Engineers, the Department of State, the Bureau of Reclamation, the Fish and Wildlife Service, and the Soil Conservation Service.

One of the major problems that faced the District was the measurement of flood discharges. The cableway below Garrison Reservoir was built during the period. It spanned 1,730 feet and was supported by steel towers. The right bank tower was 43 feet high and the left bank tower was 84 feet high. An unusual feature of construction was that on one winter day, all of the ground-water and surface-water personnel located in Bismarck walked the cable across the ice and, with the help of a truck winch, lifted the cable to a height above the expected spring high water. Some time after the cableway was put in use, although not when anyone was at the station, a right bank failure occurred, dropping the right anchor about 5 feet. Apparently the cable was at first drawn tight, and the right tower partially collapsed, but the cable did not fall into the water. Erskine worked out a design based on a model whereby an additional piece of cable was spliced to the original strand and run to an anchor on the top of the bluff. A concrete box was used as a weight shoreward of the rebuilt right tower to position the cable so that the right tower was used as a landing platform.

Outstanding floods in North Dakota usually occurred during spring breakup. Two such floods were in spring 1950 and 1952. One of the characteristics of breakup floods in this area is ice jams. The forming and breaking of ice jams, with the resultant release of water, at times caused peak stages and discharges that had no relation to the amount of snow cover or precipitation. As in all northern districts, operating personnel paid very close attention to weather and traffic reports during winter and spring. One morning in the early 1950's, the radio reported all major roads closed by a blizzard except for the mile or two of U.S. Highway 2 between Grand Forks, N. Dak., and East Grand Forks, Minn.; a 5-mile reach of U.S. Highway 10 between Bismarck and Mandan, N. Dak.; and a length of bridge between Fargo, N. Dak., and Moorhead, Minn.

In cooperation with the North Dakota Department of Highways, 60 crest-stage gaging stations were established

in 15 different areas in 1955. Records for those stations were used in future flood-frequency and magnitude analyses. The gaging-station network grew from 64 daily-discharge stations in 1947 to approximately 95 in 1957. As a part of a nationwide effort, all surface-water records prior to September 30, 1950, were published in the compilation reports (WSP's 1308 and 1309, both published in 1959).

GROUND WATER BRANCH

Two District offices were being operated by the Branch in North Dakota at the beginning of the decade. Personnel at the one at Grand Forks (the staff varied in size from four to eight persons) conducted the cooperative and local segments of the nationwide programs and continued throughout the period. The staff of the other, at Bismarck, conducted the ground-water programs in North Dakota and South Dakota as specified under the MRB program. The Bismarck District, which had between one and three employees, was under the Regional headquarters in Lincoln, Nebr. District headquarters moved to Huron, S. Dak., in 1952 when projects in North Dakota under the MRB program ended. The Bismarck District maintained an area office in Huron from 1949 until the South Dakota District headquarters was established in Huron in 1952.

Grand Forks District

By P. Donald Akin and Quentin F. Paulson

The programs and projects developed in prior years were carried forward into the decade without change. The most significant program was in cooperation with the North Dakota State Water Conservation Commission in which the State Geologist acted as technical advisor to the Commission on matters relative to the program. Local funding for these cooperative projects was shared between the individual communities and the North Dakota State Water Conservation Commission. Individual project costs generally amounted to a few thousand dollars, and the overall District annual budget was a few tens of thousand dollars. The cooperator's contributions were mostly in the form of direct services.

Under this program, semi-detailed investigations were conducted of the ground-water resources in the vicinity of communities having water-supply problems. Investigations included studies of the geology relative to the occurrence of ground water, inventory of substantially all existing water wells, collection and study of samples from test holes drilled with a State-owned hydraulic rotary drilling rig, and collection and analysis of water samples from private wells. Aquifer tests were conducted using existing or community-constructed wells as available.

These investigations were intended to represent initial work for future county-wide investigations. They generally involved a minimum of four townships, but some covered much larger areas, sometimes extending to parts of several counties. Reports of the investigations were duplicated and placed in open-file status. No county-wide reports were prepared during the decade.

Investigation reports released in open-file status and duplicated during the decade included those pertaining to Minot, Aneta, Sharon, Hope, Fargo, Zeeland, Wyndmere, Kindred, Portland, Neche, Mohall, Litchville, Minnewaukan, Streeter, Michigan City, Fairmount, Stanley, Hettinger, Hankinson, and Upham. The reports were also entitled "North Dakota Ground Water Studies, Numbers 1 through 26" and were inclusive. (In this series, however, the number 10 was inadvertently omitted.)

Projects begun during the decade, but not completed until later, included Heimdel Valley-New Rockford, Maddock-Josephine, Lakota, Richardton, Bowbells, Rolla-St. John-Mylo, Devils Lake, Strasburg-Linton, Hunter, and Minto. Toward the end of the decade, progress was being made toward completing county-wide studies. Trail and Kidder Counties were the first to be considered, but the order of completion was subsequently changed.

Probably the most significant of these investigations was that of the Devils Lake area in northeastern North Dakota. As the result of information collected during this 920-square-mile study, the city of Devils Lake (population about 7,400), for the first time in its history, was able to develop an adequate municipal water supply of relatively good quality. Prior to obtaining its new supply, the city, which was the trading and cultural center for a large surrounding agricultural area, had little prospect for growth and actually was losing population. Because of the development of its new municipal water supply, this trend was reversed and the city has grown and prospered at a rate at least equal to that of other North Dakota communities of similar size.

During the late 1940's and early 1950's, the Grand Forks District staff also conducted investigations in Minnesota. One was in the Cloquet area and another in Clay County. This was prior to establishment of a District office in that State.

P.E. Dennis was district geologist at Grand Forks until 1949 when he was succeeded by P.D. Akin, who became district engineer. Dennis continued to serve part-time until 1954, when he transferred to Little Rock as district geologist for Arkansas. J.W. Brookhart, who had been on an assignment in Guam, succeeded Akin in 1954,

although Akin continued on a part-time basis. Other members of the senior staff who remained in the District for several years included Saul Aronow (to 1954), Q.F. Paulson (1948–54), and J.E. Powell (1952–57).

Bismarck District

By George A. LaRocque, Jr.

As stated by Follansbee (v. IV, p. 227), the Bismarck District was established in March 1946 under the direction of G.A. LaRocque, Jr., for the purpose of expanding the work under the MRB program that was begun in North Dakota and South Dakota by G.A. Waring. District headquarters was located in the Rausch building at 202½ Third Street. The district chief reported to G.H. Taylor, regional engineer, at Lincoln, Nebr., who had overall charge of the MRB program ground-water investigations.

The Bureau of Reclamation designated several areas where the potential for agricultural irrigation seemed promising in that portion of the State drained by the Missouri River and its tributaries, and the District staff conducted the investigations need to determine the feasibility of each. One was the Crosby-Mohall area, which included a 20-mile-wide east-west strip just south of the U.S.-Canadian border in the northwest corner of the State that extended from a point a few miles west of Plentywood, Mont., to the Souris River. With geologic mapping provided by the Survey's Geologic Division (also participants in the MRB program) and an initial test drilling by Waring, the study was continued under the direction of H.F. Hayworth, who was on assignment from Regional headquarters. The findings provided little hope for an extensive irrigation project that would bear a favorable cost-benefit ratio. Among the requirements for a successful project were physical conditions suitable for relatively fast infiltration of from 5 to 15 percent of the applied water through and to a considerable depth below the root zone; physical conditions suitable for removal of the infiltrate through drainage wells or ditches; and relatively large contiguous land areas with suitable soil and topographic characteristics. D.W. Greenman, R.C. Vorhis, and others made subsequent tests in an unsuccessful attempt to establish project reliability.

The Heart River, Knife River, and Standing Rock Indian Reservation areas in southwestern North Dakota were being considered by the Bureau of Reclamation for irrigation through storage and diversion of the Heart, Knife, and Cannonball Rivers. However, water-quality studies by personnel of the QW Branch and the Bureau of Reclamation showed their waters to be only marginally acceptable. The only geologic data available was shallow or subsurface information from logs of shot holes drilled by the Shell Oil Company. Ground-water studies were generally limited to observation-well measurements in 1946 and 1947 by P.C. Tychsen and later by any available District personnel.

Investigations at the Fort Berthold Indian Reservation southwest of Minot were largely a drilling program pointed toward the construction of domestic and stock water wells. At the start, it was presumed that water could be withdrawn from fracture zones and openings in the underlying beds of lignite. This could prove feasible if aquifers of sufficient thickness to yield four or more gallons per minute could be developed. Where pilot holes, drilled at the desired location, revealed suitable water-bearing zones at reasonable depths, the holes were enlarged, cased, screened, gravel-packed, and developed for use of air-lift equipment. R.J. Dingman and E.D. Gordon were in charge of field activities, and the investigation was reported in WSP 1250 (1956). Except for some minor experiments, no ground-water investigations relative to the Missouri River pumping units were made.

By the early 1950's, it was evident that economically viable irrigation development under the MRB program in North Dakota was limited, and Federal interest in the proposed projects declined. In retrospect, this should not have been unexpected because most of the area north of the Missouri River is underlain to a considerable depth by deposits of glacial origin. In 1952, LaRocque moved his District headquarters to Huron, S. Dak., where his program activities were more extensive. District personnel continuing to work out of Bismarck remained only for short periods. They included R.J. Dingman, E.D. Gordon, R.C. Vorhis, D.W. Greenman, P.C. Tychsen, and Ms. E.V. Hanson, who was on the SW District staff and served as administrative officer for both the GW and SW districts in Bismarck from about 1948 to 1952. Ms. Hanson transferred to the new Huron District headquarters. She later transferred to Boise, Idaho, setting a unique record for multi-district service for clerical personnel at the time.

QUALITY OF WATER BRANCH

By Russell H. Langford

A field headquarters at Dickinson was maintained during the first half of the decade. Under the regional engineer at Lincoln, Nebr., and with a staff that varied from one to three persons, the Dickinson staff was responsible for fluvial-sediment investigations conducted by the Branch in North Dakota as a part of the Missouri River basin program. J.M. Stow was in charge until 1950 when the office closed and he transferred to Rapid City, S. Dak.

Subsequent work in the State was handled by the Regional headquarters staff in Lincoln, Nebr.

A program summary prepared at Regional headquarters in July 1951 indicates that the Dickinson staff was determining sediment discharge on a daily basis at five locations on streams and periodic measurements at another two points; daily chemical quality at three stations and periodic measurements at another five; and either daily or periodic temperature readings at most of these locations. Network statistics available as of February 1958, after the close of the decade, showed that only one daily sediment-discharge station was in operation and records of chemical quality were being collected at seven points. These were under either Federal program or Bureau of Reclamation support.

Members of the Lincoln Regional office staff conducted extensive water-quality investigations in North Dakota during the decade. H.A. Swenson and B.R. Colby prepared a definitive report (WSP 1295, 1955) on the hydrology and chemical quality of surface waters of the Devils Lake basin. Results of the study were needed by the Bureau of Reclamation in planning the Garrison diversion project. Working closely with the Bismarck GW Branch office, Swenson, R.H. Langford, and others participated in studies of ground-water resources of the Crosby-Mohall area of the north-central part of the State; this was later extended to include the entire "Souris Loup" area. Swenson also particpated in studies of ground-water resources of the Fort Berthold Indian Reservation (WSP 1259, 1954) and the Heart River Investigation Project (Circ. 34, 1950). Langford joined C.J. Robinove and J.W. Brookhart in preparing WSP 1428 on the saline water resources of North Dakota (1958). Results of studies over many years of the chemical-quality and sediment characteristics of surface waters in the Grand River basin (both before and after construction of Shadehill Dam and Reservoir) were summarized in WSP 1769 (1964) by C.H. Hembree, R.A. Krieger, and P.R. Jordan.

Ohio

OFFICE OF CHIEF HYDROLOGIST

C.V. Youngquist, a State official (Ohio Division of Water) and a former district engineer (SW) for Ohio who retained the later title on a "when-actually-employed" basis until 1949, was in that year designated as a representative of the CHE to coordinate interdistrict program plans in the Ohio River basin. This designation continued through the end of the decade.

COLUMBUS EQUIPMENT LABORATORY

The Columbus Equipment Laboratory was established when A.H. Frazier returned to WRD from the Topographic Division in Washington, D.C., in November 1948. As stated in greater detail in Part V, Frazier had already gained experience in the improvement of stream-gaging equipment while he was a staff member of the Minnesota and Wisconsin Districts. The facility was located in Columbus primarily because the District office there had been particularly active in equipment design. H.E. Cox, who had done much of this work for the Ohio District, became Frazier's principal assistant. The initial address was 1037 High Street but, in 1949, the laboratory moved to larger quarters at 1509 Hess Street. In 1948, S.E. Rickley joined the laboratory, and a year later the staff of six was greatly increased by the hiring of seven instrument makers, with C.D. King as their foreman.

In September 1954, the laboratory staff, who had been under jurisdiction of the SW Branch chief, began reporting directly to the CHE. The primary reason for the change was that the staff had increasingly become involved with instrumentation needs of all of personnel of the Branches that had field activities. In December 1955, the laboratory was placed under the TC Branch. These changes did not appreciably alter the objectives or nature of the activities but, as a part of the last action, Frazier (at his request) relinquished supervision of the laboratory to become a local representative of the research section of the TC Branch so as to have greater latitude for individual equipment research. K.S. Essex transferred from the Denver District to take charge of the laboratory in June 1956.

In July 1954, E.G. Barron transferred from the Kentucky District to take charge of a new instrumentation facility in Columbus. Personnel of this facility reported to the SW Branch chief and were devoted primarily to the development of the so-called "bubble gage" for the measurement of river levels.

SURFACE WATER BRANCH

By Lawrence C. Crawford

In the early years of the Geological Survey at Ohio State University's Engineering Experiment Station, the District staff played an important role in the pioneer development of stream-gaging equipment and a variety of on-site facilities for collection of water-resources data. As indicated, the District staff headquarters had been for a number of years at the Engineering Experiment Station, and then for a few years at 2590 West Hardin Street at an on-campus barracks facility. In the early part of the 1947–57 period, the District assisted with arrangements for a common office and headquarters in the new Columbus Equipment Development Laboratory, including a nearby garage for the storage of automobiles and other

stock and associated equipment. This location in Columbus at 1509 Hess Street was accomplished with a rental property agreement. Great memories of A.H. Frazier, E.G. Barron, K.S. Essex, H.O. Wires, W.J. Rouse, G.F. Smoot, H.E. Cox, S.E. Rickley, and Mrs. K.O. Eisel, and all of their staffs, come rolling in. Initially, in the 1915 era, Professor C.E. Sherman, and then, in the current period, Dean Charles E. MacQuigg of the College of Engineering, were noteworthy friends of the Geological Survey.

Personnel and Objectives

There were two major objectives in the decade 1947–57: (1) a continuation of the previous program, but with a much broader and fuller coverage for collecting low-to-high-water data, and (2) putting these data in the most usable form through analyses and publication of available records, especially in State cooperative reports. O.H. Jeffers, assistant district engineer (acting district engineer until 1949), L.E. Bidwell, and H.P. Brooks (after 1955) provided a compatible and friendly generalship for the first objective, and W.P. Cross and E.E. Webber, with some assistance from R.E. Hedges and W.S. Schneider, led activities in the second objective. Brooks was the know-how man with field equipment and streamflow measurements. Cox, Brooks, Cross, Jeffers, and Rickley had either a student relationship at Ohio State University or an earlier assignment with the District office, or both. This background and interest was a fine asset for meeting the objectives of this decade.

E.H. Curtis, engineer-in-charge, and G.D. Francis, T.O. Graff, Tony Tomasina, and Ms. H.E. Boyd were employees at the New Philadelphia suboffice. A field headquarters with the Mahoning Valley District in Youngstown was manned by E.J. Tripp, J.B. Shjeflo, and T.W. Weinheimer in that order until it closed in 1952.

Other personnel conducted notable tasks on many occasions. In the record Maumee River flood of 1950, Walter Hofmann (later to become chief of the SW Branch) made a current-meter measurement singlehandedly at the near-peak discharge of over 90,000 cubic feet per second. Later, D.J. Ensminger, who was stationed alone in the Bowling Green, Bellevue, and Norwalk areas beginning in 1952, was recognized with a service award for measurements during critical droughts and floods. F.N. Workmaster was a hard-working and reliable field man with long-term experience in Ohio. Misses D. Belt, H.E. Boyd, M. Jordon, and H. Vance handled the secretarial chores with remarkable patience.

C.V. Youngquist carried the title of district engineer (SW) for Ohio on a "when-actually-employed" basis until 1949. At that time, he was designated as representative of the Division Chief in the coordination of interdistrict program plans in the Ohio River basin. This designation continued through the end of the decade. L.C. Crawford, district engineer for Iowa, succeeded Youngquist and remained through the end of the decade.

Water-Resources Investigations

The 98th Ohio General Assembly in 1949 appropriated $100,000 for a survey of the pollution of Lake Erie. The plan was under the direction of the Division of Water of the Ohio Department of Natural Resources, the Ohio Water Resources Board, and an advisory committee. Collaboration was secured from other agencies and cities adjacent to the lake for the use of their laboratories and water-quantity and quality records. Formal cooperation was established with the U.S. Geological Survey to obtain streamflow and water-quality data. An interim report was issued in April 1951. The final report was published in 1953 and entitled "Lake Erie Pollution Survey." Chapter II, "Hydrology of Lake Erie Tributaries," was by L.C. Crawford and Chapter IV by W.L. Lamar. A statewide basin-by-basin inventory was authorized by the 101st Ohio General Assembly and initiated in 1955, resulting in numerous reports.

In all of these activities, the author recalls the strong support by Youngquist and his able assistants such as Jack Frost and Bob Smith as to the need for surface-water investigations. With reference to his concern and our pride, a list of a few of the "Bill (W.P.) Cross publications" follows: "Floods in Ohio 1946, Magnitude and Frequency," Ohio Water Resources Board (OWRB), Bulletin 7, and "Flood of June 16, 1946, Wayne and Holmes Counties," OWRB Bulletin 9, both published in 1947; "A Method of Determining the Probable Frequency of Floods of Ohio Streams," MSc Thesis, Ohio State University, in 1948; "Local floods in Ohio During 1947," OWRB Bulletin 14, and "Local Floods in Ohio During 1948," OWRB Bulletin 18, both in 1949; "The Relation of Geology to Dry-Weather Streamflow in Ohio," AGU Transactions, v. 30, p. 563–566, "The Crooksville Area Flood of June 16, 1950," OWRB preliminary report, and "Ohio Streamflow Characteristics, Part 1, Flow Duration," OWRB Bulletin 10, all in 1950; "Ohio Streamflow Characteristics, Part 2, Water-Supply and Storage Requirements," Ohio Dept. Nat. Res., Div. of Water Bulletin 13, and "Water Resources of the Mahoning River Basin, Ohio," USGS Circular 177, both in 1952. R.J. Bernhagn was co-author for Bulletin 10, Webber for Bulletin 13, and, M.C. Schroeder and S.E. Norris for Circular 177. Cross, aided by Webber in this and the next decade, was author or co-author of many other published

and unpublished reports, probably more than any other engineer in the Water Resources Division.

Public Relations

The water-resources investigations as outlined were but typical examples of a number of cooperative ventures leading to comprehensive studies basic to resolution of water problems in Ohio. As a fundamental part of all of the activities, Crawford, as district engineer (after 1949), maintained a continuous effort to create good public relations in Ohio and elsewhere. This work was intended to gain support for a better understanding, "outhouse and inhouse," of the Geological Survey and all of its basic-data programs. For example, the preliminary planning and arrangements for a new and complete set of 7½-minute quadrangle topographic maps for the State of Ohio were made with the Ohio Department of Natural Resources. Crawford was also prominent among a number of senior district chiefs who worked in support of a long-overdue nationwide conference for those in charge of the Division's field programs. The conference was held in Chicago, Ill., May 23–27, 1954. One of the lasting highlights of that meeting was the advice given by guest speaker Abel Wolman, an internationally recognized sanitary engineer who had a long-time interest in USGS activities. Wolman cautioned that the Division, in its historic role as collector of daily-streamflow records, might well give more emphasis to putting such data in shape for widest use. If this was not done, the mass of uninterpreted data in time might be considered just so much garbage.

Frankly, in historical reference, the Indiana, Iowa, and Ohio District offices were the vanguard of a public relations movement for a proper contact and information program that strengthened the image of the Survey's water-resources activities in Congress, in State and local agencies, and in many other ways. Governors Frank J. Lausche and C. William O'Neil appointed Youngquist and Crawford to several investigating commissions for recommendations on water-resources development in Ohio. Surely, a new togetherness and unification inside and an upbuilding outside were initiated for the WRD.

Cooperation

The Federal-State cooperative program furnished some 70 percent of all funds for the District program. The primary cooperator was the Ohio Department of Natural Resources through the Division of Water and Wildlife. Several district offices of the Corps of Engineers that had jurisdiction in Ohio transferred funds for the operation and maintenance of stream-gaging stations to obtain records in connection with operational and planning projects. A program of special interest involved the Ohio State Highway Department. The long standing cooperation with the Miami Conservancy District was continued as it was with the cities of Columbus and Springfield. Some Federal program funds were available and a small program with the Soil Conservation Service was conducted during part of the decade. In all, total funds were gradually increased from approximately $50,000 to $200,000 yearly and involved the responsibility for collection of continuous or periodic records at some 200 to 300 locations on streams throughout Ohio.

Historical Notes

The first public water-supply system in Ohio was established in Cincinnati in 1821. The first streamflow measurement of record in the United States (to our knowledge) resulted from an interest in canals, and was made on the Sandusky River in Crawford County, Ohio, in August 1823.

GROUND WATER BRANCH

By Stanley E. Norris

At the start of the 1947–57 period, the statewide cooperative ground-water program with the Ohio Water Resources Board (later the Ohio Division of Water) was little more than 1 year old. Funds amounted to approximately $47,000, nearly half of which represented direct expenditures by the State. Smaller cooperative programs, totaling about $7,500 and chiefly for local ground-water monitoring, were in effect with the Commissioners of Butler and Hamilton Counties (Cincinnati area), the Ohio Engineering Experiment Station (statewide), and the Federal Works Agency.

On the Federal side, the program supported four professional employees and two engineering aids, including district engineer E.J. Schaefer, D.W. Van Tuyl, S.E. Norris, and R.C. Smith. They were assisted by R.E. Marzluf and W.H. Nicholson, engineering aids. Virginia Adams was secretary.

The main emphasis was on the production of county reports, although Schaefer made numerous short-term aquifer tests, working with well drillers and engineering firms. Also, Van Tuyl continued quantitative studies at Canton, representing the windup of a program that started in 1944.

On the State side, the work of as many as seven employees was being credited at various times for direct

matching. Most of the direct-expenditure program was for support of the observation-well network, but funds spent for county investigations, drafting, glacial mapping, and maintenance of the well-log file were also credited (a law had only recently been passed in Ohio requiring drillers to submit well logs). During these years, the relatively large cooperator-specified direct-expenditure program was critically scrutinized by the chief and assistant chief of the GW Branch. At the time, the direct-expenditure matching seemed the only practical way to build the program to an effective level and achieve statewide scope. District chiefs E.J. Schaefer (until November 1952) and S.E. Norris (through remainder of the decade) had only nominal control.

When the Survey began its investigations in the Cincinnati area in 1938, the State had no agency for water studies. It was not until 1941 that the forerunner of the Ohio Division of Water (ODW), called the Ohio Water Supply Board, was created and began work with a two-man staff. This organization was expanded as it went through successive reorganizations and, by 1945, it had a large staff involved with regulation and dam construction as well as interpretive studies. Meanwhile, the Survey had begun quantitative studies at Canton and, more significantly, entered into a cooperative agreement in 1942 with the Ohio Engineering Experiment Station, providing for a statewide network of observation wells. The potential competitive nature of this arrangement with the expanding activities of the ODW argued strongly for coordination of the respective programs. When cooperation with the ODW was finally achieved, it provided for statewide coverage of ground-water studies and resulted in further expansion of the observation-well network. In just 1 year (1946), 64 recorders were installed, bringing the total number in operation to 102. By 1952, 133 recorders were in operation on wells in Ohio, and the number in use fluctuated between 130 and 140 during the remainder of the period. The program with the Engineering Experiment Station that got the network started ended in 1952.

The total program in Ohio grew moderately, from about $56,000 in 1947 to approximately $103,000 in 1956. It was reduced to about $82,000 in 1957, chiefly because of a cut in the direct-expenditure matching from $37,500 to $25,500. There were five full-time professional employees by 1956: S.E. Norris, W.C. Walton, G.D. Dove, G.E. Scudder, and R.R. Blankenship. There were two clerk-typists, a physical science aid, and three WAE professional employees, G.W. White (glacial mapping), J.D. Winslow, and J. Baker.

What follows is a brief history, from memory, of some of the key people associated with the Ohio program. Schaefer resigned from the Survey in 1952 to become a consultant, later worked for the ODW, and died in 1968. Van Tuyl took over the Pittsburgh, Pa., Subdistrict in about 1950, resigned from the Survey in 1952, and is now (1982) in Columbus with the Ohio Department of Energy. Smith took charge of the Morgantown, W. Va., office about 1949, resigned from the Survey, and became assistant chief of the ODW. He later became a private consultant and, later still, managed and became part owner of a drilling firm in northeast Ohio. Walton left the Survey in about 1956, became a consultant with Schaefer, and returned to the Survey in Idaho. He left again to go with the Illinois Water Survey, became head of the water-resources program at the University of Minnesota, achieved international recognition for his textbook, and is now a private consultant in Champaign, Ill. Norris retired from the Columbus District office in 1981 and is a consultant (1982). Winslow left the Survey around 1956 to work for the Indiana Geological Survey, came back to the Survey in Kansas, and recently retired from the staff at the Geological Survey national headquarters in Reston, Va. Dove went to night school and became a lawyer, resigned from the Survey to practice law in Mt. Vernon, Ohio, and later became a judge in the county court system. Baker left the Survey to teach at Ohio University, and later was on the faculty at a college in New England. Youngquist retired from the ODW in 1970 and died in 1978.

During 1947–57, those working on the Federal side of the Ohio program produced five county reports published as State bulletins (three more were in preparation at the end of the period); one technical report published by the State with two more in preparation; six site reports for the Atomic Energy Commission; 10 papers for technical journals; three Open-File reports; one Water-Supply Paper; one USGS Circular; and the major part of the glacial map of Ohio published by the USGS. On the State side, there were three reports on ground-water levels and one county report.

Some of the more significant products of the Ohio program included a report on the preglacial (buried) Teays Valley system based largely on earth-resistivity surveys, and quantitative reports on a limestone aquifer in northwest Ohio and a watercourse aquifer at Dayton. Also significant were county reports that included the cities of Cleveland, Akron, Dayton, and Springfield.

QUALITY OF WATER BRANCH

By William L. Lamar

Regional Laboratory and the Multi-State Program

In 1947, M.E. Schroeder transferred to Ohio as resident chemist to set up a small QW laboratory in the

Toledo water treatment plant. Because an important and generally highly industrialized region in the Ohio River basin and two adjoining northern States had extremely limited quality-of-water coverage, it was decided to establish a regional laboratory in Ohio. The regional laboratory was to serve seven States: Illinois, Indiana, Kentucky, Michigan, Ohio, West Virginia, and Wisconsin. In 1948, W.L. Lamar, then district chemist at Raleigh, N.C., came to Ohio to locate space for the laboratory.

Suitable space in Columbus was found and approved for the laboratory. It consisted of two completely vacant units (another unit was added later) in a one-story building at 2822 East Main Street. Later in 1948, Lamar transferred to Columbus and was district chemist for the region. The balance of the year was spent in drawing up plans for laboratory space and furniture, and letting contracts for installations and (or) construction of needed facilities.

Separate sections were planned for chemical quality, suspended sediment, constant temperature, research, and utilities. A boiler was installed to supply steam to the steam baths in the hoods. The various services, including vacuum, were supplied to the laboratory tables.

Operations were begun in 1949. The laboratory in Toledo was closed and Schroeder transferred to Columbus. Principal technical personnel in the Columbus laboratory were P.N. Brown, C.R. Collier, P.G. Drake, R.W. Elliott, J.H. Hubble, R.A. Krieger, L.B. Laird, M.E. Schroeder, and H.H. Stevens, Jr. W.L. Lamar was district chemist for the balance of the decade. At one time during the period, the program required 30 employees and had a budget of nearly $200,000.

The chemical analyses included that for common ions and chemical characteristics. Some additional tests were made for the pollution studies. The daily surface-water samples were composited in 10-day composites or in accordance with the daily specific conductance. Specific conductance was determined on all daily samples before compositing. Water temperature was taken on all samples at the time of collection. Water-temperature measurements were also taken at some gaging stations by personnel of the SW Branch. Daily sampling stations were operated for at least 1 year.

Suspended sediment was determined on daily samples for low and normal flows, and on samples collected more frequently during rapidly changing water discharge. At times, samples were collected along the cross-section. Particle-size analysis was conducted on some samples.

Extensive cooperative programs were established for Ohio and Kentucky. The former is described below and the latter under Kentucky. Cooperative programs in the five other States were limited. A cooperative program on water quality with the Ohio River Valley Water Sanitation Commission involved States on the mainstem Ohio River for chemical-quality aspects. Cooperation was maintained with the GW Branch for the analysis of ground-water samples in each of the States except Illinois. Also, some chemical-quality or suspended-sediment examinations were made for other Federal agencies. As a member of committees and task groups of the American Society for Testing Materials and the American Water Works Association, Lamar was also actively engaged during the decade in the development of nationwide methodology and standards for testing substances in water.

The Program in Ohio

From 1947 to 1957, study of the chemical quality of the surface waters in Ohio progressed to the point of essentially statewide coverage. Cooperative programs involved two divisions of the Ohio Department of Natural Resources (DNR). Generally, daily-sampling stations were operated for at least 1 year. At other points, samples were collected at intervals. Spot examples were collected at high- and low-water discharge and at various other times. The data were documented by Lamar and Schroeder for 1946–50 and published by the DNR as Bulletin 23 in 1951. This was updated for 1946–58 by Hubble and Collier and was published by the DNR in 1960.

Suspended-sediment studies were begun in 1950. Daily-sampling stations were established for the measurement of suspended-sediment and particle-size analyses. Samples were collected daily during low and normal flows and more frequently during rapidly changing discharge. Some cross-section sampling was included. Some chemical-quality analyses and (or) suspended-sediment examinations were conducted for other Federal agencies. Analyses of ground waters in Ohio were conducted in cooperation with the GW Branch.

Schroeder was a member of an interbranch team on a study of the water resources of the Mahoning River basin with special reference to the Youngstown area (USGS Circ. 177, 1952). A special study, "The Lake Erie Pollution Survey," was conducted from 1950 to 1952 inclusive in cooperation with the Division of Water of the DNR and other agencies. The Columbus regional laboratory was involved in the chemical- and physical-quality examinations. Chemical-quality stations were established at 18 locations on streams in Ohio tributary to Lake Erie water-supply intakes. A number of spot samples were also collected from other streams tributary to Lake Erie. Four suspended-sediment stations also were operated on streams tributary to Lake Erie. Lamar reported the Branch findings in Chapter IV of the Lake Erie pollution survey report published by the DNR in 1953.

The regular chemical analyses included the determination of oxygen consumed and the presence of copper and chromium. In addition, some tests were conducted for dissolved oxygen, cyanide, and phenols as C_6H_5OH. Wastewaters from a steel mill, a petroleum industry facility, a plating process facility, and a textile plant were also analyzed.

OKLAHOMA

SURFACE WATER BRANCH

By Sherman K. Jackson

At the beginning of the decade, the program in Oklahoma was under the Fort Smith, Ark., District, which maintained a staff of about 10 persons at a Subdistrict office located in the State Capitol building in Oklahoma City. F.C. Ames, who transferred from the Chattanooga, Tenn., District in 1939, continued in charge until he left in December 1947 to direct the Lake Mead sedimentation survey with headquarters at Boulder City, Nev. During this period, there were only three or four professional Survey employees assigned; the rest were State employees who were paid from cooperative funds.

In January 1948, S.K. Jackson, who had been assistant district engineer of the Fort Smith District, transferred to Oklahoma City as district engineer of the newly established Oklahoma District. He remained in that position until March 1957, when he was appointed regional hydrologist for the Rocky Mountain area with headquarters at Denver, Colo. A.A. Fischback, who had been district engineer for West Virginia, succeeded Jackson. Personnel during this period ranged from 10 to 15 employees assigned to the District staff, supplemented from time to time by detailees from other units of the Division for work in special projects. John Horton, who joined the staff in 1949, served as assistant district engineer. L.L. Laine, who remained throughout the decade, served as principal technical assistant. Other principal assistants included W.B. Sparkman, who left the District in 1955; C.R. Gilbert, who transferred from the Texas District in 1952; and K.C. Wall, who served as district clerk throughout this period.

The District headquarters remained in the State Capitol building until 1949 after which, because of space shortages for State personnel, Federal or leased space was occupied at three successive locations in the Oklahoma City area during the balance of the decade. To handle operations more efficiently, field headquarters in remote sections of the State were established at Liberal, Kans., and at Pryor, Mangum, and Elk City in Oklahoma. These offices were staffed by one or two men, depending on the workload, and were established in order to obtain discharge measurements of flash floods and to obtain frequent measurements for better definition of ratings on shifting streams, which are typical of these areas.

Cooperation

The Federal-State cooperative program furnished the major portion of funds available. The principal cooperator was the Oklahoma Planning and Resources Board, Division of Water Resources; also cooperating were the city of Oklahoma City and the Grand River Dam Authority. The Corps of Engineers and the Bureau of Reclamation transferred funds for the maintenance and operation of stream-gaging stations that were needed for planning and operational projects. The Corps also furnished some discharge records, collected by their staff, for review and publication by the Survey.

The Soil Conservation Service contributed funds and services for the collection of rainfall and runoff data on the Sandstone and Double Creek watershed demonstration projects. Of particular note was the comprehensive data collected on the Sandstone Creek watershed in western Oklahoma (see "Special projects" below). Excellent cooperation existed between the SW Branch and the other branches of the Division. Personnel of the local District offices of the GW and QW Branches worked in close cooperation with the SW staff on many projects, and had excellent technical assistance from the TC Branch on several projects.

Special Projects

The District engaged in several important projects and activities during the period that were somewhat outside usual District operations:

Arkansas-White-Red Interagency Study—District personnel, along with several detailees from other offices, actively participated in the planning studies of the Arkansas-White-Red River Basin Interagency Committee during 1950–54. This committee was composed of representatives of six Federal agencies and of each of the eight States cooperating in the study. S.K. Jackson served as the USDI representative on the Hydrologic Subcommittee and as Chairman of the Water Resources Work Group. He was assisted by W.V. Iorns and W.D. Simons on extended detail from the TC Branch. W.P. Cross of the Ohio District also served as a consultant on special hydrologic studies.

Lake Hefner Evaporation Study—In 1950, Lake Hefner, a public water-supply reservoir for Oklahoma City, was selected as a study site for the development

of more accurate information on and methods for the computation of evaporation of water from reservoirs. This site was selected from among 100 reservoirs throughout the Nation as the one best suited from which to obtain accurate data on evaporation losses. The leadership on this study was under the TC Branch and was conducted in cooperation with the Bureau of Reclamation, the U.S. Navy, and the Weather Bureau. The Oklahoma City Water Department also provided assistance. S.K. Jackson served as local coordinator on the project. One Survey employee, F.W. Kennon, was assigned full-time to field work; two employees of the Navy Electronic Laboratory were also assigned for the duration of the project from 1950 to 1951. Technical supervision of the project was by W.B. Langbein and G.E. Harbeck of the TC Branch.

Hydrologic Effects of Small Reservoirs—Controversy developed during these years concerning the upstream watershed projects of the Soil Conservation Service (SCS) relative to the major dams being built by the Corps of Engineers and the Bureau of Reclamation. These activities involved not only the effectiveness of flood control, but also the effect on water yield by the upstream conservation practices developed by the SCS. Water yield was particularly important in the semiarid and arid regions of the southwestern United States. The controversy was especially rampant in Oklahoma, as evidenced by much media comment. Of particular note was the publication of a book in 1954 by the prominent Oklahoma City editorial writer, Elmer Peterson, entitled "Big Dam Foolishness." In cooperation with the SCS, a comprehensive study of the hydrologic effects of small reservoirs in the Sandstone Creek watershed in western Oklahoma was undertaken, beginning in 1951. The watershed was a principal demonstration area selected by the SCS, and involved the installation of a comprehensive system of small reservoirs for upstream flood and erosion control, source of stock and irrigation water, and recreation. The total size of the study area was 85.4 square miles. Runoff from 64.3 square miles, 75 percent of the area, was controlled by erosion-control and flood-retarding structures. An elaborate system of rainfall and stream-gaging stations was established. One full-time Survey employee was assigned to this project throughout the period. Financial support and field operation of rain gages was supplied by the SCS. A compilation of basic data for this study for 1951–56 was prepared by C.R. Gilbert, and was published as Oklahoma Water Resources Bulletin 17 in 1959. A later report, prepared by F.W. Kennon, was published as Water-Supply Paper 1839-C in 1966, and contains significant data as to the effectiveness of these programs.

Water-Use Study—As a contribution to the 1950 nationwide report on water use, an extensive effort was made to obtain reliable data for Oklahoma (such data was quite sketchy at the time). An engineering professor from a State university was employed full-time for summer 1951 to assist on this project. All cities and major industries were contacted, and estimates were made for other uses. The GW and QW Branch staffs also participated. A report, "Public Water Supplies in Oklahoma," Oklahoma Water Resources Board, L.L. Laine, S.L. Schoff, and T.B. Dover, 1951, presented the data obtained from this project.

Unusual Hydrologic Events

Oklahoma, as is typical of the southwestern semiarid regions, is subject to extremes of flood and drought, and both occurred during this decade. The floods of May 1951 in western Oklahoma were of unusual severity. Maximum known discharges were recorded at many gaging stations and record-breaking floods also occurred on small streams. Many special determinations of peak flows were made. In addition to the full use of District personnel, valuable assistance was obtained by the detail of several flood specialists from nearby districts. Of particular note was the flood on Deer Creek near Bridgeport on May 16, 1951, in which a slope-area measurement indicated a peak discharge of 46,800 cubic feet per second from a drainage area of 90.2 square miles. Unofficial rainfall data showed amounts of 15 to 18 inches over the watershed. A number of motorists were caught by the floodwaters and drowned on U.S Route 66, which paralleled Deer Creek for about 10 miles.

Another great flood in northeastern Oklahoma occurred in several major streams that drained areas affected by torrential rains in Kansas in July 1951. A party from the Oklahoma District office was sent to help personnel of the Kansas District obtain a measurement of the Neosho River at Iola, Kans. With the help of the owner of a power boat, a discharge measurement of some 80,000 cubic feet per second was obtained; the peak discharge at this site exceeded the 50-year maximum by about nine times.

The drought of the 1950's was one of the worst on record in Oklahoma. Deficiency in streamflow began in July 1951, following the widespread floods of June of that year, and reached peak severity in 1956. Many cities had critical water shortages. District personnel made special efforts to obtain data on minimum discharges at ungaged sites and answered many inquiries regarding water-supply problems.

GROUND WATER BRANCH

By Stuart L. Schoff

July 1947 opened the second decade of cooperative ground-water work in Oklahoma. The original State

cooperating agency—the Oklahoma Geological Survey—was still the participant on the State side, and R.H. Dott, Sr., was still its director. An effective and helpful cooperator, Dott continued as director until 1952 when he resigned to go with the American Association of Petroleum Geologists. The State survey provided office space in its quarters on the campus of Oklahoma University in Norman, plus one geologist and some clerical, secretarial, and drafting assistance in addition to its financial support.

When Dott left, he was replaced by W.E. Ham, acting director, and then, after a couple of years, by C.C. Branson as State Geologist. About 1950, the Oklahoma Planning and Resources Board became a cooperator, and a field office was established with the Board in Oklahoma City. As the decade neared its end, a second field office was established in Woodward. Both State agencies continued their cooperation to the end of the decade.

The District had a cooperative agreement with the U.S. Bureau of Reclamation in 1948. The agreement was for the investigation of a small area of Arkansas River floodplain near Ft. Gibson, but was never intended to be more than a short-term contract for a single job.

In charge for the U.S. Geological Survey was S.L. Schoff, a geologist who had opened the cooperative program in 1937 as a new appointee under the supervision of W.N. White, and who then was based in Austin, Tex. Other staff members in 1947 were E.W. Reed, engineer, who had headed the office from 1942 to 1946 during Schoff's absence on military furlough, and L.V. Davis, geologist of the State survey who later was to move to Federal employment. Each had an assigned project as well as other duties.

Interest in ground water and demand for information about it were growing, and additional staff was needed. In fiscal year 1950, J.L. Mogg and Wayne Steele, engineers, and C.L. Fair and J.L. Barclay, geologists, were hired. It was not many months before Fair, Steele, and Mogg were furloughed for military service in the Korean War. Oklahoma University students were hired part-time to do some of the observation-well work and, in 1952, the District's first full-time secretary, A.F. Moses, was hired. Also in 1952, Reed transferred to national headquarters in Washington—a substantial loss, for after 10 years, he was knowledgeable in all phases of District operations.

Mogg returned in 1952 and remained on the District staff until 1955, when he resigned. L.C. Burton and C.E. Steele became full-time staff members in 1954 after having served as part-time field assistants. Schoff transferred early in 1955 to the Foreign Hydrology Section and an assignment in Peru, and Barclay took charge as acting district geologist for about a year before he transferred to Florida and A.R. Leonard became district geologist. Other changes as the decade ended were the transfer of L.V. Davis to New Mexico, and the arrival of H.H. Tanaka and M.E. Davis, the latter having been assigned to a field headquarters in Woodward.

The studies underway as the decade opened were of ground-water resources in rocks of Tertiary age in Beaver County, the Rush Springs sandstone in Grady County, and the Roubidoux formation in Ottawa County. The Roubidoux formation study seemed the most advanced, because a first-draft report had been completed. It turned out, however, that much revision was needed, and several years passed before the report was approved for publication. Periodic measurements of water levels were being made in about 180 wells located principally in areas of active or anticipated investigation in the western half of the State. In the files were several batches of data and some reconnaissance reports worthy of expansion into full-scale investigation and publishable reports. Some of these were necessary because of demands created by World War II. Once the immediate need had been satisfied, data went back into the files so that other "brush fires" could be brought under control.

By July 1951, 11 projects were scheduled. In addition to the three mentioned above, the following had been started with the Oklahoma Geological Survey as cooperator: Cleveland and Oklahoma Counties (Garber and Wellington formations); Canadian County (alluvium mainly in the North Canadian River valley); McCurtain County (Trinity sand); and Caddo and adjacent counties (Rush Springs sandstone). Projects in cooperation with the Oklahoma Planning and Resources Board were Major, Garfield, and Kingfisher Counties (terrace deposits); Beckham County (terrace deposits flanking North Fork Red River); and Tillman County (terrace deposits east of North Fork Red River). The one Federal research project underway was to establish the relation between ground-water levels and streamflow in the Pond Creek basin of Caddo County.

The scheduled projects often had to be pushed aside to make room for short-term unpredictable demands. A summary dated July 15, 1947, indicates this situation. Field study and analysis of chemical, water-quality, and pumping-test data in the fiscal year just ended revealed new and better sources of water, had proven the adequacy of known sources, or indicated the appropriate spacing of wells for several Oklahoma towns interested in using ground water, among them Durant and Pauls Valley. For another town, the study showed that two sources of ground water were probably inadequate and (or) did not warrant development. Summaries had been prepared for the Soil Conservation Service on the ground-water potential of two areas under consideration for irrigation by water pumped from wells. A field reconnaissance for the Bureau of

Reclamation was conducted on an area of Arkansas River bottomland, which similarly was being considered for well-water irrigation. The well-water irrigation study developed in 1948 into an arrangement for test drilling and test pumping and the ultimate publication of the report as a circular of the State survey.

Not in the list of recognized projects but receiving attention nevertheless were other papers: A summary of ground-water supplies and uses in Oklahoma, prepared by Schoff and published in 1948 in the proceedings of the Third Oklahoma Conservation Conference; a paper on geology and water-well construction by Schoff, published in the Journal of the American Water Works Association (1950); a paper on ground water in alluvium in Oklahoma by Schoff and Reed, published in Economic Geology (1951); a paper on public water supplies in Oklahoma by L.L. Laine, Schoff, and T.B. Dover (1951); and several short papers on ground-water topics pertinent to Oklahoma for the Oklahoma Geological Survey's Mineral Report series, a mimeographed publication distributed mainly to mineral producers within the State. Somewhat later (1955), a map showing ground-water reservoirs in Oklahoma and their estimated yields was prepared, principally by Schoff.

QUALITY OF WATER BRANCH

By Tyrus B. Dover

At the beginning of the decade, the office and laboratory remained where originally established by the Branch in 1946, in space provided in its Chemistry building by Oklahoma A&M College in Stillwater (Follansbee, v. IV, p. 381). Its staff was increasing rapidly at the time. A personnel listing as of August 1946 showed only the chemist in charge. By January 1948, there were eight people on the staff. The number grew to 12 a year later and gradually diminished to about five Federal employees and two State employees. Space in the Chemistry building became inadequate and, in 1950, the laboratory moved to space provided by the college at 1203 West 6th Street in Stillwater. In 1952, the QW office was given District status.

The Division of Water Resources, Oklahoma Planning and Resources Board, gradually assumed the role of principal cooperator for QW activities in the State and, in 1954, the District moved from Stillwater to Oklahoma City. This new location allowed for much closer coordination of program activities with the principal cooperator and with the staffs of the SW and GW Districts. Temporary Federal space was provided at an old Veterans Administration hospital near Will Rogers Field, the Oklahoma City Municipal Airport. After a few months, a more permanent location was provided in a Federal building at 2800 South Eastern Avenue.

I.W. Walling, chemist in charge, had established the laboratory in 1946 and remained in that position until 1951 when he transferred to California. He was succeeded by T.B. Dover who had been stationed in Pennsylvania before transferring to Oklahoma in 1948. Dover's title was changed to district chemist in 1952. Other members of the senior staff included J.M. Myers (1949–54); D.S. Conner (1951–52); F.B. Walling (1952–54); R.N. Hood, Jr. (1955 on); and J.J. Murphy who served as assistant district chief from 1954 on.

The Federal-State cooperative program furnished the major portion of funds available. The principal cooperator was the Oklahoma Planning and Resources Board, Division of Water Resources; also cooperating were the Chemistry Department and the Experiment Station, both of Oklahoma A&M College. The Bureau of Reclamation transferred funds for the maintenance and operation of water-quality and sediment stations needed for their planning and operational projects.

OREGON

SURFACE WATER BRANCH

Condensed from documentation by K.N. Phillips, R.W. Childreth, M.E. Leichner, and A.M. Moore

The District office was located in the Post Office building in Portland until 1953 when it moved into the newly constructed USDI building in the same city. The headquarters staff increased from less than 20 to about 25 during the period. An area office at Medford, where two to four persons were assigned, was maintained through the decade, as was a one-man field headquarters at Salem. Other field headquarters were established at LaGrande in 1952 and at Eugene in 1953.

G.H. Canfield, district engineer since 1928, retired in 1948 and was succeeded by K.N. Phillips, who had been assistant district chief (biographical memoir for Canfield in *WRD Retirees* newsletter, November 1978). Phillips continued as district chief well beyond the decade, retiring in 1962. A.M. Moore joined the District staff early in 1949 by transfer from the Boston District, and served as assistant district engineer through and beyond the end of the decade. The senior staff at District headquarters initially included W.T. Miller, who transferred to the New Mexico District in 1948, and W.W. Dean, who transferred to the Bonneville Power Administration in 1950. G.A. Kirkpatrick and D.L. Miller then served as senior staff members. M.E. Leichner was district clerk until 1955. H.W. Meyer was fiscal clerk during 1948–51 and

in 1955. Alta Conrad became district clerk in 1956 and continued through and beyond the decade. R.W. Childreth, who joined the District in 1943, was active in snow gaging as well as stream gaging during the decade.

C.A. Young was in charge of the Medford area office until 1954, when he retired and was succeeded by H.J. Thompson. D.L. Miller, from District headquarters, replaced Thompson in 1956. G.A. Kirkpatrick was stationed at Salem until 1948 when G.A. Backe took over for the balance of the decade. J.F. Cleaver was assigned to LaGrande and D.L. Weiss was in charge at Eugene.

Canfield reported (in response to a WRD Circular dated July 15, 1947) that of the 277 gaging stations then in operation, 6 were under the Federal program; 173 were under the cooperative program with the Oregon State Engineer; 7 were in cooperation with the cities of Corvallis, Eugene, McMinnville, and Portland, and the Umatilla County Court; and 13 were supported by funding from permittees and licensees of the Federal Power Commission. The rest were paid for by other Federal agencies as follows: Bureau of Reclamation (37), Army Engineers (38), Fish and Wildlife Service (2), and Bonneville Power Administration (1, stage only).

In 1951, District personnel collected daily-discharge measurements at about 300 stream locations, of which about 60 percent were supported under the cooperative program and 30 percent were supported by other Federal agencies. Stage records only were recorded at an additional 120 points. Water samples were taken at many stream stations for analysis by the QW Branch staff. In addition to the operation of the gaging-station network and flood investigations, the District conducted correlative studies of streamflow and runoff relative to precipitation, evaporation, ground water, snow-water storage, and topographic, geologic, and vegetative cover influences.

The Columbia River flood that crested in June 1948 had a great impact on the normal work schedules and earlier program plans of the District. Most of the staff were busy in the field, trying to establish ratings and make sure gage-heights were recorded for the flood period; but some stations were inaccessible, and of course the flood also occurred on ungaged streams. Hence, post-flood, indirect measurements were emphasized, and crews became proficient in slope-area and contracted-opening techniques. That proficiency in turn helped to make possible, in 1952, a continuing program of floodflow measurements in small areas in cooperation with the State Highway Engineer for use in culvert design. L.W. Downing was in charge.

On May 31, 1948, W.W. Dean, with a newly hired assistant, measured from a 1,727-foot cableway a flow of 1 million cubic feet per second in the Columbia River near The Dalles, Oreg. This is believed to be the largest flow measured by current meter by a Survey employee in the United States up to that time. Dean recalls (written commun., 1983) that the task was strenuous: "We encountered a maximum depth of 70 feet, velocities up to 16 feet per second, and floating debris consisting of small buildings, whole cottonwood trees with roots, dead cattle, and complete hay wagons, and had to move or crank up the current meter and 150 pound weight frequently." Flow records at this site provided a base for the design of the reservoirs, dams, and powerplants that were later to stairstep the water surface of the Columbia River from the Canadian border downstream to tidewater. (Annual peak stages at The Dalles are on record since 1858 and daily flows are continuous from June 1878.)

The 1948 Columbia River flood, which caused damage estimated at $100 million, was documented in WSP 1080 (1949). The cost of the flood surveys, the report, and the rehabilitation or replacement of gaging-station structures were estimated at about $250,000, much of which came from a supplemental appropriation. Other major floods occurring in Oregon during the decade were from October through November 1950 (WSP 1137-E, 1953), in January 1953 in western Oregon (S.E. Rantz, WSP 1320-D, 1959), and in December 1955 (Walter Hofmann and S.E. Rantz, WSP 1650-A, 1963).

In 1953, the District was involved in a lawsuit brought against the U.S. Government by a marine towing company. The suit followed an accident in which a hook on a tall crane being transported on a barge on the Columbia River snagged and destroyed the cableway at the Maryhill station. The suit was settled in favor of the Federal Government.

The District pioneered in the design and construction of long cableways because of the great width of the Columbia River and sparsity of bridges spanning the river. Faced with an elevation change in unloaded cable sag that varied as much as 40 feet between temperatures of −10° and 100 °F at one location, the District staff studied the practicality of using a so-called suspended-anchor cableway. The use of such a suspended anchor, moving parallel to one tower, would provide a uniform tension and thus a uniform sag on the cable. Enroute to Washington, D.C., by automobile in 1952, Phillips discussed the concept with A.H. Frazier and staff at the Columbus (Ohio) Equipment Development Laboratory. Phillips recalls that "they set up for me a small model cableway using a suspended anchor. Frazier then placed the model car (complete with its dummy hydrographers) at midspan, and added weight to simulate a sounding line with drift caught on it. When he cut the sounding line, the dummy figures in the car shot upwards like projectiles . . . It was apparent that some restraint had to be applied to the falling anchor."

(Some time after the end of the decade, Harry Hulsing conducted further studies that led to the successful

construction and operation of such a cableway, but designed to prevent a rapid fall of the suspended anchor. It was located on the Willamette River at Dexter and is believed to be the only one ever built for stream gaging anywhere.)

As chairman and Federal representative on the Klamath River Interstate Compact Commission, Phillips was instrumental in having a survey conducted of irrigated lands in the Klamath Indian Reservation to provide better protection for the irrigator's rights with the State and under the Compact. He also arranged for the collection of continuous water-quality samples at the Oregon-California line as a means of determining conformance to the Compact requirement that the water at that point not be degraded.

Partly to supply the needs of other agencies that used or controlled large amounts of water, the Current Records Center was set up in October 1952. Hollis Orem was hired by transfer from the Federal Power Commission in San Francisco to be in charge. Pending Orem's arrival, Moore wore two hats for a month or more, getting the Center started and serving as acting district engineer (SW) in Phillip's absence. Mimeographed records were thereafter furnished monthly to interested agencies, and the Center also served as a clearinghouse for inquiries about storage, daily flows, and water temperatures, inquiries that otherwise would have been directed to all districts in the Columbia River basin.

GROUND WATER BRANCH

By Reuben C. Newcomb

At the beginning of the decade, the work in Oregon was oriented within a 20-year plan previously started by A.M. Piper. Under this plan, the ground-water hydrology was to be studied with three main concurrent objectives: (1) reconnaissance reports on the most heavily populated areas and drainage basin units with the most urgent problems; (2) detailed reports on areas of greatest potential ground-water use and problems; and (3) overall statewide summary reconnaissance reports on ground-water occurrence, use, and quality. The pursuit of these objectives was kept near schedule, although funding was less than originally visualized. Federal unmatched research funds available for areas predominantly of Federal concern helped to keep the work on schedule. The original objectives were amended by the injection of high priorities to two hydrologic settings, volcanic terranes and coastal sand-dune units.

During the early years of the decade, experienced and trained hydrologists were in short supply. The educational and training gaps left by World War II had carried over, and it was not until the mid-1950's that well-qualified personnel had been trained. In this training process, the Branch's Ground Water School was of considerable help. The enactment, in 1955, of the progressive Oregon Ground Water Law, which the District helped formulate, also assisted in subsequent derivations of hydrologic conditions. An agitation for more modern topographic maps resulted in modern maps being published by the Topographic (now National Mapping) Division during the subsequent decades.

R.C. Newcomb was in charge of District activities throughout the decade. The District included the State of Washington until 1949 and the Hanford Atomic Reservation, in Washington, until 1958. Newcomb's principal assistant until 1952 was F.D. Trauger who, in that year, transferred to the Albuquerque District. J.E. Sceva was a leading investigator until he transferred to Tacoma in 1950. R.A. Young, who had joined the staff in 1949, succeeded Trauger until he transferred to the Minnesota District in 1954. D.H. Hart, with the District since 1949, continued as senior staff member until near the end of the decade when he was succeeded by G.M. Hogenson who had been recruited in 1951. S.G. Brown transferred to the GW Branch from the Corps of Engineers in 1954. Brown completed many projects during the latter half of the decade. E.R. Hampton joined the staff as a hydrologic field assistant in 1954 and advanced to senior project investigator in the following decade. F.A. Watkins served on the staff for the first 6 years of the period. Mrs. R.L. Smith served as district clerk throughout the decade.

The District staff in Portland, four or five persons at the beginning, increased to 10 in 1952, and decreased to five during the final 3 years. District headquarters remained in Portland during the entire time. It was in the Post Office building until 1954 when the staff joined those of the other Branches in the new USDI building (now known as the Bonneville Power Administration building).

A field headquarters in Richland, Wash., was established in 1948 under J.R. Strand as a base for the geology and hydrology project conducted for the U.S. Atomic Energy Commission's (AEC) Hanford project. A report for the project was completed in 1953 (PP 717, 1970). In 1950, the AEC asked the Survey to direct the drilling program of monitoring wells on the Hanford Reservation, a project that continued until 1958 under F.J. Frank.

Funding for the Oregon program during the decade has been set down from memory. Dollar values are, of course, rounded and approximate. Federal program allotments permitted investigations in the Umatilla and Rogue River basins (1950–53, a 4-year total of about $16,000 for each basin); in the Coos Bay dunelands (1952–53, $8,000); in the Klamath River (interstate) basin (1954–56, $14,000);

the Grand Ronde River basin (1954–56, $19,000); and the Fort Rock basin (1957, $5,000). The Federal-State program included cooperation with the Oregon State Engineer that grew from about $5,000 (both sides, Federal and State) during the first 2 years to about $10,000 annually thereafter. Cooperation with the cities of Tacoma (1947, $500), Spokane (1947–48, $500), and Florence (1955–56, $6,000) permitted small increments to the program, as did the program with Walla Walla County (1948–49, $8,000). The State of California helped fund work under the Klamath River Compact in 1954 ($6,000).

The Bureau of Reclamation transferred about $14,000 for studies in the Columbia River basin during 1947–49 and about $5,000 for studies in Clark County in 1949. The AEC provided a total of about $70,000 during 1947–49, plus funds to meet needed drilling costs. The U.S. Navy transferred about $5,000 for 1956–57 studies in the vicinity of the Klamath Air Base.

As of July 1951, the District staff collected water-table records from approximately 100 observation wells, nearly all of which were under the cooperative program with the Oregon State Engineer. By the end of the decade, the number of wells had increased to about 300. Throughout the decade, the District funneled what funds were available into chemical analyses of ground water, and built the meager data bank from scarcely 100 to several hundred analyses.

Many of the investigative reports were initially unpublished because of the clamor for the immediately available open-file reports, the lack of people trained in writing for publication, and lack of base maps. Most were later published as Water-Supply Papers. The following list, taken largely from McGuinness (WSP 1800, 1963, p. 704–5), identifies a portion of the reports produced: "Snohomish County in Washington" (WSP 1135, 1953); "Walla Walla Basin" (R.C. Newcomb, Washington Water-Supply Bull. 21, 1965); "The Baker Valley in Baker County" (F.D. Trauger, open-file, 1951); "The Swan Lake-Yonna Valleys Area in Southern Klamath County" (J.D. Meyers and R.C. Newcomb, open-file, 1952); "The Tualatin Valley at the Northwest Edge of the Willamette Valley" (D.H. Hart and R.C. Newcomb, WSP 1697, 1965); "Lake County" (F.D. Trauger, open-file, 1950); and the entire Klamath River basin in Oregon (R.C. Newcomb and D.H. Hart, open-file, 1958). A brief open-file report by R.C. Newcomb in 1951 described the general ground-water situation in Oregon.

QUALITY OF WATER BRANCH

By Herbert A. Swenson

In the first half of the decade, work in Oregon was the responsibility of the Regional office in Salt Lake City, Utah. In 1953, H.A. Swenson, who had been staff assistant to the regional engineer (QW) in Lincoln, Nebr., established temporary headquarters in Corvallis as district chemist for Oregon, Washington, Idaho, and western Montana. An office and access to a laboratory were provided courtesy of Oregon State College through the help and strong support of Professor Fred Merryfield, Department of Civil Engineering. J.F. Santos was Swenson's principal assistant. In 1954, the District office moved to more permanent quarters in Portland at the USDI building. Laboratory facilities were installed in space made available by the Corps of Engineers at Troutdale Airport about 15 miles east of Portland.

Throughout the 1947–57 decade, the water-quality program in Oregon was supported largely by allocations of Federal program funds that, because of limited availability and keen competition, were at near-poverty level. State agencies expressed no interest during the period in cooperative water-quality programs. Moreover, Survey policy at the time frowned on its local representatives making the initial overture that could possibly lead to a Federal-State cooperative agreement. The one exception in program support was a small cooperative study in 1951 that examined the ground-water quality in 17 wells. The U.S. Air Force provided funds throughout the period for annual quality assessment of base and airfield water supplies from wells, springs, and surface sources.

Standard network operation adhered to multipurpose guidelines used in the national assessment of streamflow quality. Key station sites were selected on the Columbia River and tributary flows, as well as on coastal streams, where water-quality information would reflect differences in time and place of the chemical characteristics and dissolved-solids loads of major drainage basins. In addition to the standard or primary network, an irrigation network was in operation during the period. Criteria for site selections, as recommended by the Federal Interagency River Basin Committee, stressed points where irrigation development was adversely altering or likely to alter stream quality. To fill gaps in information, limited-reconnaissance water-quality surveys of rivers, wells, and springs, as well as freshwater and saline lakes, were made statewide from time to time.

INTERBRANCH ACTIVITIES

A.M. Piper, staff scientist, Pacific Northwest, continued to use Portland as his headquarters until near the end of the decade, first in the Post Office building and later in the USDI building. He had been in charge of the GW Branch activities in both Oregon and Washington until 1946 when he was succeeded by R.C. Newcomb.

Piper represented the CHE in coordinating Federal-type program plans for the Pacific Northwest. He also represented the Director on nationwide investigations for the AEC, on the Departmental Northwest Field Committee, and as coordinator of the Survey's program plans for the Pacific Northwest Region. In July 1956, newly appointed as division hydrologist for the Pacific Coast Area, Piper moved to the Survey's regional facility at Menlo Park, California.

Water resources of the Portland area were studied by an interbranch team, W.C. Griffin (SW), F.A. Watkins (GW), and H.A. Swenson (QW), with results printed as Circular 372 in 1956. A report on Oregon's water supplies, future needs, and problems was prepared by K.N. Phillips (SW), R.C. Newcomb (GW), H.A. Swenson (QW), and L.B. Laird (QW), and published as WSP 1649 in 1965.

PENNSYLVANIA

SURFACE WATER BRANCH

By David Barton

The District, which had been established in 1931, had its headquarters in the State-owned Education building in Harrisburg during the entire decade. The headquarters staff varied between 6 and 12 employees supplemented, from time to time, by detailees from other districts for work on special projects. J.W. Mangan, who had opened the District in 1931, continued as district engineer until his death in July 1956. He was succeeded by J.J. Molloy who had transferred to the District as the assistant district engineer in April 1949 from the Ithaca, N.Y., Subdistrict. David Barton, F.L. LeMert, S.E. Craighead, and R.W. Reichle were on the headquarters staff during the entire period. John Horton, assistant district engineer to 1949, transferred to the Oklahoma District at that time. I.A. Heckmiller accepted a foreign assignment to Afghanistan in March 1954.

The District program was conducted by personnel operating out of either the headquarters office in Harrisburg or from the large Subdistrict office in Pittsburgh. The Subdistrict, together with its personnel, funding, and activities, is described under a separate heading in the latter part of this statement.

Cooperation

The Federal-State cooperative program furnished the major portion of the funding needed for the operation of the District office. The principal cooperator was the State Department of Forests and Waters (later to become the Department of Environmental Resources) through the Water and Power Resources Board. Also cooperating in the collection of streamflow data were many city, county, and State agencies, and industrial and power companies. The Corps of Engineers furnished financial assistance for the operation and maintenance of stream gages needed for its planning and operational projects.

Special Projects

The District staff conducted several projects and activities during the period that were somewhat outside the usual District operations. These are described in the following subsections.

Hydraulic and hydrologic aspects of flood-plain planning—In the latter part of the period, S.W. Wiitala and K.R. Jetter, Survey employees, and A.J. Sommerville, a State employee, prepared a report under the subject title. This report, which dealt with the problems of flood-plain occupation, was used in later years in the extensive flood-plain mapping program in Pennsylvania. Originally cataloged as a USGS Open-File Report, it was published later as WSP 1526 (1961).

Forest and Water Research project, Delaware-Lehigh experimental forest—This was a cooperative research project with the State Department of Forests and Waters dealing with runoff in a small drainage area in a heavily-wooded basin.

The use of water in Pennsylvania—In 1951, a report entitled "The Water Resources of Southeastern Bucks County, Pennsylvania" by J.B. Graham (GW), J.W. Mangan, and W.F. White, Jr., (QW) was prepared. This report was of great use to Federal, State, and municipal authorities during the ever expanding growth of the suburban Philadelphia area following World War II.

Unusual Hydrologic Events

Pennsylvania, like most States in the Northeast, is subject to extremes of flood and drought, and both were experienced during 1947–57. In October 1954, floods caused by Hurricane Hazel struck central Pennsylvania, causing millions of dollars worth of damage and heavy loss of life. In August 1955, Hurricane Connie, followed by Hurricane Diane about a week later, caused the worst flood of record in central and eastern Pennsylvania. Many lives were lost and property damage was extremely high.

Many indirect measurements of peak flow were obtained. Results of these measurements were incorporated in WSP 1420, "Floods of August–October 1955, New England to North Carolina," by D.B. Bogart, published in 1960.

In startling contrast, the drought of the 1950's was one of the worst on record in Pennsylvania, especially in eastern Pennsylvania and neighboring States. As described in Part III (Interstate activities in the Delaware River basin), cooperation with the Interstate Commission on the Delaware River basin intensified during the decade. Many low-flow partial-record measuring sites were established throughout the State and data on minimum discharges were obtained. The Federal-State Flood Forecasting Service, established in earlier years (Follansbee, v. IV, p. 110) as a joint venture by the District, the State, and the U.S. Weather Bureau, continued to provide, via microwave-radio relay system, the rapid transmission of river stage and discharge data for the U.S. Weather Bureau to use in flood forecasting.

Pittsburgh Subdistrict Office

By Carl J. Rossow

The Pittsburgh Subdistrict office had a staff of about nine in the late 1940's and early 1950's and as many as 15 late in the decade. It was under the direction of F.N. Hansen until 1948, when he was appointed district engineer for Louisiana. He was succeeded by M.E. Noecker, who had been in charge of the Houghton, Mich., field office. Noecker resigned in 1954 and was succeeded by George Anthony who had been on staff of the Nebraska District. Anthony transferred to the Iowa District in January 1957, and was succeeded by R.D. Schmickle who had been conducting a mine drainage project in the Wilkes-Barre area. E.A. Burti, C.J. Rossow, and R.E. Bartoo were on the staff during the entire period. R.E. Fish, who had been assigned to the Subdistrict since 1941, transferred to the North Carolina District in 1951. J.F. Amoroso joined the staff in 1949 and R.W. Schmitt in 1950.

Following the catastrophic and record-breaking floods in March 1936 in western Pennsylvania, the Subdistrict was established in 1938 to provide more adequate data for flood forecasting and control works to reduce loss of lives and property. During 1947–57, Subdistrict personnel continued to provide the basic streamflow data needed for such projects as flood control, water supply, and highway and bridge construction.

The gaging-station network averaged about 66 regular stations each year, while miscellaneous-discharge measurements at other sites ranged between 20 and 50 per year. Gaging-station records were used by the Corps of Engineers, Pittsburgh district, in designing and operating Conemaugh Dam (completed in 1953), as well as seven other flood-control dams built in previous years. The completion of Conemaugh Dam reduced the flood crest at Pittsburgh for a flood comparable to that of March 1936 by a computed 10.1 feet. Operators of navigation locks and dams on the Allegheny, Monongahela, and Ohio Rivers required data also to determine flow augmentation from East Branch Clarion, Tygart, and Youghiogheny Rivers and the Pymatuning Reservoir, and thus relied heavily on streamflow records furnished to the Corps of Engineers and to Pennsylvania's Department of Forests and Waters. The Pittsburgh office personnel computed discharge records and prepared finished manuscript before transmittal to the District office for final review and assembly for publication. Major funding for network operation in western Pennsylvania was provided by the Corps of Engineers. Pennsylvania's Department of Forests and Waters also cooperated by providing funds and personnel.

Several special projects were completed in this decade. In 1951, summer flow measurements of 10 streams in Pennsylvania that drain into Lake Erie were incorporated in USGS Circular 174, "Water Resources of the Lake Erie Shore Region in Pennsylvania," published in 1952. As part of the nationwide compilation of streamflow records through September 1950, C.J. Rossow and R.E. Bartoo worked full-time with five part-time aids, except for several interruptions, in reviewing, revising, and compiling flow records of western Pennsylvania streams. These were then incorporated into WSP 1305 (1957). The interruptions in the compilation effort were caused by Hurricane Hazel floods in October 1954, Hurricane Diane floods in August 1955, and the rain plus snowmelt floods of March 1956. During and after these events, most Pittsburgh personnel conducted floodflow measurements, both direct and indirect, in the upper Ohio River basin and also in the upper Susquehanna River basin in northeastern Pennsylvania. Many man-months were devoted to work in documenting these historic floods.

GROUND WATER BRANCH

By Jack B. Graham and Paul H. Jones

At the start of the decade, GW Branch activities remained concentrated in the heavily populated and industrialized regions of Philadelphia and Pittsburgh. The cooperating agency, the Pennsylvania Topographic and Geologic Survey, maintained its support of an on-going statewide inventory of ground-water resources, but recognized that higher priorities were emerging in certain more local areas. In addition to Philadelphia County in the

southeastern part of the State, areas of concern were Bucks, Montgomery, Chester, and Delaware Counties.

Tabulations as to the withdrawal of ground water in Pennsylvania were underway and plans existed for periodic updating. Water-quality studies were being broadened to aid in understanding changes in quality associated with river-induced recharge to wells located in valley outwash deposits. The intensive quarrying of carbonate rocks, particularly in eastern areas of Pennsylvania, was of increasing interest as it related to potential ground-water pollution, due in part to the disposal of wastes in some of the numerous abandoned pits and quarries.

In the initial establishment of a cooperative ground-water program between the Geological Survey and the Topographic and Geologic Survey in Pennsylvania in 1943, the District office was located in Philadelphia primarily because the large Naval shipbuilding and airfield facility in south Philadelphia was dependent on its own wellfield for water supply. The wellfield was located within the perimeter of the Naval Base. The supply was being obtained from relatively shallow coastal plain sediments partially entrenched by the Delaware River that, at times of severe low flow, carried brackish tidal water adjacent to the Naval Base. The combination of heavy industrial ground-water use along both Pennsylvania and New Jersey shores of the Delaware River and the related vulnerability to pollution were the chief determining factors in the initial office location.

As the 1947–57 decade began, emphasis shifted from the localized Philadelphia and Pittsburgh areas to the broader metropolitan regions of both cities, with Bucks County in the southeast being given particular attention. District headquarters, then adjacent to the Geology Department in the Academy of Natural Sciences building in Philadelphia, was convenient to the QW Branch laboratory operated by N.H. Beamer in the U.S. Customs House in Philadelphia. J.B. Graham, who established the District in 1943, continued as district geologist. He was assisted at headquarters by J.C. Kammerer and R.R. Huber.

Close liaison was maintained with the Interstate Commission on the Delaware River, later reorganized as the Delaware River Basin Commission. The nearness of a relatively large number of colleges and universities in and adjacent to Philadelphia offered an opportunity to present the objectives and values of the District's cooperative ground-water activities to a number of geology departments and natural resources agencies. Liaison was developed with the Pennsylvania Water and Power Company through its use of weekly water-level data from wells adjacent to the lower Susquehanna River. These data were helpful in predicting inflow above the lower hydroelectric dam and generating station.

The Pittsburgh field office, opened in 1945, remained active until 1953. The office was supervised by J.H. Adamson (from the beginning of the decade until 1949), by D.W. Van Tuyl (until 1952), and finally by D.W. Greenman. In 1950, W.A. Mourant was stationed at Bethlehem, Pa., for a study of problems in the adjacent Lehigh River locality. The Bethlehem field office closed in 1953.

Fortunately, the Water Resources Division personnel in Pennyslvania—dispersed though they were in Philadelphia, Harrisburg, Pittsburgh, and in some smaller field offices—managed fairly frequent professional contacts and coordinated effort, as in the formation of a Pennsylvania Water Resources Council that was effective in the preparation of some joint, data-type reports. This interest in personnel of the three Branches existed prior to the decade as illustrated by the regional field conference in Downingtown in August 1946: about 50 or so people attended from the Washington, D.C., office. During this 2-day conference, problems and plans of water-resources programs in several Northeastern States were reviewed. The conference was concluded by a visit to the Philadelphia Naval Base as guests of the staff of the Navy aeronautics laboratory. This conference is believed to have been the first formal regional meeting of its kind to be scheduled outside of Washington, D.C.

In 1952, Graham transferred to Washington, D.C., to replace W.F. Guyton as chief of the section of water utilization in the General Hydrology Branch. Graham resigned in 1954 to become a partner in a new consulting firm. Upon Graham's transfer in 1952, he was succeeded as district geologist by P.H. Jones who transferred from the Louisiana District. Ground-water investigations in Pennsylvania continued under cooperation with the State Topographic and Geological Survey but, in 1952, to improve effectiveness of the statewide program, a change of location of District headquarters from Philadelphia to Harrisburg was proposed with the concurrence of the cooperator. At this time, intensive studies of the ground-water conditions of the Pittsburgh area were nearing completion, and a regional study of a 13-county area in northwestern Pennsylvania was begun with Greenman as project chief. N.H. Klein, who had been a member of the Pittsburgh staff, moved to Philadelphia in 1952 to assist in the detailed study of ground-water conditions in Bucks County and to take over the observation-well program in eastern Pennsylvania.

Transfer of the District office from Philadelphia to Harrisburg was accomplished in fall 1953. Kammerer was left in charge of the Philadelphia field office, but transferred to the PC Branch in Washington, D.C., in November 1953. Klein, who succeeded Kammerer, resigned in 1955 to avoid transfer to Louisiana. During this period, emphasis of studies was shifted from the

Philadelphia Navy Yard to the coastal plain and Piedmont areas between Morristown and Philadelphia in anticipation of the basin-wide study of water resources proposed by the Interstate Commission on the Delaware River.

Studies of ground-water conditions in limestone aquifers in the Lehigh-Bethlehem area, with emphasis on the effects of heavy withdrawals for mine-water control in the Saucon Valley, had been in progress by Mourant since 1950. When the Bethlehem office closed, Mourant moved to Harrisburg and continued his work from this location when the District headquarters was established there. At the same time, limestone aquifer studies were extended southwestward in the Great Valley.

Shortly after the Harrisburg headquarters was established, D.R. Rima arrived from Memphis, Tenn. Rima worked on several locality studies in eastern Pennsylvania, and gave principal emphasis to the Lansdale area in Montgomery County where borehole geophysical logging was being conducted with excellent results.

Greenman transferred from Pittsburgh to Harrisburg in 1954 as assistant district geologist and was mainly concerned with expediting completion of reports in manuscript form. He also assumed responsibility for the Bucks County study and report following Kammerer's transfer to Washington in 1953. Mourant's transfer to Roswell, N. Mex., in 1955 was approved before he was able to complete the report on the Bethlehem-Allentown area. Other members of the Harrisburg staff during the latter part of the decade included W.M. Lockwood, J.T. Hollander, C.W. Poth, and Harold Meisler.

It was during 1953–55 that the objective of the program of studies was changed from the long-established "county report" to the more meaningful regional "geological province" report. The initial emphasis was on Triassic rocks of the Newark basin, extending from the New York State boundary on the north to the Maryland State boundary on the south; to Paleozoic limestone aquifers of the Great Valley; and to sandstone aquifers of Pennsylvanian age west of the folded Appalachians. It had become apparent that county-scale studies could add little to the information already available in the monumental series of reconnaissance reports completed in the 1930's by Piper, Hall, Legette, and Lohman, and published by the Pennsylvania Topographic and Geologic Survey. It was necessary to study the regional hydrology of important water-bearing geologic formations, rather than continue statistical-type, well-inventory studies for limited areas in which many different geologic formations occurred.

It was also during this period that a close working relationship was developed between the Pennsylvania Water Well Contractor's Association and the Geological Survey that led to the accumulation of many drill-cutting samples as well as new, first-hand knowledge about subsurface conditions relative to the occurrence and availability of ground water in so-called "hard rock" terrains. Fault zones in the Philadelphia area and rock contacts of differential aqueous solubility in the vicinity of Marietta were successfully explored, and geomorphic terrane in Brandywine Valley was analyzed. These studies ended with the reassignment of district geologist Jones to Calcutta, India, in June 1955. He was succeeded by Greenman, who continued in that position through the end of the decade.

QUALITY OF WATER BRANCH

By Norman H. Beamer and Walter F. White, Jr.

District headquarters remained in Philadelphia during the entire decade, having been established in September 1946 when N.H. Beamer transferred from Branch headquarters in Washington, D.C., to Philadelphia where, as chemist-in-charge, he set up a laboratory at the city's Northeast Sewage Disposal Plant. Beamer reported to W.F. White, whose regional responsibilities as staff official of the branch chief included that of serving as district chemist for Pennsylvania. Beamer succeeded White as district chemist in 1953 and continued as such through the end of the decade. The laboratory and staff moved to quarters in "temporary building 720" at the U.S. Naval Shipyard in 1948. This space proved to be inadequate as the program expanded and was in an inconvenient location that had security problems. Learning that the former Panama Canal testing laboratory in nearby Jenkintown was available and had adequate facilities, Beamer made arrangements with the authorities, and the District office moved there in 1952 until such time promised space in the U.S. Custom House in Philadelphia became available. The Panama Canal Company was paid a token $1,000 for use of the completely equipped lab. In 1955, the District office moved to the Custom House in space vacated by the Corps of Engineers and established a modern laboratory.

The headquarters staff varied from 6 to 21 employees. In addition to determining complete and partial analyses, the chemists and technicians were responsible for establishing sampling and monitoring stations. Samples were received not only from projects in Pennsylvania, Delaware, and New Jersey (which were part of the Philadelphia District), but from project work in other States when their local laboratory facilities were overloaded. District programs in Delaware and New Jersey are described under those States. The District laboratory became one of the most modern of such facilities in the Geological Survey and was the first to use an atomic absorption spectrometer for metal analysis.

The senior personnel on duty at District headquarters for extended periods included M.J. McGonigle (from

1948); E.F. McCarren (from 1949); C.N. Durfor (from 1952); and David McCartney (a former New Mexico SW Branch employee, from 1956). W.B. Keighton, head of the Chemistry Department of Swarthmore College, served from 1951 as a part-time member of the District staff. Ms. C.M. Casey began a long period as district administrative clerk in 1951.

A field headquarters was established in October 1947 in Schuylkill Haven, the most advantageous location from which to conduct the Schuylkill River investigation described below. C.F. Lindholm, who transferred from the Iowa District in October 1947, was engineer-in-charge and reported to W.F. White in Washington, D.C. In 1951, Lindholm was succeeded by J.P. Eiler who remained until 1955 when he transferred to the Willow Grove Naval Station. J.K. Culbertson, from the New Mexico District staff, succeeded Eiler and remained until the Schuylkill project was completed. The field headquarters closed in 1956. The staff ranged from 6 to 11 persons during the life of the project. Culbertson and some of his staff (including A.B. Commings, N.L. Hawley, H.H. Leymeister, and A.A. Spotts) transferred to Harrisburg in 1956 to establish a field sediment laboratory at 100 North Cameron Street.

The primary financial support for the Pennsylvania program came through State and municipal cooperation. Agencies included the State Planning Board of the Department of Commerce, a cooperator since 1944 (Follansbee, v. IV, p. 372), the Department of Forests and Waters, the Pennsylvania Department of Agriculture, and the city of Philadelphia. Special recognition should be given to the assistance and encouragement given to the District by the late "Sam" Baxter, Philadelphia Water Commissioner and a cooperating official. Baxter, a nationwide leader in water-supply and sanitary-engineering fields and professional organizations, took a personal and helpful interest in District projects, particularly in instrumentation research and intepretive studies and reports of the Delaware River basin and estuary.

Support also was received from the Corps of Engineers and the U.S. Air Force. Some funds were allocated from the Division's Federal program appropriation for specific purposes. Brief descriptions of major projects and reports by the District during the decade are given below.

Two networks of stream-sampling stations were operated by District staff during the decade, one in which the samples were analyzed for chemical quality and the other for transport of fluvial sediments. White reported (in response to a WRD circular dated June 11, 1951) that daily chemical-quality samples were at the time collected at six sites with periodic sampling at an additional 22 locations. Program statistics for fiscal year 1958 showed the number of such stations to be 18 and 61, respectively. The sediment stations, according to the same information sources, were 14 daily and 15 periodic in 1951, and 10 daily and 25 periodic in 1958.

Early in the decade, an investigation of the sediment and chemical quality of the Schuylkill River and its tributaries was begun in cooperation with the Department of Forests and Waters. The sediments were largely coal residues (culm) deposited during more than a century of anthracite mining operations in the headwaters of the basin. The findings, initially reported by White and Lindholm in 1950 and published by the Department of Forests and Waters, were used in the design of desilting basins needed in the Corps of Engineers dredging activities and in the determination of the industrial utility of the waters in the basin.

From 1954 through the end of the decade, the District became involved with automatic, continuous water-quality monitoring instrumentation. McCartney was assigned to the testing, application, and installation of these monitoring devices and, with the district chemist, prepared several papers on monitoring that were presented at national American Water Works Association meetings. By 1960, District personnel had developed a monitor that could continuously record temperature, dissolved oxygen, pH, specific conductance, and turbidity. (The work in Philadelphia was the forerunner of the Instrumentation Group under G.F. Smoot and the much enlarged Instrumentation Development Laboratory that now includes water-quality monitoring instrumentation.) These monitors were used largely to identify and confirm hydraulic and hydrologic factors affecting the movement of salinity and pollutants in the Delaware estuary from Trenton downstream to the Delaware Memorial Bridge. It was the first known use of such instrumentation in estuarine studies. The project was conducted in cooperation with the city of Philadelphia Water Department, the Delaware Geological Survey, and the Delaware River Master. The findings were first summarized by Bernard Cohen and W.B. Keighton in a 1957 USGS Open-File Report; they were later published as WSP 1262 in 1955.

Commonwealth of Puerto Rico

No water-resources investigations were conducted by the Division during the decade. C.L. McGuinness, who had made a reconnaissance of the Island's ground-water resources in cooperation with the Puerto Rico Aqueduct and Sewer Service, completed his field work in 1946 (Follansbee, v. IV, p. 219, 315). He did visit Puerto Rico in 1949, enroute from the Virgin Islands to Washington, D.C., to observe the program of drilling for water for public supplies by the Aqueduct and Sewer Authority (WRD Bull., August 1949).

R.L. Nace recalls (written commun., 1982) that "Senor Quiñones, from the Puerto Rico Water Resources

Authority, visited [A.N.] Nelson Sayre in the Ground Water Branch (I think this was early in 1957). He was seeking a co-op study of the ground-water resources of Puerto Rico. I was called into the discussion and I questioned the wisdom of studying only ground water.'' Nace, then associate chief hydrologist, spent 6 days in Puerto Rico during which a ''comprehensive plan was worked out'' with the relatively new Water Resources Commission toward the reestablishment of cooperation. As the principal agent for the Commonwealth, the Water Resources Authority also was represented in these negotiations with the Survey, as was the Aqueduct and Sewer Authority, the Industrial Development Company, and the Puerto Rico Legislature.

In keeping with plans for an eventual reorganization of field activities of the Division, Nace recommended that the new Caribbean District be under the direction of a single district chief whose staff would represent the disciplines of the several branches. Such a District was activated late in 1957 with the designation of D.B. Bogart as district chief, one of the first of the ''consolidated'' districts that were established nationwide in the mid-1960's. The term ''Caribbean'' was specified to include the U.S. Virgin Islands as well.

Rhode Island

SURFACE WATER BRANCH

The Rhode Island program was conducted by personnel assigned to and headquartered at the Boston District. The activity was almost exclusively devoted to operation of a network of 10 gaging stations from which daily-discharge records were calculated and published. As of 1958, shortly after the end of the decade, eight of those stations were funded under cooperation with the Rhode Island Department of Public Works, with the remaining two funded by allocation from the Federal program. Periodic measurements of water temperature were made at four of the stations. So far as is known, any special studies of the surface-water records of Rhode Island were made as a part of a District-wide effort and described in the Massachusetts statement.

GROUND WATER BRANCH

By William B. Allen

During and immediately after World War II, reconnaissance ground-water studies conducted in the greater Providence area indicated the availability of plentiful ground-water supplies. As a result of these studies, several State agencies in 1947 asked the Geological Survey to start a statewide cooperative survey of ground-water conditions. State agencies that became involved were the Rhode Island Industrial Commission (1947–48), the Rhode Island Port and Industrial Commission (1949–50), and the Rhode Island Development Council (1951–57). Matching funds for studies grew from an estimated State contribution of $2,500 in 1947 to about $32,000 in 1957.

A Subdistrict office was maintained in Providence in the Customs House (1947–50) and in the Post Office Annex (1950–57). W.B. Allen was in charge. W.H. Bierschenk, D.J. Ryan, and R.A. Mason assisted in field work and report preparation. The Subdistrict office was a part of the New York-New England District. From 1947 to 1950, work was under the general direction of H.N. Halberg in Boston; from 1950 to 1956, work was directed by J.E. Upson and by G.C. Taylor in 1957, both located in Mineola, N.Y.

At the beginning of the decade, ground-water and geological studies were being conducted in the same areas. Geological work was under the direction of A.W. Quinn, professor of geology at Brown University. The plan of study was for statewide coverage using Geological Survey 7½-minute topographic maps as a base. A quadrangle report consisted of three parts—surficial geology, bedrock geology, and ground-water resources. Combined reports for the Pawtucket and Georgiaville quadrangles were published in 1948 and 1951, respectively. A similar type of report for the city of Woonsocket was published in 1950. Difficulties of coordination, publication, and a clamor for immediate ground-water data resulted in separate reports for the Bristol quadrangle (1954), the East Greenwich quadrangle (1956), and the Kingston quadrangle (1956). From 1955 through 1957, manuscript ground-water reports were prepared for the Coventry-Oreco quadrangle, the Fall River quadrangle (partly in Rhode Island), the Crompton quadrangle, and the East Providence quadrangle. These reports were unpublished, but their data were included in a new series of ground-water maps published in the following decade and were designed to further speed up statewide coverage. In 1953, a statewide ground-water reconnaissance report with a section on surface water was published. In 1957, a new series of State Hydrologic Bulletins was initiated to include information on water levels starting with 1956. A number of special studies and progress reports were made during the decade. These included Mashapaug Pond (1948); Exeter School (1948); north-central Cranston (1950); additional water supplies studies (1953); and yield of rock wells (1953). It should be noted that most of the reports referred to were published by the State cooperating agencies.

QUALITY OF WATER BRANCH

Water-quality studies in Rhode Island were under the direction of F.H. Pauszek, district chemist, New York-New England, Albany, N.Y. These studies were conducted as part of the cooperative programs established by

the SW and GW Branches with State agencies. Water samples were collected by local SW and GW personnel, and analyses were made in the QW Laboratory in Albany.

South Carolina

SURFACE WATER BRANCH

By Woodrow W. Evett

An appraisal of the activities of the South Carolina District in the mid-1950's indicates a program geared mostly to the collection and publication of basic streamflow data. Because of the relatively short period as a separate District (since 1930), emphasis had been placed on establishing a gaging-station network for the entire State. Many of the station stage-discharge ratings remained undefined for floodflow and low flows.

During 1947–57, District headquarters was located at 207 Creason building in Columbia. All field and office activites were conducted from this location. A.E. Johnson continued as district engineer, and four of the staff, F.W. Wagener, W.W. Evett, L.L. Finley, and W.T. Utter, served for the entire period. R.W. Lamson and E.D. Felder were assigned to the District for several years in the early 1950's. F.A. Johnson and W.M. Bloxham joined the staff in 1954.

Federal-State cooperative programs formed the financial backbone of the District. Cooperative programs with the State Highway Department, the State Public Service Authority, and the State Research Planning and Development Board continued. Also cooperating were the city of Spartanburg and, to a lesser extent, the town of Duncan.

In 1952, a significant program was begun with the newly created State Water Pollution Control Authority (WPCA). South Carolina was one of the first States to come to grips with the growing problem of stream pollution. With the establishment of the new authority by the legislature, a clean-up of the rivers and reservoirs in the State began in earnest.

Under the cooperative program signed in 1952, WPCA personnel were responsible for all sampling, laboratory analysis, and contacts with those responsible for creating the problems. District personnel were responsible for determining stream discharge, time-of-travel of pollutants downstream, and water temperature. Data from the existing network of gaging stations were used extensively. To fully conduct the program, however, it was necessary to design, fabricate, and install portable automatic-recording streamflow gages, weirs, and flumes to accurately measure small streams and canals. Early results from the program made South Carolina a pioneer in the classification of streams for domestic water uses, as well as the enforcement of maximum-allowable pollution-control standards for discharge into streams. The work conducted by the WPCA resulted in the reclamation of many South Carolina streams that were formerly unsafe for domestic use. Evett was assigned to the project to conduct the field investigations, prepare reports, and supply information to the WPCA.

The Corps of Engineers, U.S. Navy, Atomic Energy Commission (Charleston), and the U.S. Soil Conservation Service (SCS) provided funds for the maintenance and operation of stream-gaging stations and the special studies required for their planning and operational projects. A tidal-flow gaging station was installed and operated for several years for the U.S. Navy.

The program with the Atomic Energy Commission required the collection of runoff data on small streams that drain the area encompassing the Atomic Energy Plant at Aiken. Also included were periodic water-temperature and velocity-distribution studies based on field investigations at several discharge outfalls from the plant. The resulting reports had national security classification. The techniques used in collecting the required field data and the use of these data for the special reports were developed by Wagener.

During the mid-1950's, the SCS was advocating the construction of small flood-retarding structures to alleviate extensive overbank flooding in the river reaches below the dams. The reservoirs also would be used as a source of water for stock, irrigation, and recreation. Two demonstration structures were built by the SCS on Rices Creek in the Twelvemile Creek demonstration area. Under the program, District staff secured and installed rainfall and stream-gaging equipment at these structures. Crest-stage gages were installed at a number of points along the stream below these structures to document the downstream flood profiles. Numerous discharge measurements were made at these structures to verify the theoretical ratings for the design of each structure. Rainfall-runoff studies were conducted for all floods above a given base. The SCS used these studies to evaluate the effectiveness of the design.

An extensive effort was made in working up the South Carolina segment of the nationwide compilation report for available streamflow records up to and including the 1950 water year. Station rating curves were studied and refined on the basis of the latest information available. Many fragmentary gage records collected in earlier years at the same locations as current stations were recomputed and gaps filled in, thus increasing the "total years of record." Prior to publication of the 1950 compilation report, a report entitled "Surface Water Supply of South Carolina" that presented monthly and yearly discharge was published in two volumes by the South Carolina Research Planning and Development Board.

Unusual Hydrologic Events

South Carolina is blessed with generally adequate rainfall. Mean annual runoff varies little from year to year. Major floods can occur, however, as a result of tropical storms spawned in the South Atlantic and the Gulf of Mexico that move onto the mainland. During the hurricane season, moderate to major flooding may occur over most of the State, with the highest peaks in the upper Piedmont region. During this decade, however, no major floods of record occurred.

Drought conditions are usually limited to short periods of a few months when rainfall is deficient to the extent that streamflow diminishes to critical low flows. During the decade, however, the worst drought of record occurred when the trend of deficient rainfall began during 1951 and continued to October 1954. Numerous small cities and towns had critical water shortages during summer 1954. The District made hundreds of low-flow measurements on ungaged streams. In 1954, an effort was made to document the points of zero flow at most bridge crossings in the State. Also, many domestic water-supply systems, especially for cities using small streams as a water-supply source, were surveyed.

Summary

The South Carolina District experienced significant change during the 1947–57 decade. During the early years after the District was established, major emphasis was placed on the collection and publication of basic streamflow data. The limited staff in those years had little time for special programs and reports. Planning, selection of programs, and interpretation of field data were conducted by the district engineer, and very little authority was delegated to the staff.

Programs of the cooperating State agencies expanded during the postwar period. Their requirements for water data increased and became more specialized. This required the District staff to provide information not found in regular streamflow records. As the staff increased, responsibility for implementing new projects was delegated to staff members.

A.E. Johnson, district engineer since the District was established, was well known in engineering circles. He had served as secretary-treasurer of the South Carolina Society of Engineers and the South Carolina Section of the ASCE for many years. In this capacity, he served with highly qualified engineers from all sections of the State. Through these connections, he established good will between the Survey and State agencies that has continued into the 1980's.

GROUND WATER BRANCH

By George E. Siple

In September 1945, A.E. Johnson, G.L. Parker, and M.J. Mundorff of the USGS and representatives of the South Carolina Research, Planning, and Development Board initiated a cooperative program for ground-water investigations in South Carolina. G.E. Siple transferred from the Geologic Division to the GW Branch and began field work in October 1945. No previous systematic ground-water studies had been made in the State. Thus, the first priority was to obtain basic knowledge of the geology and hydrology of the State through a study of the ground-water resources used by municipalities, industries, and military installations. Findings were published in 1947 as State Bulletin 15, "Ground Water Investigations in South Carolina." The report identified the major geologic units and aquifers within the Piedmont and the Coastal Plain, and included a definition of the surface extent and subsurface structure of formations in the Coastal Plain as well as the yield and water quality of these aquifers.

From 1945 to 1950, Siple was the only Branch employee working in the South Carolina program. During this period, the headquarters for the program was located in Raleigh, N.C. In 1952, the South Carolina program was given District status and Siple was appointed district geologist. Space for the District headquarters was provided by the University of South Carolina on Bull Street in Columbia. The first additional professional person to be hired was R.W. Jones in 1952. He was assigned principally to a field headquarters at the Savannah River Plant of the Atomic Energy Commission (AEC) in Aiken, but resigned in 1955 to resume graduate training. AEC funding in 1951 for investigations at their sites in Aiken and in Barnwell Counties, together with funding by the U.S. Navy for ground-water studies at the Parris Island Marine Base in Beaufort County, enabled the District to be self-supporting. Previously, because of insufficient funding for South Carolina ($2,000), Siple, in different fiscal years, assisted Mundorff on a study of alluvial water supplies for Elizabeth City, N.C. During several months in 1947–48, Siple assisted in a test-drilling project in Memphis for the Tennessee District and prepared a report on the results.

In 1950, the South Carolina progam concentrated on more studies of the geology and hydrology of the Coastal Plain, the potential alluvial aquifers in the flood plains of major streams in the Piedmont, and on-site reports for potential industrial development. In addition, an observation-well monitoring program was initiated and maintained throughout the State. Some reports released during this time, in addition to Bulletin 15, included "Memorandum on Ground-Water Conditions at Elizabeth City, North Carolina," Open-File Report, 1948; "Memorandum on Ground-Water Supply in Resources of South Carolina," South Carolina Development Board, Bulletin 22, 1955; and "Memorandum on Ground-Water Conditions in the Savannah Area, Georgia-South Carolina," Open-File Report, 1948.

The study supported by AEC funds in Aiken and Barnwell Counties involved intensive test-well drilling,

geophysical logging, surface geophysical surveys, aquifer tests, and additional advanced procedures in the determination of the hydrologic regimen of the area. The first report on this project, "Geology and Ground-Water Conditions in Parts of Aiken, Barnwell, and Allendale Counties, South Carolina," Open-File Report, 1957, contained many innovative ideas concerning the interpretation and evaluation of an artesian system, and reflected the counsel and advice of C.V. Theis and H.H. Cooper, Jr. One of the more significant contributions concerned recharge-discharge relations along a major drainage system typical of conditions throughout the Atlantic Coastal Plain. It was perhaps the first report to demonstrate, contrary to previous reports and textbook illustrations, that the outcrop area of major artesian aquifers along the Fall Line of the Atlantic Coastal Plain constituted areas of discharge rather than those of recharge.

The study in Beaufort and Jasper Counties during 1954–58 concerned the integrity of the shallow Eocene limestone as a source of freshwater for the Marine Depot, Hospital, and Marine Air Base, particularly during times of mobilization requiring heavy water demands. The first report, "Memorandum on the Geology and Ground Water Resources of the Parris Island Area, South Carolina," Open-File Report, 1956, identified the aquifer thickness, potentiometric surface, transmissive and storge coefficients, tidal effect, and present and potential extent of saltwater contamination. It was the first report to identify a domal structure in the Eocene limestone in the vicinity of Beaufort.

Additional reports prepared in the interval include "Ground-Water Studies in South Carolina," in 1957, published by the South Carolina Division of Geology; "Ground-Water in the South Carolina Coastal Plain," in 1957, published in the Journal of the American Water Works Association; and the "Guidebook for the South Carolina Coastal Plain Field Trip of the Carolina Geological Society," November 1957, published as Bulletin 24 by the South Carolina Division of Geology (now the South Carolina Geological Survey). This report contained a number of novel interpretations of the structure and geology of the Coastal Plain and has remained a very useful reference on the stratigraphy of the Coastal Plain to the present time (1982).

R.E. Taylor, geologist, was assigned to the District in 1956, but was on duty only a few months before entering military service. Hydrologic field assistants were recruited from the Geology Department of the Unversity of South Carolina for part-time duty during 1952–57.

QUALITY OF WATER BRANCH

By Felix H. Pauszek

The program of South Carolina was under the jurisdiction of the Raleigh, N.C., District during the decade. In 1945, a modest water-quality program was established in cooperation with the Research, Planning, and Development Board. In this endeavor, A.E. Johnson, district engineer, SW Branch, was most helpful in arranging meetings with State officials. The program consisted of operating stations on the Lynches River near Bishopville, 1945–46; Saluda River at Chapells, 1946–47; and Wateree River near Camden, 1946–47. At the stations, daily samples were collected and temperature measurements were made. The samples were then composited over a 10-day period and analyzed for their chemical content. During 1947–48, monthly sampling stations were operated on the Broad River near Carlisle, Enoree River near Enoree, and North Fork Edisto River at Orangeburg. Three stations were operated from 1948 to 1949 on the Congaree River at Columbia, North Tyger River near Moore, and Pee Dee River at Pee Dee. During 1949–50, stations were operated on the Broad River near Gaffney, the Edisto River near Branchville, and the Savannah River at Augusta, Ga. Water samples were collected on a monthly basis and analyzed in the laboratory.

In addition to the samples taken from the stations above, single samples were collected throughout the river basins for a wider assessment of water quality. In support of the ground-water studies in South Carolina, water samples were collected by GW Branch personnel and analyzed by QW Branch personnel. In cooperation with the armed services, analyses were made of water supplies at military bases and results were sent to the base concerned. A study was also conducted for the Navy during 1951–56 to determine the extent of saltwater movement upstream in the lower Combahu River, which was being considered for a supplementary source of water supply for the Marine Base at Beaufort.

Generally, the mineral content of most surface water in the State was satisfactory for most domestic and industrial uses. If the requirement was more stringent, some treatment was necessary. Concentrations of iron and color in some waters, both surface and ground, required treatment for removal.

The water-quality program in South Carolina was under the immediate supervision of district chemist W.L. Lamar, 1947–48; F.H. Pauszek, 1948–52; and G.A. Billingsley, 1953 on. Laboratory work was conducted by B.F. Joyner, K.F. Harris, and Evelyn Holloman. A.E. Johnson furnished the stream-discharge data needed in water-quality studies.

The water-quality records of streams were published periodically by the Research, Planning, and Development Board through its Bulletin series and under the heading "Chemical Character of Surface Waters of South Carolina." Bulletin 16 (1945–47) was by W.L. Lamar; Bulletin 16A (1945–50) was by F.H. Pauszek; Bulletin 16B (1945–55) was by G.A. Billingsley; and Bulletin 16C (1962) was prepared by K.F. Harris. These

records also were published in the annual series of Geological Survey Water-Supply Papers entitled "Quality of Surface Waters of the United States—Parts 1–4." Selected records were also incorporated in WSP 1299, "The Industrial Utility of Public Water Supplies in the United States, 1952, Part I, States East of the Mississippi River," by E.W. Lohr and S.K. Love, 1954.

South Dakota

SURFACE WATER BRANCH

By Kenneth I. Darmer

The program in South Dakota was administered from the District headquarters at Bismarck, N. Dak., during the decade, with operations handled out of the Subdistrict office at Pierre. The latter was located at 101½ South Pierre Street until 1948 and in the Federal building thereafter. A field headquarters was maintained at Rapid City during the entire period. A two-man headquarters was started at Yankton in 1953 and, from 1951 to 1953, one person was stationed at Pickstown. Of the 10 to 15 personnel usually engaged in the South Dakota program, about 7 to 11 were normally at the Subdistrict headquarters. The staff at Rapid City varied from two to five in number.

W.M. Littlefield was in charge of the Subdistrict until 1951 when he transferred to the Los Angeles Subdistrict in California. He was succeeded by K.I. Darmer. During the latter part of the decade, Darmer's senior headquarters staff included G.G. Jamison and R.E. West. D.E. Quinney was in charge of the Rapid City field headquarters until 1947 when he resigned. He was succeeded by L.J. Snell who transferred from the Pierre Subdistrict staff and remained until 1952 when he took an assignment in Afghanistan. L.B. Yarger then assumed charge for the remainder of the period. A.A. McCollam, who transferred from the Rapid City field headquarters, was responsible for the activities from the Yankton headquarters, and K.R. Dorman for work conducted from Pickstown.

The program was geared primarily to the data needs of the Missouri River basin program and the design and construction activities of the Bureau of Reclamation and the Corps of Engineers. These programs were comprised of the construction of a series of mainstem Missouri River reservoirs and projects on several of the major tributary streams in South Dakota. The feasibility of irrigation from these projects was of particular interest in the semiarid areas of the State.

During this decade, the State cooperative program developed substantially, in part because of the establishment of a State Water Resources Commission with a technical operating staff. This support made it possible to establish data-collection sites designed to improve the areal hydrologic information base for the State.

The gaging station on the Missouri River below Fort Randall Dam presented some interesting operating challenges. A cableway with a span of 2,040 feet (the longest to be constructed by the Geological Survey at that time) was built in an area accessible only by "fair weather" trails. Access to the cableway and gage for discharge measurements was usually by boat from the Fort Randall Dam site. These boat trips were often made under rugged wind and temperature conditions. Round-the-clock discharge measurements at the cableway and of a diversion channel at the dam site were made to document the effectiveness of the Corps of Engineers' hydraulic-fill method of dam closure.

The April 1952 floods on the Missouri River and many of its tributaries were the greatest in memory. Highway overflows restricted access to many gages even when four-wheel drive vehicles were used. Combined bridge and boat measurements were commonly required to measure this great flood. Peak flows were measured at most stations, and they served as a basis for reevaluation of the spillway design for the Missouri River dam projects. The Survey office was called on throughout the flood for timely information on the progress of the flood and the likely need for evaluation of flood protection measures.

The difficulty encountered in designing highway culverts led to a cooperative program with the South Dakota Department of Highways. Some 60 crest-stage gages were installed at carefully selected sites to reflect the variety of hydrologic situations commonly encountered in culvert design. In addition, storms of severe intensity were investigated to document extreme-runoff occurrences, usually the result of a summer thunderstorm.

Much of the stream gaging in the Black Hills was in response to the need for irrigation water. The loss of surface water from the mountain streams as it passed over a limestone formation was evaluated by operation of gaging stations both above and below the loss zone on several streams.

(In forwarding his manuscript, Darmer conveyed the following additional and noteworthy recollections by letter dated May 31, 1982: "From our viewpoint today, of course, the program was rather limited. It was a real struggle, however, to get support for even a 'bare-bones' data program. The operational problems were often difficult—roads were inadequate in places. Ice measurements of the Missouri River were often treacherous. I suppose we took too many chances but were fortunate not to have any fatal mishaps. The USGS was looked upon as *the* source of flood and drought information in South Dakota. The Weather Bureau and Corps offices were out-of-State, so we were 'on the scene' and tried to fill that

need. It was interesting, too, that the population of South Dakota was small, and Pierre was a small Capital city. We knew the State officials, including the Governors, on a social basis (at the grocery store, church, Lions Club) so it was a situation far different from the one I met later in New York. We had a staff of people that were a real team. They worked hard and long, and I can't recall many grumbles when I had to ask them for some onerous task such as weekend work. Overtime wasn't known then.'')

GROUND WATER BRANCH

Condensed from documentation by G.A. LaRocque, Jr.

No personnel were stationed in the State until 1949 when an area office was established in Huron and a one-man field headquarters at Rapid City. Both were under the Missouri River basin program and under the jurisdiction of G.A. LaRocque, Jr., the district engineer in Bismarck, N. Dak., who, in turn, was under the regional engineer in Lincoln, Nebr. Investigations in South Dakota relative to the Missouri River basin program had been started in 1945 by G.A. Waring, who was on detail to the Bismarck District from the Washington, D.C., and Regional offices, and continued until he retired in 1948. The Rapid City headquarters, established in 1949, closed in 1951. The Huron office staff varied from two to about seven persons. C.B. Simmons, initially in charge, was succeeded by LaRocque in 1952 when the latter moved his District headquarters from Bismarck. The new Huron District reported directly to the branch chief and became responsible for all Branch programs in South Dakota. J.R. Jones succeeded LaRocque in 1953 after LaRocque took an assignment in Pakistan. A.J. Rosier maintained the Rapid City headquarters from 1949 until 1951 when he transferred to Bozeman, Mont.

During the decade, many other engineers and geologists were assigned to District headquarters and its Rapid City suboffice. A partial list of those assigned or detailed to South Dakota, together with the projects with which they were associated follows: C.B. Simmons, 1950–53 (Oahe-James); E.D. Jenkins, 1950–52 (Oahe-James); F.C. Koopman, 1951–56 (Oahe-James; Brown and Marshall Counties); K.E. Vanlier, 1952–55 (Oahe-James); W.H. Bush, 1950 (Oahe-James); W.B. Hopkins, 1956 (Eastern S. Dak.); R.W. Maclay, 1950–51 (Cheyenne and Standing Rock Indian Reservations); A.J. Rosier, 1950–51 (Rapid Valley and Belle Fourche irrigation project area); P.C. Tychsen, 1948 (lower Grand River); and R.C. Vorhis, 1949–50 (lower Grand River). The administrative services functions at Huron were provided by Ms. E.V. Hanson who transferred from Bismarck to Huron in 1952 with the relocation of District headquarters. She later transferred to Boise, Idaho.

Initially, the Huron office was responsible only for Federally-financed ground-water investigations directly related to the development of the Missouri River basin surface-water resources. In spring 1953, talks and correspondence were exchanged with the South Dakota State Engineer's office regarding the possibility of implementing a program of cooperative ground-water investigatons. As stated later, an agreement for a cooperative program was finally reached about 1957, but with the South Dakota Water Resources Commission.

In the Oahe-James area, the U.S. Bureau of Reclamation conducted many of the physical investigations—geophysical surveys, test drilling, installation of pumps and observation wells, and operations of pumping equipment for aquifer tests. Within South Dakota, there was unnecessary concern about what effect backwater from the Fort Randall and Oahe Dams would have on flowing wells located in the to-be-drowned floodplain of the Missouri River. The Corps of Engineers plugged several of the locatable wells and in the process lost one rotary drilling rig. Plugging of the wells, particularly in the Fort Randall reservoir area in the vicinity of Chamberlin, was both physically and hydrologically unnecessary because reservoir levels for many wells were higher than static or shut-in pressures and, for other wells, would greatly diminish their flows.

Public and press relations were friendly and constructive. The *Huron Daily Plainsman* was most supportive and interested in all phases of ground-water investigations in South Dakota. Their editor, quite ''water conscious,'' gave extensive coverage to Geological Survey releases and District projects. In South Dakota, water consciousness was closely related to drought severity. Two years of sustained drought usually brought increased cooperative funding from the legislature.

J.R. Jones recalls (oral commun., 1982) that, from the time of his arrival in 1953 and through the balance of the decade, the District staff was heavily engaged in the ground-water aspects of the Oahe-James project, a part of the MRB program, and they worked closely with the Bureau of Reclamation's Huron office. Other activities during the balance of the decade included operation of the Federal observation-well program and small studies for the National Park Service. Very late in the decade, an investigation of water-supply sources on the Pine Ridge Indian Reservation was begun for the Public Health Service. The first State cooperative project of the South Dakota District was a statewide investigation of artesian aquifers that started about 1957 after the South Dakota Water Resources Commission was established. Follansbee (v. IV, p. 209) states that cooperation with the State geologist ended in fiscal year 1945 when Missouri River basin funds became available to the District.

Recollections furnished by F.C. Koopman (written commun., 1983) include the following:

- The agricultural community benefited greatly from irrigation and drainage studies mainly to the north and northwest of Huron. "When we prospected for coarse-grained material (kames) under the glacial clays (till), we found quite a few areas where farmers were able to install irrigation wells."
- The District "was instrumental in getting reverse-rotary drilling started, despite initial objection from local drillers. This permitted the development of large diameter shallow wells for irrigation."
- The geophysical logging of the deeper wells in the artesian-type Dakota Sandstone in several counties around eastern South Dakota during November–December 1956 with a truck-mounted rig furnished by the Denver Hydrologic Laboratory was interesting but rugged. With 20- to 30-foot mounds of ice surrounding many of the "spraying" wells, "I used ladders borrowed from local fire departments to get to the top of some of them and made a 'ram' to batter a hole down to ground surface—and was fortunate in several instances in finding the well aperture so that we could log it."
- The many long hours the staff spent "trying to unravel the mystery of well hydraulics and drainage" was worth it in terms of knowledge gained. It was made a more pleasant experience largely because of the working environment established by LaRocque.

QUALITY OF WATER BRANCH

By Russell H. Langford

An area office at Rapid City was established in 1950 under the jurisdiction of the Regional office at Lincoln, Nebr. It was supported by Missouri River basin program funds and its personnel conducted the water-quality studies required in the part of the basin that lay in South Dakota. The office was under the initial supervision of J.M. Stow who arrived from the Dickinson office in North Dakota; Stow transferred to the Albuquerque District in 1953. He was succeeded by A.R. Gustafson who continued in charge for the balance of the period. Other senior members of the staff included O.J. Ramsvick (1951–54), R.P. Orth (1951–1953), and D.E. Sloan (1951–1953).

Some of the Branch projects in South Dakota were also conducted directly by members of the Lincoln staff. Extensive work in the field and laboratory was conducted in close cooperation with the GW Branch staff in Huron on the Oahe unit area of east-central South Dakota to help the Bureau of Reclamation in planning diversions from Lake Oahe to lands in the James River basin to the east. Several members of the staff worked closely with the GW Branch personnel in studies of the geology and ground-water resources of the lower Grand River valley (WSP 1298, E.R. Jochens, 1955), the lower Niobrara River and Ponca Creek basins (WSP 1460-G, R.A. Krieger, 1959), and the Angostura irrigation project (Circ. 54, H.A. Swenson, 1949). In addition, members of the Lincoln staff prepared summary reports of the chemical quality and sediment characteristics of streams in the Grand River basin of North and South Dakota (WSP 1769, C.H. Hembree, R.A. Krieger, and P.R. Jordan, 1964) and in the Moreau River basin (Circ. 270, B.R. Colby, C.H. Hembree, and E.R. Jochens, 1953).

TENNESSEE

SURFACE WATER BRANCH

By Milburn Hassler

The District headquarters was located in the Chattanooga Post Office building until 1955, when it moved two blocks south to the Edney building. The district engineer, F.M. Bell, left to take charge of the Denver District in 1948, and was replaced by W.R. Eaton who was previously district engineer of the Louisiana District. In 1954, J.W. Gambrell, also from the Louisiana District, transferred to Chattanooga to serve as assistant district engineer. In the years 1947–49, field headquarters were located in Jackson with G.H. Wood in charge and in Lebanon with W.J. Perry in charge. These two field headquarters were combined in 1950 to form an area office in Nashville with Perry as engineer-in-charge. The staff in Nashville grew from two to six by 1957. Another area office in Knoxville, established in 1947, grew from three to six people by 1956. M.F. Cook was engineer-in-charge until his transfer to the Louisiana District in 1953; he was succeeded by E.P. Mathews. In 1956, an area office was established at District headquarters in Chattanooga with six assigned people and Milburn Hassler engineer-in-charge. C.T. Jenkins was assigned to the District office in 1954 to head a special project supported cooperatively by the Tennessee Department of Highways. A field unit of the special reports and investigations section was established in the District office in 1953; it's personnel reported to the Branch chief and were headed by P.R. Speer.

Other members of the staff included C.E. McCashin, who had been district chief until 1941 (Follansbee, v. IV, p. 136) and who retired in 1953; J.M. Terry, who transferred to Colorado in 1952; Charles Wells; A.M.F. Johnson (from 1948); L.G. Conn; J.B. Swing;

P.M. Frye (1949–56); D.W. Ellis (1950–56); I.J. Hickenlooper (from 1954); J.M. Slaughter (1949–50; 1954–55); and T.J. Quarles, who served as district clerk during the decade.

District engineer Eaton also served as chief liaison officer between the Tennessee Valley Authority's hydraulic section and the Geological Survey District offices within the Tennessee River basin. He was the key member of the Tennessee WRD Council, and scheduled and prepared the agendas for most of the meetings. He also was the author of a Survey report published in 1955 entitled "Location of Gaging Stations in Tennessee District, and Delineation of Areas of Certain Annual 3-Day Minimum Discharges Occurring Once In 2 Years and Once in 10 Years."

Cooperation

The principal cooperator was the Tennessee Department of Conservation. The greatest portion of these funds were used for continuing the collection of streamflow records in western Tennessee, and for records on smaller streams in the Tennessee and Cumberland River basins. The State was primarily interested in small streams that were sources for municipal water supplies and outlets for sewage and industrial wastes.

In 1953, a new cooperative agreement was initiated with the State Department of Highways to investigate and report on selected hydrologic problems closely related to highway drainage and design. The leadership and supervision of this project was conducted by Jenkins, who later authored "Floods in Tennessee, Magnitude and Frequency." Jenkins was assisted by Hickenlooper beginning in 1955. The project involved establishing, servicing, and rating about 85 crest-stage gages in addition to making many indirect measurements of peak flow. Funds furnished by the Department of Health were primarily used for special measurements at various sites intended to calculate minimum flows.

The principal cooperator was the Tennessee Valley Authority (TVA) in the "Other Federal Agencies" program and, because of this, the District's operations depended largely on the requirements of this agency. One of the highest priorities was placed on flood measurements, and Mother Nature did her share by producing a number of record-breaking floods during the decade. Many high-water measurements were obtained at or near the flood crests because of early advance knowledge of the rainfall patterns obtained from TVA's hydraulic studies section, which, of course, obtained this information from their vast system of rainfall gages and telemarks, as well as from their forecasting section.

Funds furnished by the Corps of Engineers were used for continuing the collection of streamflow records in the Cumberland River basin. Funds furnished by the U.S. Air Force at the Arnold Engineering Development Center were used for the operation of two gaging stations on the Elk River and two more on its tributaries. To develop a rating for a variety of settings of the taintor gates, many additional discharge measurements were made by boat downstream from Elk River Dam. During the decade, the number of regular gaging stations in operation varied from year to year, but with a net change of only one station from 126 to 127.

Stream-Gaging Program

Condensed from documentation by A.M.F. Johnson

A number of special efforts that enhanced the coverage and accuracy of records from the stream-gaging network during the decade are historically noteworthy. One was the use of indirect peak-flow measurements where current meter measurements could not be made during the record-breaking 1948 floods that occurred throughout the State. Earlier floods had occured in 1946. Under the guidance of Hollister Johnson, on detail from the branch chief's staff, Charles Wells and A.M.F. Johnson developed special techniques for selecting, surveying with a minimum of brush clearing, and recording the needed slope, crest stage, and frictional values at a number of sites at which peak flows were calculated. This improved methodology was described in a manual and used by personnel of other districts. To augment this type of training, A.M.F. Johnson conducted several instructional sessions for newer professional employees.

The floods of March–April 1951 in Alabama and adjacent States (WSP 1227-A, 1953) required a major effort by the District staff, particularly because its station network included a large part (the Tennessee River basin) of northern Alabama. The design and construction of cableways also challenged the innovativeness of the District staff as illustrated by the following examples:

- Following the destruction of a swinging measuring bridge on the Ocoee River at Emf by the 1946 flood and because of the difficulty in making subsequent measurements by boat, a cableway was constructed at one of the few good gaging sites. This was a difficult undertaking because of a roadway along each bank. The right anchorage was a mass of concrete poured into a floodplain and the high, left bluff anchorage had rock of uncertain stability.
- An upgrading of the accuracy of measurements on the Hiwassee River, in response to large industrial water use, was accomplished by building another cableway in 1953, despite problems of possible settlement of anchorages and tower supports.

- A long-standing cableway on the Tennessee River at Florence, Ala., was pulled down by a crane being transported by boat. Liability for damage to the crane boom hinged on whether or not the cable had sagged from its prescribed clearance since it had been constructed. Scrutiny of measurement notes over the entire period revealed that cable clearance had not changed.
- Through a joint effort with the Kentucky District, a unique cableway was constructed on the Tennessee River just downstream from Kentucky Dam. The cable was lowered by winch to the channel bottom when not in use, which minimized hazards to river traffic.

Station maintenance had been held to a minimum because of shortages of men and materials during World War II. Later, as personnel returned from military service and construction materials became available, Perry headed a special project to upgrade station structures. In doing so, increased safety as well as reduction in future maintenance was considered. Wooden walkways, for example, were replaced by steel structures with railings. Once completed, responsibility for upkeep was returned to the field personnel assigned to operate the stations.

McCashin extended the useful life of many of the older weight-driven water-level recorders during the decade. He determined that frequent clock stoppages were due to seasonal differences between the torque delivered through the recorder to the clock and optimum torque for clock accuracy. He then devised a slotted nut to increase weight for cold-weather use and a calibrated, portable torque tester.

Special Projects

A number of special projects were also conducted during the period. Among them was the 1954 study of water use that focused on areas where future requirements might exceed the amounts measured in certain streams during the prolonged dry season in 1950. Particularly critical was Bradley County with its increased industrial and suburban water use. As a part of a joint effort with the GW Branch, A.M.F. Johnson conducted a 3-year investigation of flows and water quality of the county's larger springs. Results were documented in the Tennessee Division of Geology Bulletin 58 (pt. 1) published in 1958.

Two water-loss studies were conducted, one in a reach of the Duck River and the other at a dam on the Tennessee River. For some time prior to 1950, District personnel had been having trouble justifying the differences in daily discharge during certain periods as measured at the end of a 190-mile reach of the channel on Duck River between Shelbyville and Hurricane Mills. In September 1950, after a long dry season, personnel from several offices in the District made two coordinated series of discharge measurements at many points along the reach, and also of the inflow from all intermediate tributaries. The results showed conclusively that there was a significant loss to ground-water storage and that station discharge records were correct.

Leakage under Hales Bar Dam, a pre-TVA structure on the Tennessee River below Chattanooga, had been a source of concern since the dam was built. Various schemes to stop the leakage had been tried without success. By the mid-1950's, the variance between the Survey's discharge measurements at a bridge 1.4 miles downstream from the dam and the TVA powerhouse release records at the dam became too great to disregard. On a weekend when TVA could keep the powerplant out of operation and the Corps of Engineers could suspend operation of the navigation lock, the Chattanooga office put its entire male personnel (plus some people from the Hydraulic Data Branch of TVA) into service manning all available streamflow-measuring equipment. In addition to numerous discharge measurements, continuous single-point velocity observations were made at several points across the section, and vertical-velocity curves were measured at all points where discharge observations had been made. The results showed that between 1,200 and 1,800 cubic feet per second of water was leaking under the dam. Ultimately, TVA abandoned all attempts to stop the leakage at Hales Bar Dam and constructed a new dam (Nickajack) about 7 miles downstream.

The District's segment of the nationwide compilation of streamflow records through 1950, primarily by Wells and Johnson, was published in WSP's 1306 (1958) and 1311 (1955). Eaton prepared three reports, the first showing the locations at which streams were gaged, the second giving a summary of flow duration and low flow at station sites, and the third presenting low-flow frequency data. Although not published until 1955, 1958, and 1960 (in that order), the work on all three had been started during the decade. The methodology and tabular format, accomplished by hand prior to the computer era, was a pioneering effort that was adopted by other districts. Eaton's long experience in gaging Tennessee streams included his share of unique situations. He used to delight in telling new engineers how, early in his career, he had the distinction of measuring streamflow velocities in excess of 22 cubic feet per second while swinging from a cableway at Caney Fork near Rock Island!

GROUND WATER BRANCH

By Elliott M. Cushing

At the beginning of the decade, the only ground-water work in Tennessee was in the Memphis area in

cooperation with the Memphis Light, Gas, and Water Division, the municipally-owned utility. This work was primarily to define the subsurface geology and areal extent of the aquifers being used for the municipal and industrial water supplies, to measure water levels in wells, to collect pumpage data, and to correlate the fluctuations of water levels with the pumpage data.

In 1947, Major T.H. Allen, president of the Memphis utility, and H.B. Burwell, State geologist, worked with and through the Shelby County delegation to the State Legislature to obtain State funds for cooperative ground-water work throughout the State. The funds, shown as a separate item in the Governor's appropriations bill, amounted to $45,000 a year for the 1948–49 biennium. The State geologist was responsible for administering the funds. In the following biennia, funds for the State cooperative work were included in the State geologist's budget.

The first priority of the State cooperative program was to complete the reconnaissance ground-water studies of the State. Three such studies had been completed in the late 1920's and early 1930's with results published in WSP's 640 (1932), 656 (1933), and 677 (1936). Concurrently, detailed studies were to be made in selected areas of the State where development of additional ground-water supplies seemed imminent. To effectively accomplish the proposed State studies, Federal and State officials agreed that offices in Memphis, Nashville, and Knoxville would be ideal. The Memphis project office was designated District headquarters, and E.M. Cushing was named district engineer. A Subdistrict office was established in Knoxville in 1948 with G.D. DeBuchananne in charge, and a field headquarters in Nashville in 1949 with Roy Newcome, Jr., in charge. Work with the AEC at Oak Ridge began in 1948, and was conducted by Knoxville office personnel until 1954 when a field headquarters was established with Wallace deLaguna in charge.

In the 1948 fiscal year, the GW Branch matched only $25,000 of the $45,000 offered by the State. Actually, only $18,750 was matched because a 25-percent abeyance was imposed on all Water Resources Division cooperative matching funds that fiscal year. Because the State funds were a separate item in the Governor's appropriations bill, the State geologist received permission to offer all unmatched biennium funds in the 1949 fiscal year. As a result, the State offering for the 1949 fiscal year was more than $70,000, which the Branch matched. During this fiscal year, four test holes were drilled or started, three in the Coastal Plain sediments in west Tennessee, and the fourth in the Paleozoic sediments in middle Tennessee. All were completed as observation wells.

As a part of the reconnaissance study of the ground-water resources of eastern Tennessee, a base map of the area was compiled by Knoxville office personnel. Topographic maps, generally 7½-minute quadrangles, were available for most of the area. These were photographically reduced commercially to a scale of 1:125,000 and compiled into 14 maps. These 14 maps were used to plot the locations of the wells and springs inventoried for the ground-water study and also to compile the geology of eastern Tennessee. The geologic compilation was prepared by John Rodgers, Geologic Division, who was detailed to the GW Branch for this project. (See Tenn. Div. Geol. Bull. 58, pts. 1 and 2.)

Two detailed ground-water studies were conducted in eastern Tennessee. One was in the Cleveland area by G.D. Swingle (Tenn. Div. Geol. Bull. 61, 1959), and the other in the Elizabethton-Johnson City area by R.W. Maclay (WSP 1460-J, 1963). R.M. Richardson investigated the water problems in the zinc mines in the Jefferson City area (open-file, 1955) and concluded that most of the water in the mines was seepage from stream and drainage ditches as they crossed fault zones intersecting the mines. The management personnel of one small mine, which had about 1 million gallons of water a day pumped from it, built water-tight flumes over those reaches of its drainage ditch that crossed fault zones. The remedy was so effective that water had to be pumped into the mine for its normal operation.

Reconnaissance studies in middle Tennessee included those pertaining to ground water in the central basin by Roy Newcome, Jr., (Tenn. Div. Geol. Report Inv. 4, 1958) and ground-water resources of the Cumberland Plateau by Newcome and Ollie Smith, Jr. (Tenn. Div. Water Res. Series 1, 1958), a State employee working on the cooperative program. Newcome also prepared several structure-contour maps showing the tops of key marker beds in middle Tennessee as an aid in predicting the depths to which wells would have to be drilled to obtain water from a particular geologic unit. One of these maps defined the top of the Knox dolomite (Tenn. Div. Water Res. Series 5, 1962), a unit at that time considered by some hydrologists to be a potential source of ground water for much of middle Tennessee. The test hole drilled in 1949 was into the Knox dolomite.

Because the reconnaissance study of the ground-water resources of western Tennessee had been completed and reported on by F.G. Wells in 1933, studies during the decade in this part of the State were primarily to define and delineate the principal Tertiary and Cretaceous aquifers. Geologists from the District office mapped the Porters Creek clay outcrop across western Tennessee to differentiate the potential areas of recharge for these aquifers. Possible recharge to the Tertiary aquifers was in the area west of Porters Creek, and that to the Cretaceous aquifers was in the area east of Porters Creek to the edge of the Paleozoic rocks.

Two of the test holes drilled in western Tennessee during 1948–49 were in Madison County. They were

drilled to obtain additional information on the McNairy Sand of Cretaceous age, which is the source of most domestic and municipal ground-water supplies in the eastern part of western Tennessee. Both holes were drilled through the Coastal Plain sediments and a short distance into the Paleozoic rock. Both were plugged back to the McNairy Sand, cased, screened, and developed as observation wells.

The third test hole drilled in western Tennessee was in Fayette County. It was drilled a short distance into the Porters Creek clay, the lower confining bed of the "1,400-foot" sand in the Memphis area. This hole was cased and a screen was set in the "1,400-foot" sand. An offset observation well was drilled, cased, and screened in the "500-foot" sand of the Memphis area.

Detailed studies of the ground-water resources in western Tennessee include one in the Dyersburg area by R.L. Schreurs and M.V. Marcher (Tenn. Div. Geol. Report Inv. 7, 1959), one in the Mississippi alluvial valley in Tennessee by S.I. Strausberg and Schreurs, and one in the Jackson area by Bruce Campbell, a State employee working on the cooperative program. Also, C.R. Lanphere obtained data on the municipal ground-water supplies in western Tennessee, and his report was published by the State in 1955 (Tenn. Div. Geol. Report Inv. 1).

The cooperative program with the Memphis Light, Gas, and Water Division continued throughout the decade. Work on this program was conducted primarily by hydrologic field assistants and part-time personnel until about 1954, when J.H. Criner, Jr., was designated as the project chief. Two progress reports on the ground-water supply of the Memphis area were prepared (Circulars 33 in 1949 and 408 in 1959).

E.M. Cushing, project chief of the Memphis area program at the beginning of the decade, was named district engineer in 1948 and held this position to the end of the period. Robert Schneider was his assistant until he transferred in 1950. A replacement was not named until 1955 when R.M. Richardson transferred to Oak Ridge to take charge of the AEC program, and P.H. Jones transferred into Tennessee as assistant district chief.

Mrs. M.S. Hankins served as district clerk throughout the decade. G.D. DeBuchananne was in charge of the Knoxville Subdistrict office from 1948 to 1952. He was followed by R.M. Richardson until 1955, and then by R.W. Maclay. Roy Newcome, Jr., was in charge of the Nashville field headquarters from 1949 to 1954. He was followed by C.R. Lanphere in 1955. In 1956, only State employees working on the cooperative program manned the Nashville office; in 1957, M.V. Marcher transferred from Memphis to take charge of the office.

QUALITY OF WATER BRANCH

Branch activities in Tennessee were under the jurisdiction of the Fayetteville, Ark., District until 1953 when Tennessee was included within the boundaries of the Raleigh, N.C., District. No Branch personnel were stationed in Tennessee during the decade.

The Fayetteville District staff reported (in response to a WRD Circular dated June 11, 1951) that chemical-quality analyses were currently being made on water samples taken periodically from 20 stream locations, 15 observation wells, and 8 springs for use in the nationwide report on "The Industrial Utility of Public Water Supplies in the United States, 1952" (WSP 1299, 1954). This was funded from a Federal program allotment. Concurrently, similar analyses were made of periodic samples from 39 wells and 16 springs as requested and funded by the GW Branch to meet the needs of its cooperative program. In addition, periodic sampling was conducted at three stream sites and two wells for another Federal agency.

As of fiscal year 1958, shortly after the end of the decade, a program analysis sheet showed that the District was receiving a $750 allotment of Federal program funds to support the State segment of a nationwide evaluation of data networks. It also revealed that $670 was provided by the Armed Forces for chemical analysis of water resources for military use.

TEXAS

SURFACE WATER BRANCH

Condensed from documentation by Trigg Twichell

The District program doubled in size during the decade because of the increasing need for more adequate definition of the surface-water resources in a State undergoing rapid post-war development for which ever larger water supplies were needed. The total number of personnel in the District increased from about 26 in 1947 to nearly 40 at the end of the decade. The portion of the staff assigned to District headquarters in Austin varied more widely as area offices were enlarged or reduced and field headquarters were established or closed in support of the varying requirements of the more distant investigational programs. In 1946, for example, only about half of the District personnel were at its headquarters. The availability of qualified personnel was a problem. The District's annual report for 1957 recorded 7 accessions and 11 resignations, and noted that "it was impossible to recruit engineering graduates primarily because of the low starting salary offered under Civil Service standards."

Four area offices were maintained during the entire decade. Three of these, at Fort Worth, Houston, and San Angelo, were about the same size and varied from two

to five persons. The fourth, at Wichita Falls, ranged from one to three persons. In 1952, an area office was established in Austin with a staff of about seven assigned to operate the gaging-station network in that vicinity. This office closed in 1953, largely because of the death of the engineer-in-charge; it reopened in 1955. The area office personnel not only operated and maintained the stations in their assigned networks, they also made final computations of daily flow for all or a portion of the stations as designated by the District headquarters staff. A field headquarters was maintained at Lufkin from 1948 until 1951 and, in 1952, two others were activated, one at Mount Pleasant and the other at Stamford. A third, at Jasper, was added in 1953, but all were closed in 1954. All were one-man headquarters.

C.E. Ellsworth, having been appointed district engineer in 1918, continued in that position until his retirement in April 1953. (A biographical memoir of Ellsworth is published in the *WRD Retirees* newsletter for November 1975.) He was succeeded by Trigg Twichell who had been assistant district engineer from 1929 to 1950. Twichell recalls (written commun., 1982) Ellsworth's great interest in the surface-water resources of Texas and his personal involvement in numerous studies of water supply in relation to needs in each section of the State. The record also shows that Twichell, as Ellsworth's successor, continued to maintain the strong cooperator and public relations that he had developed much earlier with Ellsworth's blessing, plus an equally satisfying, employee relations climate.

In addition to his intradistrict responsibilities, Twichell served from 1955 on as Federal representative on the Arkansas River compacts between Arkansas and Oklahoma and between Kansas and Oklahoma. He was also the Survey member of the Interior Department's Southwest Field Committee, and provided the liaison between the Survey and the Department's representative on the Arkansas-White-Red Basins Interagency Committee.

Members of the senior headquarters staff at the beginning of the decade included V.L. Austin, S.D. Breeding, and H.C. Pritchett. In 1952, Austin was put in charge of the Austin area office. The assignment ended with his death in 1953. Breeding became assistant district engineer in 1950 and, from 1954 on, he also served as a field representative of the technical standards section of the Branch headquarters organization. In this latter capacity, Breeding advised the Texas and other Districts on the measurement and reporting of major floods. Pritchett continued on the headquarters staff, in charge of the re-established Austin area office from 1955 on.

W.H. Goines had charge of the area office at Houston until 1952 when he transferred to the Mississippi District. He returned to Texas and joined the headquarters staff in 1955. H.K. Hall succeeded Goines at Houston. L.N. Jorgensen was in charge of the Fort Worth area activity until about 1951; then the supervisory position was held successively by M.D. Hale, F.B. Sessums, R.L. Allen, and J.H. Montgomery. H.J. McDowell was in charge at San Angelo, followed by T.W. Weinheimer, I.D. Yost, and G.H. Hughes. J.O. Joerns was in charge of the Wichita Falls headquarters during the period.

By the end of the decade, the senior headquarters staff at Austin also included Yost and D.L. Milliken. Ms. E.M. Ogden remained with the District during the entire period, serving initially as clerk stenographer and later as editorial clerk. Mrs. T.C. Schmitt, who joined the District in 1934, continued to serve as accounting clerk during the decade. Others on the headquarters staff throughout the decade were W.C. Dodd and P.H. Holland. H.W. Albert remained at San Angelo during the entire period. L.L. McDaniels was at District headquarters except for the period from 1948 to 1951 when he was stationed at Lufkin.

The District budget increased from about $197,000 in 1947 to $399,000 in 1957. In 1957, about 70 percent of the funds (both sides, Federal and State) were derived from the cooperative program with the Texas Board of Water Engineers, a cooperation that had begun in 1915. The board, however, received about half of its share of cooperative funds from several municipalities and river authorities. Additional cooperative agreements with the Sabine River Compact, the Pecos River Commission, and the Red Bluff Water Power Control District added another three percent to the budget. Financial support from the Corps of Engineers comprised 17 percent and the Soil Conservation Service 3.5 percent of the District funds. The remaining 6.5 percent was from the Federal program allotment.

The number of gaging stations in operation during 1947 was 224, and this increased to 294 by 1957. On an average, about 20 percent of these stations were operated out of the Austin area office. The Fort Worth, Houston, and San Angelo area offices each maintained from 20 to 25 percent of the total stations and the Wichita Falls office about 10 percent. In addition to the streamflow program, the District also collected other types of water data, such as the water content of reservoirs (24 locations in 1951) and periodic measurements of temperature at more than 200 points along stream channels. According to Twichell (written commun., 1983), there was an increased demand during the decade for streamflow data for use in the design of storage reservoirs to assure a more continuous supply of water for industrial, irrigation, and public use. The result was a sizable gage-construction program. The State Highway Department required that gage structures be designed to blend with the adjoining bridges and roads. Holland, in charge of the construction program, designed and built semi-portable, well-ventilated, bug-proof metal gage shelters that were prefabricated at

the District shop in Austin and hauled to the site by a special-use truck. Cableways and controls were constructed as necessary.

Numerous special studies and investigations were conducted and reported on by members of the District staff during the decade. Twichell described the Trinity River tributary area in 1947, analyzed the interrelation of surface and ground waters of Texas in 1952, and reported on ''water facts'' relating to the Trinity River at and above Dallas in 1953.

Breeding added sections describing stream runoff to reports on ground-water investigations of Liberty County (WSP 1079-A, 1950), Gregg County (WSP 1079-B, 1950), and Comal County (WSP 1138, 1952). Breeding also reported on the flood of May 17, 1949, at Fort Worth, made a comparison of floods of September 1951 and September 1953 in the southern Coastal Plain, and, with Holland, described the manner in which water was delivered from Whitney Reservoir to Richmond.

Austin, with W.O. George, reported on their low-flow surveys from Dam B Reservoir to the mouth of Village Creek along the Neches River in October 1952. D.E. Havelka and E.M. Parten described the movement of water from Belton Reservoir to the Brazos River at Richmond.

Holland was author of a number of reports during the period. They included the investigation of seepage gains and losses in the Atascosa, Frio, and Nueces Rivers conducted at several times during 1951, and also his studies of the diversions and related channel losses from the Red River to Lake Dallas during February and March 1954. He and Burdge Irelan described Guadalupe and Blanco seepage investigations in 1955 and, with F.C. Lee, similar surveys of the Pedernales River in January 1956.

Joerns described sources of low flow into Double Mountain Fork of the Brazos River in February 1955 and also documented sources of natural pollution in the Wichita River basin above Lake Kemp during 1951–57. Yost described results of seepage investigations along the Noyes Canal in Menard County during May 19–20 and on July 2, 1953. Texas Board of Water Engineers Bulletin 5101, by Goines, A.G. Winslow, and J.R. Barnes, described the water supply of the Houston Gulf Coast region. Unless otherwise noted, all of the special studies described were reportedly among the open-file reports.

GROUND WATER BRANCH

By Raymond W. Sundstrom

The decade 1947–1957 found Texas in a boom situation. The population of the State was growing rapidly. Industry was expanding and flourishing. Houston, Corpus Christi, San Antonio, Austin, Fort Worth, Dallas, Midland, Big Spring, Amarillo, and El Paso were increasing greatly in size and outgrowing their water systems and supply. Irrigated agriculture grew by leaps and bounds. For all of these situations, Texas found itself with many water problems and the need for water studies and solutions. In 1947, Texas was using more than 1 billion gallons a day of ground water for public, industrial, and irrigation supplies, of which about half was used for irrigation in the Southern High Plains.

The phenomenal increase in the use of ground water during 1947–1957 continued at an ever increasing rate. Midway through the decade, Texas was using about 7 million acre-feet of ground water annually, of which about 83 percent was used for irrigation, about 10 percent for industrial purposes, about 4 percent for municipal supply, and about 3 percent for rural domestic supply and livestock. This indicates an increase in the use of ground water of six times that for 1947. The acreage of irrigated land grew from 1.9 million acres in 1949 to 5.3 million acres in 1959. This acreage includes 10 areas of Texas, about four-fifths of which is in the Southern High Plains. Throughout the 10 irrigated areas, water-level measurements made under the cooperative program with the Board of Water Engineers showed progressive annual declines in water levels. Owners of irrigation wells throughout the areas were expressing increased concern about the declines of water levels, well yields, and the effect of pumping on nearby wells. Almost every irrigator was becoming conscious of and concerned about the problem of ground-water depletion.

In 1949, the Texas Legislature enacted legislation that allowed the creation of ground-water control and conservation districts in areas where the irrigators wished to establish them by vote. The Southern High Plains was the first district established shortly after the passage of the Act. Some time later, a district was also created for the High Plains north of the Canadian River. The creation of these two districts put the use and development of irrigation in most of the irrigated areas under local control. Water-level records throughout the irrigated areas of Texas became necessary and valued documents.

C.R. Follett and B.W. Swartz of the USGS spent most of 3 years preparing the alltime water-level records in 69 counties of Texas. The number of wells in the State in which the water level or artesian pressure was observed increased from about 1,200 in 1947 to more than 3,000 in 1957. Follett and Swartz also prepared maps of water-table decline for many counties. In the Southern High Plains, a field office was located at Plainview, Tex., with J.R. Barnes in charge. He was assisted by W.C. Ellis, E.R. Leggat, and R.A. Scalapino. In 1949, Progress Report no. 7 on the geology and ground water in the irrigated region of the Southern High Plains was prepared.

W.O. George assisted in the preparation of the report, and Burdge Irelan prepared the section on quality of water. The report was published by the Texas State Board of Water Engineers (TSBWE). On completion of the report, Barnes and his assistants were assigned to other projects, and J.G. Cronin was assigned to the field headquarters in Plainview. He was assisted by Donald Frazor and Lloyd Wells. Five other field headquarters were established at Dumas, Kerrville, Alpine, McAllen, and Uvalde, where project-type ground-water investigations were in progress. More permanent area offices were continued in El Paso, Fort Worth, and Houston.

The city of El Paso, along with the U.S. Army at Fort Bliss and the Air Force at Biggs Field, were in a quandary concerning the adequacy of the water supply of the El Paso area, and their representatives approached the Survey for a study and appraisal of the ground-water resources of the Hueco Bolson northeast of El Paso. A cooperative agreement with these agencies and the TSBWE was finalized in 1953. A detailed study, including the drilling of 33 test wells with a total footage of 32,456 feet, was conducted. D.B. Knowles and R.A. Kennedy of the Survey authored the detailed report published by the TSBWE as Bulletin 5615. The investigation revealed that about 30 million gallons of water a day could be recovered from storage for a period of 110 years. During the course of the field investigation, nine engineers and geologists from WRD and the two from the TSBWE assisted in the study.

San Antonio was in dire need of assurance of the adequacy of its water supply. The city was experiencing a very severe and prolonged drought. The flow of Comal Springs was diminishing. The development of ground water for irrigation in three counties in the recharge area of the Edwards Limestone seemed imminent. San Antonio became very water-conscious, and started two major projects: an appraisal of its ground-water supply and the construction of Canyon Reservoir on the Guadalupe River above the Balcones fault zone. An area office was established and has been maintained in San Antonio since that time for ground-water data collection and appraisal. Two reports were released in 1954 and 1956 as bulletins of the TSBWE. The first report was by J.W. Lang and the second by W.O. George.

The city of Galveston was facing problems of saltwater encroachment in its Alta Loma wellfield on the mainland. The city approached the TSBWE and the Survey for cooperative help. A test drilling program was started by the city and the area was studied. B.M. Petitt established headquarters at City Hall in Galveston and conducted the investigation, assisted by A.G. Winslow and others, and results were published in WSP 1416 in 1957.

Saltwater problems in connection with the development and protection of fresh ground water were prevalent throughout the State. WSP 1360-F (1957) described saltwater and its relation to freshwater in Harris County. The report was prepared by Winslow, W.W. Doyel, and L.A. Wood. Occurrence of saltwater in wells throughout Texas was also reported by Winslow and L.R. Kister. Extensive interpretation of electric logs from oil wells throughout the State supplied information to the TSBWE as to the depth to which freshwater should be protected.

W.L. Broadhurst and R.W. Sundstrom co-authored four reports describing the public water supplies in Texas. Each report covered a geographic segment—Eastern Texas, Central and North Central Texas, Southern Texas, and Western Texas. These reports were all published during the decade as WSP's 1047 (1948), 1069 (1949), 1070 (1950), and 1106 (1951).

In the coastal area around Houston, Pasadena, Baytown, Texas City, and Galveston, subsidence of the land surface was observed in some of the areas where pumpage from wells was very heavy and the decline in artesian pressure was great. Monitoring stations were installed at strategic locations to observe the cause and effect of the subsidence.

Many other important activities in ground-water studies occurred during the decade. During the period, 11 WSP's were issued on Texas projects. The annual water-level reports were published in 11 areal WSP's. The TSBWE published 69 of the reports as bulletins. Eleven short reports were published as articles in scientific magazines and 17 unpublished reports were added to the WRD open-files of the Survey and the TSBWE.

Available funds for the cooperative program continually increased during the decade. The annual cooperative State funds available prior to the 1947–1957 decade ranged from $34,222 in 1944 to $45,725 in 1946, and averaged $37,475 annually from 1940 through 1946. State cooperative funds amounted to $51,000 in 1947 and $404,000 in 1958. Intermediate amounts are not on hand for each year within the decade, but annual increases were maintained.

At the beginning of the decade, there were six Federal and about five State employees in the program. At the end of the decade there were 28 Federal and six State employees. Four Branch employees assigned to the national observation well program were also stationed in Austin.

W.N. White closed out his illustrious career with the Survey on June 30, 1947, and was succeeded by W.L. Broadhurst as district geologist. Broadhurst continued in that capacity until spring 1953 when he resigned. R.W. Sundstrom followed Broadhurst, heading the program as district engineer; he still held that post at the close of the decade.

The following Branch personnel served in the District during the decade. R.W. Sundstrom was on duty for the

entire period. Those on the rolls on July 1, 1947, and remaining until the year indicated include W.L. Broadhurst (1953); P.P. Livingston (1955); W.O. George (1955); and J.W. Lang (1953). Those on the rolls on April 30, 1957, and who arrived in the year indicated include W.H. Alexander, Jr. (1955); O.C. Dale (1950); E.R. Leggat (1951 or 1952); J.G. Cronin (1952); B.M. Petitt (1952); L.A. Wood (1952); W.E. Clark (1952); C.E. Armstrong (1956); F.W. Welder (1955); K.J. DeCook (1956); Theodore Arnow (1955); R.C. Baker (1956); William Ogilbee (1956); R.E. Smith (1954); R.B. Anders (1956); G.L. Audsley (1955); D.B. Knowles (1950); R.T. Littleton (1954); and B.W. Swartz (1953). Others who were with the District during the period indicated include J.R. Barnes (1948–50); D.E. Outlaw (1948–52); T.M. Culbertson (1949); G.J. Stamel (1949–50); J.W. Hood (1950–54); C.L.R. Holt, Jr. (1951 or 1952–53); C.H. Gaum (1952–53); W.W. Doyel (1953–54); E.A. Brown (1953–54); G.W. Willis (1953–54); and J.H. Dante (1954). (Periods of employment are based partly on directory listings, and on information from reports and project data. They may not conform exactly to official employment records.) Mrs. Leio Krueger was both district and editorial clerk throughout the decade. The office of staff engineer for the coordination of the Federal observation well program, headed by P.P. Livingston, 1952–1955, and W.E. Clark, 1956–57, had four Federal employees on the staff as of April 30, 1957.

QUALITY OF WATER BRANCH

By Burdge Irelan

During World War II, the Texas District had jurisdiction for quality-of-water programs in Arkansas, Louisiana, Mississippi, and Oklahoma, but its activities during 1947–57 were more heavily focused on problems in Texas. A small, service-type analytical program continued in Louisiana and gradually expanded (see Louisiana). Separate districts were established in Arkansas and Oklahoma as of January 1948. Mississippi was placed under the jurisdiction of the new Arkansas District.

Quality-of-water programs in Texas expanded steadily during 1947–57 and were increasingly variable and complex. The work was coordinated through the Texas Board of Water Engineers (TBWE) with whom each of the three branches had a cooperative agreement. Smaller individual cooperative agreements were made with various State and local agencies, including the Lower Colorado River Authority, the Brazos River Authority, and the Canadian River Water User's Association. From time to time, arrangements were made for the local authorities to funnel their money to the TBWE for inclusion in the annual cooperative agreement between the TBWE and the Survey. The Bureau of Reclamation and the Corps of Engineers each financed some stream-sampling programs. Many of the systematic studies were arranged to predict water quality downstream from reservoir projects planned or proposed for construction in Texas. By the end of the period, the water quality of all of the major rivers of Texas and many of their tributaries had been systematically sampled at one or more stations. Chemical analyses of the water samples from Texas streams were published annually in a report prepared for publication by the TBWE.

Sediment studies by the Branch staff in Texas were minimal. A national network station, funded by the Federal program, was operated on the Colorado River at San Saba. Sampling by automatic devices was arranged at several small Soil Conservation Service reservoirs in an effort to predict the life of the reservoirs. Some additional sediment sampling was also conducted on the lower Colorado River and on the Trinity River.

Studies of ground-water quality in Texas were mostly coordinated with the GW District. Hundreds of water samples collected by members of the GW Branch staff were analyzed each year. Assistance to program planners and report writers made up a considerable part of the ground-water quality program. Repeated samplings were made at Houston, Galveston, and El Paso because, in these areas, there was a history of gradually-increasing mineral content of water pumped from some wells. A study in the High Plains of West Texas included injection of water of known quality into a test well whose natural composition was different, and then pumping it out to determine (through chemical analyses) the amount of injected water recovered.

A series of reports on the public water supplies of Texas published during 1946–51 were composed mainly of analyses of ground waters collected by the Texas GW staff. After the completion of this series of reports, chemical information in District files was kept up-to-date by special sampling as new sources of municipal water were developed, particularly by the larger, rapidly growing cities of Texas. Files were maintained of results of chemical analyses of and other pertinent information on individual water wells in each county in Texas.

Texas had more military posts than any other State, and Department of Defense regulations called for annual chemical analyses by Survey laboratories for each source of water used at each post. Keeping up with this program was an important part of the District work and provided valuable information on the variations in chemical quality of water obtained from aquifers in many areas, as well as in the changes in water quality resulting from variable pumping patterns.

District personnel grew in number from six to a maximum of 15, with about 11 on duty at the end of the decade.

District headquarters was at 302 West 15th Street in Austin. W.W. Hastings was district chemist and had been in charge since 1941. He left to join the staff of the branch chief in 1948. He was succeeded by Burdge Irelan who had joined the District in 1941. Other members of the senior staff on duty during the decade included J.R. Avrett (1947–54); H.R. Feltz (1952–57); L.S. Hughes (1954–57); L.R. Kister (1954–56); George Porterfield (1949–55); Sam Rutherford (1950–52); John Santos (1950–53); F.B. Walling (1950–52); and D.E. Weaver (1948–50). Avrett served as assistant district chief until 1954 when he transferred to the New Mexico District and was succeeded by Hughes. They were largely responsible for the assemblage of records for the annual State reports on the chemical composition of surface waters.

Rutherford, who transferred from Pennsylvania, was responsible for supervising collection of samples in Louisiana, as well as for doing general laboratory work. He was furloughed during the Korean War and did not return to the Survey. Feltz and Walling were recruited when the Civil Service Commission was slow in coming up with prospective employees. Ms. W.M. Jones, Clarence Welborne, and Herbert Mendieta worked for a time on the State payroll before being given Federal appointments. John Santos, who later transferred to Portland, Oreg., was recruited following academic work at the University of Texas. Weaver was in charge of chemical analyses and left to take charge of the chemical-quality lab in Washington, D.C.

During 1947–57, members of the Austin District staff assisted in a variety of special projects. Irelan served as quality-of-water advisor to the Arkansas-White-Red Interagency Committee, assisting in its report preparation and preparing a map showing quality of stream-water variations in the basins that was published in the comprehensive report. Irelan also directed the quality-of-water phase of the southwestern Louisiana resources investigation and was one of the authors of the final report. Kister transferred to Austin from Lincoln to assist in data collection for the national public water-supply study. With A.G. Winslow, he prepared a report on the saline-water resources of Texas and contributed to the study of the saline-water resources of the United States. Irelan and Mendieta prepared a report detailing observed variations in the chemical quality of water in the Brazos River basin. Many of the county or areal ground-water reports prepared by the GW District staff included sections on quality of water prepared by the senior members of the QW District. Porterfield transferred from the Texas SW District to be responsible for the collection of sediment records.

BUREAU- AND DIVISION-LEVEL ACTIVITIES

As stated earlier, Trigg Twichell, assistant District engineer (SW), had two additional responsibilities: He represented the CHE in the coordination of Federal program plans for the USDI's Southwest Region, and represented the Director on the USDI Field Committee to coordinate the Survey's program plans for the Southwest Region. In 1950, Twichell was relieved of his assistant district engineer responsibilities so that he could devote full time to his Bureau- and Division-level commitments. These commitments again became part-time assignments in 1953 when he was designated District engineer (SW).

In the late 1940's, Mrs. T.C. Schmitt, then chief clerk for the SW District, also provided bookkeeping and clerical services for the GW and the QW Districts. In 1952, when the Texas WRD Council was established, she became chief of a Division-level administrative services section to service the districts of all three branches. The section was under the direction of the elected chairman of the Council. The headquarters staff of each of the three districts was located at 302 West 15th Street in Austin during the entire period, except for the office of the staff engineer (GW), which was at 1406 Colorado Street.

UTAH

SURFACE WATER BRANCH

By John W. Odell

The District headquarters for Utah and Nevada was located in the Federal building in Salt Lake City during the entire period. The number of headquarters personnel varied from 19 at the beginning to more than 30 at mid-decade, but decreased to about 20 by 1957. M.T. Wilson was district engineer for the entire decade, and was assisted by D.R. Woodward until Woodward moved to the Los Angeles Subdistrict in 1949. Wilson was then assisted by J.W. Odell until his transfer to become district engineer for Maryland-Delaware in April 1957, and finally by G.L. Whitaker who continued beyond the end of the decade. A.B. Purton, who had been district engineer until he asked to be relieved in 1942 because of a physical disability, continued as a senior staff member until he retired in 1956 (Follansbee, v. IV, p. 176). H.W. Chase, another member of the senior staff, served during the entire period. A.V. Maxwell, who was office engineer, resigned in 1955. W.P. Somers, who joined the District in 1950, also served part-time as field staff engineer of the technical standards section of the Branch beginning in 1954. R.C. Culler transferred to the TC Branch in 1949.

An area office was established at Vernal in 1951 or 1952 with a staff of two to six employees. The office was operated under the supervision of L.N. Jorgensen until 1955 when he was succeeded by D.J. Webb. Field

operations were conducted from Mexican Hat, Green River, Hite, St. George, Roosevelt, Vernal, and Excalante during the decade by individuals assigned for varying periods of time. The District also had a field headquarters in Nevada.

The expansion of the stream-gaging network in the Colorado River basin, begun in fiscal year 1946 in cooperation with the Bureau of Reclamation and the State of Utah, continued with 100 new stations added during the decade. The data were used in the division of Colorado River water alloted to the upper basin States and Utah's contribution to the Colorado River water supply (Follansbee, v. IV, p. 176). Eighteen of these stations were on transmountain diversions at elevations of 8,000 to 10,000 feet above mean sea level, and were operated to determine the amount of water transferred from the Colorado River basin to the Great Basin. The transfer of water between basins was accomplished by constructing ditches near the headwaters of streams to divert the flow across a low point on the divide, or through a short tunnel near the source of the stream. Thirty-two stations were established in the Great Basin to provide data for the central Utah project. Almost two-thirds of the new stations were established in the first half of the decade.

Many of these stations were located in remote areas that were difficult to reach for both construction and operation. The District had established a well-equipped shop where all cableway equipment, gage shelters, and stilling wells were built. The stilling wells and recorder shelters were generally made from galvanized, corrugated culvert pipe; however, many of the shelters for the small streams were constructed of lumber at the station site. A large percentage of the new stations in the Colorado River basin were located in desert areas where the principal streamflow occurred during summer thunderstorms.

Inasmuch as it was almost impossible to reach a gaging station during the brief periods of high water, it was therefore necessary to define the rating curves by use of indirect measurement of the peak flows. The slope-area method was used for most of the computations, and the District personnel became quite proficient in locating high-water marks, surveying the reaches, and computing the flows. The library on "n" (channel roughness) values compiled by the Branch for nationwide use was most helpful and some contribution was made toward verification of such values when current-meter measurements were obtained at a few stations.

The high-elevation stations posed special problems of operation, particularly the transmountain diversions. Most of the high-elevation stations would completely freeze up during the winter months and, although there was some flow except in the transmountain diversions, it was not practical to obtain a gage-height record. A visit to the station was required to "open them up" and prepare them for operation at about the time snowmelt started in the spring. This was accomplished in a variety of ways. The first and most strenuous was by snowshoeing or skiing. As it was necessary to travel long distances and carry considerable weight, other means of travel were sought. The development and Survey use of the Tucker Sno-Cat was a big help, as it reduced the physical effort of the personnel. It was still time-consuming, however, and traversing treacherous snow fields and coping with stormy weather was dangerous and difficult. Later, when improved helicopters that could operate at high altitudes were used, the task became considerably less arduous. The schedule of opening the stations was cut from weeks to days, and the man-hours and physical effort required were greatly reduced.

Interesting and unique problems were encountered in constructing several of the stations. The station on the Uinta River below Gilbert Creek near Neola, Utah, was located at an altitude of about 9,950 feet in a National Forest where no vehicles were allowed. The site was about 15 miles from a ranch and could only be reached by hiking or on horseback. All of the materials had to be transported by pack horse. Arrangements were made with a local rancher to furnish the necessary horses and an experienced packer to pack equipment. The stilling well was a 4-foot section of 24-inch diameter galvanized culvert pipe. This was a full load for one pack horse. Usually the pack was arranged to be equally distributed on both sides of the pack saddle. However, this was not practical for a length of pipe, so a platform was constructed on the top of the pack saddle and the pipe was lashed to the platform. The center of gravity of the load was rather high and, to no one's surprise, the horse showed its displeasure by rearing and bucking until it wound up flat on the ground, unable to get back on its feet until the pipe was removed. The second try had better results and the horse reluctantly accepted the strange pack. The experienced packer was busy elsewhere on the ranch, and his replacement obviously had much to learn about packing the type of gear used in gaging-station construction. Much time was lost, and it was late afternoon before the last man with his pack animals started up the mountain. One of the horses had too heavy a load, and it was necessary to make frequent rest stops. The last pack load included all the "grub," and since it didn't arrive until about midnight, the rest of the crew had gone to bed without supper. However, a nice sunny day followed and the station was installed without further mishap.

The desert country posed problems as well. The station, at the mouth of the Escalante River, was located about 50 miles southeast of the town of Escalante and about 30 miles from the end of a wagon trail to a ranch cabin. The area between the ranch cabin and the gage site was in desert country, with little more than sand and

"slick rock," except in the bottoms of the various small canyons where there was enough moisture to support vegetation. The station was to be operated to determine streamflow, sediment loads, and chemical constituents, so it was necessary for an operator to live at the site. The area could be traversed with a four-wheel-drive vehicle, but the dips and irregularities in the "slick rock" were so abrupt and deep that it was difficult to move living quarters to the site. The most practical solution seemed to be a house trailer. The crew attached an axle with two small wheels under the rear of the trailer. This worked well for part of the trip but the axle couldn't stand the heavy strain; it was replaced with a metal "shoe" (skid) that served the purpose, but not without some damage to the bottom rear of the trailer.

The trail to the station was so obscure over the stretches of "slick rock" and there were so many blind alleys, it was necessary to paint markings on the rock to keep the traveller on course. Some time later, when a reporter for the *National Geographic* was writing an article on the Escalante area, he referred to the trail as the cheapest highway in the U.S.: 30 miles of road; cost, one gallon of paint. The isolated location of the station and the hazardous nature of the work made it necessary to install two-way short-wave radios at the station and at the field headquarters in Escalante. Contact was made at a scheduled time daily to be sure all was well with the station operator. If the contact could not be made, the headquarters man immediately drove the 50 miles to the station.

In spite of the many problems and long hours of arduous effort, the target goals were achieved and the programs satisfactorily completed. If one person can be singled out for special commendation, it is M.T. Wilson, the district engineer, who had the overall responsibility for District activities.

Bear River Project

The SW Branch also maintained a project office at Logan during the decade for surface-water investigations to meet the needs of the Bear River Compact among the States of Idaho, Colorado, and Utah, and the U.S. Bureau of Reclamation. The project, conducted by the Boise, Denver, and Salt Lake City Districts, was under the direction of W.V. Iorns until 1952 when he was succeeded by A.B. Harris. Other senior members of the staff included W.N. Jibson, M.S. Peterson, and A.F. Pendleton, Jr.

GROUND WATER BRANCH

By Harold E. Thomas, Herbert A. Waite, W. Biard Nelson, and Ben E. Lofgren

The District, which began the decade with a staff of three and ended with a total of 11, had its headquarters in the Federal building in Salt Lake City during the entire period. In 1953, field headquarters were established in Ogden (March) and Cedar City (May). Staffed by only one person at each location, Ogden closed in June 1956, and Cedar City closed briefly in December 1954, but was reopened in May 1956 with G.W. Sandberg as engineer-in-charge. In July 1956, a new field headquarters was established in Richfield for the Central Sevier River Valley project and was staffed by two persons.

H.E. Thomas was district geologist until 1949, during which time he was also involved in field studies and report preparation on the ground-water resources of Tooele Valley, the East Shore area (Bountiful District), Utah Valley, and Escalante Valley. In 1949, he also participated in a project of the USGS military geology unit, a strategic engineering study of the Sixth Army area. His special contribution was a study of ground water in the eight westernmost states. In September 1949, Thomas was asked by the Survey to take leave to make a survey of the national ground-water situation for the Conservation Foundation headquartered in New York City. This assignment lead to publication of the book *Conservation of Ground Water* published by McGraw-Hill in 1951.

With Thomas' departure in 1949, P.F. Fix became acting district geologist and continued in that role until his transfer to the Geologic Division in 1952. Thomas returned to Utah in October 1950 as staff scientist to supervise and review the Survey's cooperative ground-water programs in Arizona, New Mexico, Nevada, and Utah. In 1955, his responsibilities were expanded to include California, Hawaii, and Guam. As staff geologist, Thomas continued to maintain his headquarters in the Salt Lake City Federal building until September 1956 when he transferred to Menlo Park, Calif., to become branch area chief of the newly established Pacific Coast area.

H.A. Waite, who had been in charge of ground-water investigations in Nebraska, succeeded Fix as district geologist in July 1952 and continued in that position through the balance of the decade. W.B. Nelson served on the District staff throughout the period, as did R.G. Butler. B.E. Lofgren, hired by the District in 1949, left in September 1955 to join the California District in Sacramento. J.H. Feth was headquartered in Ogden from March 1953 until the end of June 1956 where he was in charge of ground-water investigations that were being conducted as a part of the Bureau of Reclamation's Weber basin project. Feth occupied office space in the Bureau's offices in Ogden, and a number of other services were provided under a cooperative arrangement between the Bureau and the Survey. Waite was absent from Utah during a 90-day overseas assignment to the Sudan (February–May 1955), arranged by the Survey's Office of Foreign Hydrology.

Cooperation with the State Engineer, begun in 1935, continued during the decade. The Utah Water and Power Board contributed some funds to be used for matching purposes on cooperative ground-water studies. At the request of the National Park Service (NPS), ground-water studies were conducted at a number of its sites in Utah to determine water-supply possibilities. These included a study of the ground-water resources of the Bryce Canyon National Park area (I.W. Marine), as well as studies of water-supply possibilities in Dinosaur National Monument (R.E. Smith), Arches National Monument (B.E. Lofgren), Zion National Park, Cedar Breaks National Monument, and other areas of special interest to the NPS. These investigations were financed in part by a transfer of funds from NPS.

Some cooperative ground-water studies were conducted with the Atomic Energy Commission (Grand Junction, Colo.) in southeastern Utah, notably a study of water-supply possibilities in Montezuma Creek Valley, with special reference to wells supplying the Galigher uranium ore processing mill at Monticello. Reconnaissance studies were also conducted in the White Canyon area near Blanding.

A fairly extensive observation-well program, in operation in Utah since 1935, was continued during the decade, although the size and scope of the program fluctuated. Studies were continued in the populous Ogden area (in which the Clearfield Naval Supply Depot, Hill Field Air Force Base, Ogden Arsenal, and Utah General Depot were situated) to determine the extent and rates of withdrawal, the source and rate of recharge, the chemical quality of the ground water, and possible impact of this chemical quality on its use.

At the request of officials at Dugway Proving Ground situated in southwestern Utah, ground-water studies were conducted intermittently at that military installation. These investigations were supplemented by a geophysical survey conducted by Survey personnel from Phoenix, Ariz.

Utah was fortunate to have a State ground-water law, initiated in 1935. The State Engineer was responsible for the administration of the water resources, both surface water and ground water, and he needed sufficient basic hydrologic data to help adjudicate these resources wisely. Although the overall program of ground-water investigations in Utah differed somewhat from year to year during the decade and was affected by the availability of funds and personnel, the results obtained were important in supplying the kinds of hydrologic information necessary to assist in planning an orderly development of the ground-water resources of the State and in preventing over-development in some critical areas.

Ground-water studies were continued in the East Shore area in Davis, Weber, and Box Elder Counties (R.E. Smith), and water-level measurements of selected wells and chemical analyses of ground water were collected and compiled for publication. Projects were also conducted in the Jordan Valley in southeastern Salt Lake County (I.W. Marine), and in the northern part of the Utah Lake Valley in Utah County (Seymour Subitzky). Studies in the Escalante Valley were continued and expanded to determine ground-water conditions in the Milford and Beryl-Enterprise pumping districts, and in Cedar City and Parowan Valley in southern Utah (G.W. Sandberg). Some contract test drilling for water wells was also conducted in connection with these studies. Systematic pumpage was inventoried and water-level observations in key wells were measured. Ground-water investigations were conducted in the Central Sevier River Valley and Sanpete Valley from a suboffice in Richfield by R.A. Young and others. Studies were also continued in Ogden Valley, where the municipal water supply for the city of Ogden was obtained from artesian wells that are now covered by the water of Pineview Reservoir.

The results of many of the project studies derived from the cooperative program in Utah are published in a numbered series of technical publications that are a part of the biennial reports compiled and published by the State engineer. Many of the technical publications also are published separately from the biennial reports. The results of some investigations in Utah have also been published by the Survey as Professional Papers, Water-Supply Papers, and Circulars. Detailed records of ground-water levels were published in an annual series of Water-Supply Papers. Some results of studies were released in the open-files of the Survey. The annual cooperative funds supplied by the Utah State Engineer for cooperative ground-water studies in Utah ranged from $8,000 in 1947 to $119,000 in 1958.

Thomas believes he was supported entirely by Federal allotments from October 1950 onward. This is because he immediately became involved in editing and writing chapters for the report of the interdepartmental comprehensive survey of Lake Mead, in making four reconnaissance trips (each of several weeks' duration) throughout the western states in 1951 with Dr. J.R. Mahoney (that led to publication in the Congressional Series on the Physical and Economic Foundations of Natural Resources), and a study of the effects of long-term drought in the Southwestern United States. These assignments covered several years' duration.

The most memorable projects (as recalled by Thomas in 1982) of 1951–55, insofar as Utah cooperative work was concerned, were a reconnaissance of the Green and Colorado Rivers with M.T. Wilson and some of his SW staff using "cataract boats" to measure inflow-outflow during the 1948 low-flow period, and studies of Navajo Lake, also with Wilson, to determine the proportion of lake water that flowed underground to the Virgin and

Sevier Rivers. The lake accumulates water and the rocks divide it to the Colorado Basin and Great Basin.

Waite recalls a boat trip on the Great Salt Lake in October 1954 to collect depth-integrated samples of lake water for chemical analysis. At the invitation of J.G. Connor, district chemist, Salt Lake City, the following crew in addition to Connor and Waite made the trip: Commander Flynn, USN, who furnished a large and appropriate U.S. Navy craft for the expedition, Wilson, and Thomas and his son John. The sampling equipment was expertly handled by Connor—"the rest of us basked in the salt spray. It made a nice break in routine for us freeloaders. No fish were caught because there aren't any in Great Salt Lake."

QUALITY OF WATER BRANCH

By John G. Connor

The first regional laboratory for chemical analyses and sediment-discharge determinations was established at Salt Lake City, Utah, in January 1947 with Federal program funds. It was located at Fort Douglas, in the foothills above the University of Utah, and remained there during the entire decade. The two-story barracks building served as the Region office, with a chemical laboratory downstairs, a sediment laboratory upstairs, and storage space for equipment and supplies.

C.S. Howard established the Salt Lake City regional facility while serving as district chemist for the Albuquerque, N. Mex., District. His official transfer to the Salt Lake City District as district chemist came in August 1948 and his title changed to regional chemist in 1949. In 1952, he was designated as representative of the branch chief "to assist and guide in the formulation of programs and the coordination and review of investigations in the western United States (except the Missouri River basin), Alaska, and Hawaii," and he moved to the Western Division headquarters in Palo Alto, Calif., in 1954.

R.T. Kiser transferred from Albuquerque to set up the Salt Lake City laboratory in January 1947. He was assisted by W.M. Webster (1948–52) and E.L. Singleton (1949–54). Kiser was senior staff assistant to Howard during this period. I.C. Frost, a chemist from the U.S. Bureau of Mines, joined the staff in mid-1950 and was staff assistant until 1953.

R.E. Cabell, engineer, transferred from the Holbrook, Ariz., office to set up the sediment laboratory in 1952, and was senior staff assistant for that section. G.E. Johnson, engineering aid at Lee's Ferry, Ariz., moved to the regional laboratory to assist Cabell in the sediment section. Both men were on duty through 1957.

During the expansion period of 1950–52, W.D. Goss and M.L. Porter, chemists, assisted with the analytical workload. Mrs. L.W. Romer was employed as clerk-stenographer from 1948 to 1955.

In July, 1953, J.G. Connor, district chemist, Charlottesville, Va., transferred to Salt Lake City to succeed Howard. In view of Howard's move and of the planned release of some of the regional responsibilities to the newly established QW laboratory in Corvallis, Oreg., the Salt Lake City facility was redesignated as a District and Connor was named district chemist, the position he retained to the end of the decade.

C.G. Mitchell and Osamu Hattori, chemists, reported for duty in 1951 and 1952, respectively. Hattori was on furlough to the Armed Forces during 1953–55. Both he and Mitchell were on duty through 1957. Singleton transferred to the Atomic Energy Commission (AEC) in 1954, and Kiser accepted an assignment to Lahore, Pakistan, in 1955. B.F. Joyner, assistant to the district chemist in Raleigh, N.C., transferred to Salt Lake City in 1955 as senior staff assistant for the chemical-quality section, a position he held till the end of 1957.

When the Salt Lake City laboratory became operational, supported chiefly by Federal funds, most of the analytical work was on chemical-quality samples from the upper Colorado River basin in Colorado, Utah, and Idaho, and from the Pacific Northwest. However, with the increased interest in water quality during post-war industrial and municipal growth, additional monies became available for both surface- and ground-water studies from the Federal-State programs, and by transfer from other Federal agencies (Bureau of Reclamation, AEC, and military installations). By the end of the decade, the sources of financial support had shifted considerably from the Federal program to Federal-State projects, such as that with the Metropolitan Water District of Salt Lake City, and those with other Federal agencies.

Although the number of sediment samples collected and analyzed during the period increased only slightly, the addition of particle-size analyses increased the workload considerably. The number of daily chemical-quality samples from key locations on the mainstem of the rivers increased very little, but the number of periodic samples increased considerably, reflecting a desire to define the chemical character of sub-basin waters. As a part of increased efforts to define the chemical character of numerous underground basins in Utah, ground-water samples collected for chemical analyses more than doubled during the decade.

There was good cooperation between staff of the branches of the Division during several special studies involving both ground- and surface-water problems, for instance, "A Case of Underground Piracy," by H.E. Thomas and M.T. Wilson, 1960. Chemical analyses and dye-tracers were used to identify the sources of ground- and surface-waters in Ashley Valley, Utah.

District assistance also was provided in the solution of several problems involving ground-water supplies used by military installations.

Use of radio equipment obtained from U.S. Army surplus enabled the Salt Lake City District to join a network of radio stations reporting water-stages for the Colorado River from Cisco, Utah, downstream to Grand Canyon, Ariz. In addition to having current stage information, the network was also a means for isolated residents to communicate with the outside world in the event of an emergency. The Bureau of Reclamation asked for daily information from the Survey's upstream station while they were in the process of building Glen Canyon Dam so as to ensure the safety of their operators and the heavy-duty equipment at the bottom of the damsite.

In 1956, a start was made on the compilation of all known chemical-quality data for surface and ground water in Utah. Such information was obtained from the State Engineer, two universities, military and other Federal installations, and numerous city water boards. When completed, all information was put in one publication, Utah State Technical Publication 10, "A Compilation of Chemical Quality Data for Ground and Surface Waters in Utah," 1958, by J.G. Connor, C.G. Mitchell, and others.

Other publications worked on or published by District personnel during the decade included "Suspended Sediment in the Colorado River, 1925–41," by C.S. Howard (WSP 998, 1947) and "Quality of Water of the Colorado River, 1925–40," also by Howard (USGS, open-file, 1955). District records were published in the two annual series, "Quality of Surface Water of the United States," parts 9–14, and "Quality of Surface Water for Irrigation, Western United States." Records also were provided for "The Industrial Utility of Public Water Supplies in the United States, 1952, Part 2, States West of the Mississippi River," by E.W. Lohr and S.K. Love (WSP 1300, 1954).

TECHNICAL COORDINATION BRANCH

The Branch maintained an office in the Federal building, Salt Lake City, throughout the decade, but the size and nature of its program changed substantially during the period. Until his death in 1948, R.R. Woolley, district engineer, and two administrative employees continued to supervise Federal Power Commission permits and licenses, and to conduct hydrologic investigations of the relation of the streamflow in the Great Basin to climatic and physiographic conditions and to water use (Follansbee, v. IV, p. 395.) He also served as a representative of the Director's office.

H.V. Peterson arrived from Los Angeles in May 1949 with the title of staff geologist. He and his staff of four continued their S&M studies on the western public domain. In 1954, Peterson transferred to Denver. R.C. Culler, on the staff since 1949, succeeded him on such studies, but with a staff that was reduced to two persons. On Culler's departure for Denver in 1955, C.T. Snyder continued the remaining work without assistance through the end of the period.

DIVISION-LEVEL AND INTERBRANCH ACTIVITIES

One of the earliest instances of administrative services of several branches being handled by a single unit occurred in Salt Lake City. Beginning in November 1946, T.S. McIlhenny, attached to the TC District, was hired to keep the accounts not only for the three districts of the Water Resources Division, but also for local field units of the Geologic Division. Such service continued by McIlhenny after his transfer to the SW District in 1949 and by his successor, J.R. Renshaw, after the former transferred to Denver in 1950 as a member of the Director's field staff. The personnel listing of January 1, 1952, shows the existence of a seven-person interbranch administrative services section, but no reference is made then or later regarding assistance to the Geologic Division. Renshaw, who transferred to the Bureau of Land Management in 1954, was succeeded by R.S. Lawrence, who continued through the end of the period. Ms. V.A. Johnson was Renshaw's and Lawrence's principal assistant.

VERMONT

SURFACE WATER BRANCH

The program in Vermont was under the jurisdiction of the Boston, Mass., District and was conducted by personnel whose headquarters remained in Boston. No field headquarters were used in Vermont during the decade. The activity was primarily the collection of field data for the computation of daily streamflow. Program statistics for fiscal year 1958, shortly after the end of the decade, show that there were 39 gaging stations in Vermont. Three sites were funded from allocations from the Federal program, 22 were supported under the cooperative program with the Water Conservation Board, 12 were operated with Corps of Engineers fund transfers, and the remaining two were financed by monies from power companies as permittees or licensees of the Federal Power Commission. The field staff also made periodic measurements of water temperature at these sites. The water content of snow was measured at 19 sites, all under the cooperative program. (The findings used in the

monthly Water Bulletin and the Snow Conference are described in the discussion of the Massachusetts program.)

The special compilation of streamflow records through September 1950 were published in WSP's 1301 (1954) and 1307 (1958). Floodflow in Vermont streams during the New Year's flood of 1949 are documented in USGS Circular 155 (1952).

GROUND WATER BRANCH

The Branch had no formal investigative programs in Vermont during the decade.

QUALITY OF WATER BRANCH

Water-quality studies in Vermont were under the direction of F.H. Pauszek, district chemist for the New York-New England District located in Albany, N.Y. These studies were conducted in support of the cooperative programs established by the SW and GW Branches with State agencies. Water samples were collected by local SW and GW personnel, and analyses were made in the QW laboratory in Albany.

VIRGINIA

SURFACE WATER BRANCH

Condensed from documentation by J.S. Cragwall, R.O. Abrams, and Allen Sinnott

District headquarters remained in Charlottesville during the entire decade, occupying space on the grounds of the University of Virginia until 1953. In about 1954, the headquarters moved to the National Resources building where space was provided for all three local branches of the Division. District headquarters personnel ranged in number from about 11 to more than 20. Intermediate fluctuations in total staff indicate that the program was of greatest magnitude in 1952, and again in 1956. A field headquarters with two or three persons at Marion was maintained throughout the period; its staff was engaged in operating the station network in the remote southwestern corner of the State.

The primary cooperating agency for nearly all of the decade was the Division of Water Resources and Power of the State Conservation Commission; however, the cooperative programs for all three branches ended as of June 30, 1957. Other State and municipal agencies that continued cooperation through the end of the decade included the State Highway Department, Chesterfield County, and the cities of Alexandria, Charlottesville, Newport News, Norfolk, Portsmouth, Roanoke, and Staunton. Among the Federal agencies contributing funds for specific studies or data were the Corps of Engineers, Richmond Quartermaster Depot, Quantico Marine Base, Forest Service, Soil Conservation Service, Tennessee Valley Authority, and Federal Power Commission's permittees and licensees. Federal program funds also were allocated to the District.

D.S. Wallace was district engineer for the entire decade, having been in that position since about 1941. Wallace had a dual role in that he also served as the State Conservation Commission's chief engineer for its Division of Water Resources and Power (Follansbee, v. IV, p. 37). A.R. Green was second in charge until 1953 when he transferred to the Indianapolis, Ind., District. He was succeeded by D.F. Dougherty who had been in a similar position in the Maryland District.

Other members of the senior headquarters staff present at the beginning of the decade included O.D. Mussey, R.H. Tice, and R.E. Curtis. Those joining the District later in the decade included C.W. Lingham (1951 on); D.D. Dickstein, Jr. (1954 on); E.M. Miller (1951 on); P.C. Bent (1949–53); and W.G. Bonham (1950 on). E.H. Ogilvie served on the headquarters staff for the full period, as did R.O. Abrams for all except the first year.

The Marion office was under J.S. Cragwall's direction until 1948 when he joined the staff of the Louisiana District. He was succeeded by C.H. Hannum, who in turn was succeeded in 1954 by W.G. Bonham. S.G. Anderson was a member of the Marion staff for the entire period. W.E. Hendrick, Jr., joined the staff in the early 1950's. The Marion office staff not only operated the assigned station network, they also computed the records for publication.

The primary activity of District personnel during the decade was the operation of the network of stream-gaging stations. A review of the three WSP's in which the discharge records were published for the 1947 water year indicates a statewide total of about 133 stations. At the end of the decade, according to 1958 program statistics, daily-discharge records were collected at 103 locations. Stage only was collected on a daily basis at two additional sites and periodically at 37 other points on streams. Two daily-reservoir lake-level stations also were operated.

District personnel measured, analyzed, and prepared reports on the magnitude and nature of the several floods in Virginia streams during the decade. This was generally done under the leadership of Tice, a flood specialist who, beginning in 1954, also served part-time as a member of the technical standards section, a staff unit of the branch chief. The flood of June 1954 in the Stocksville-Bridgewater area was reported on by Mussey in Virginia Division of Water Resources (VDWR) Bulletin 10 in 1950. The magnitude and frequency of floods in the

Shenandoah valley of Virginia were analyzed by Tice (USGS open-file, 1950), as were the peak discharges for the Rockville County flood of September 1950 (open-filed). District personnel contributed to WSP 1420 (1960), which covered the flood of August 1955 that extended from New England to North Carolina. The floods of January–February 1957 in southwestern Virginia were documented by Tice and others in an open-file release. A statewide summary of flood discharges for drainage areas of less than 100 square miles was open-filed in 1953. Major storage reservoirs were reported on by Mussey in 1948 (VDWR Bull. 9).

GROUND WATER BRANCH

By Allen Sinnott

The ground-water cooperative program in Virginia, which began with informal headquarters in the Washington, D.C., office of the Survey, continued later with temporary field locations in southeastern Virginia, and finally moved to Charlottesville in the mid-1940's. Thus, by the beginning of the decade, office space had already been occupied in the Brooks Museum on the campus of the University of Virginia for 2 or 3 years. The offices adjoined those of the cooperating agency, the Virginia Geological Survey (VGS). When construction of the VGS building was completed in about 1950, the USGS was assigned generous office space consisting of three large rooms and a storeroom, all on the main floor in the rear of the building. These quarters were occupied through the rest of the decade. A few years later, in about 1954, the building was enlarged and renamed the Natural Resources building in which office and laboratory space was provided for the SW and QW Branches of the Survey.

At the beginning of the decade, formal ground-water studies were underway primarily in the Coastal Plain, although some work had been conducted 2 years previously in the Appalachian valley in the Roanoke area. Assistance was routinely provided to the State geologist in responding to statewide inquiries relative to ground water.

After about 1950 when a ground-water specialist was hired for the staff of the VGS, responsibility for ground-water studies was allocated as follows: U.S. Geological Survey, Coastal Plain; VGS, balance of State (Piedmont, Blue Ridge, Appalachian valley, and Cumberland plateau in the southwest). Even so, the Survey continued to provide assistance in an advisory capacity from time to time for the areas studied by VGS staff.

Early in the 1950's, substantial amounts of additional cooperative funds were offered. These were promptly matched, and provided support for formal investigations in Spotsylvania County by Seymour Subitzky, and in northeastern Virginia and in Accomack and Northhampton Counties on the Eastern Shore peninsula by Allen Sinnott and G.C. Tibbitts, Jr. The Eastern Shore work was launched with a canvass of wells, followed by a program of test drilling along the peninsula, and published in Professional Paper 424-D by Subitzky in 1961, and also as VGS Circulars 2, 3, and 6. The Spotsylvania County study was documented also in USGS Professional Paper 424-D and in VGS Circular 4.

D.J. Cederstrom had been in charge of the Virginia cooperative ground-water program since its inception in about 1937. At the beginning of the decade, he was reassigned to a new program of ground-water investigations in Alaska. However, he maintained his residence in Charlottesville, and was *ex officio* in charge of the Virginia program for a year or so until the Alaska program was fully underway. For short periods, generally during winter months, Cederstrom completed work on the York-James peninsula report (WSP 1361, 1957) and assisted the Virginia program in micropaleontological studies related to stratigraphic problems.

Allen Sinnott transferred from Long Beach, Calif., early in the decade to take over the Virginia cooperative program, first as resident geologist, then in 1950 as geologist-in-charge, and district geologist from 1951 through the end of the decade. C.E. Milner assisted part-time in fieldwork during the early years of the decade. Tibbitts also was employed part-time early in the decade (1948) as a field assistant, and later as field and office colleague in the investigation of the ground-water conditions on the Eastern Shore peninsula. Tibbitts had been co-author of several publications resulting from the investigations in the Eastern Shore peninsula. Among the clerical staff, Mrs. N.M. Ragland (nee Morris) served as office secretary from 1943 to 1950. She returned to work in the QW Branch District office in about 1951. Mrs. F.H. Dowell (nee Head), although primarily working on preparation of camera-ready copy of water-level data for Water-Supply Papers, assisted with clerical duties from time to time during 1947-50. After Mrs. Ragland's departure, Mrs. Dowell became office secretary, holding that position through the end of the decade.

Cooperation between the U.S. Geological Survey's Water Resources Division and the Virginia Conservation Commission (of which VGS was a part) was scheduled to end as of June 30, 1957, so the District program in Virginia was brought to a close at about the end of the decade. Sinnott left in February 1957 to become district geologist for New Jersey. Subitzky joined the Utah District in 1956 and Tibbitts went to Libya, also in 1956. Mrs. Dowell continued until June 1957.

QUALITY OF WATER BRANCH

By Merle E. Schroeder, George W. Whetstone, John G. Connor and Stanley F. Kapustka

At the beginning of the decade, the laboratory was located in the basement of the Cobb Chemistry building of the University of Virginia in Charlottesville where it had been established by G.W. Whetstone in 1945 under the direction of W.L. Lamar, district chemist, Raleigh, N.C. Whetstone was assisted by Mrs. M.J. Carr, chemist, from 1945 until she resigned in 1948, and also by D.G. Walker, scientific aid, from June to September 1947. R.L. McAvoy, chemist, joined the staff in 1948. Mrs. S.B. Noland, chemist, who had served in the D.C. and the Philadelphia laboratories, transferred to Charlottesville in 1951 to process manuscripts for reports on a part-time basis. She resigned in 1953. Jack Lowdon, a scientific aid, served on a part-time basis from 1953 to 1955. Mrs. N.M. Ragland, clerk-stenographer, who had been with the GW District from 1943 to 1950, joined the staff in 1951, and remained until she was reassigned to the local SW District in 1956.

The plan of intensive water-quality investigations of river basins, adopted when cooperation with the Virginia Conservation Commission (VCC) began in 1945, continued into the 1947–57 decade. D.S. Wallace, chief engineer of VCC's Division of Water Resources and Power (who was also district engineer, SW Branch, through a dual-role arrangement) continued as the immediate cooperating official (Follansbee, v. IV).

In 1948, detailed studies were conducted in the Shenandoah River basin, in 1949 in the Roanoke River basin, and in 1950 in the Tennessee River basin. Studies of the other seven basins were in later years of the decade. The laboratory also made analyses and provided support services for QW investigations in South Carolina. For 3 months in 1948, M.E. Schroeder of the Washington, D.C., laboratory was assigned to Charlottesville to catch up on the analyses of a backlog of samples from Pennsylvania. At the request of the VCC and other State and local agencies, numerous water analyses were made of samples from potential industrial sites. Some groundwater analyses were made to support the needs of the GW Branch.

In 1949, Whetstone's title was upgraded to district chemist. McAvoy was his principal assistant. In 1950, at the request of the U.S. Corps of Engineers, plans for sediment investigations in the Roanoke River basin were developed to support construction of hydropower and flood control structures in connection with the John H. Kerr Reservoir.

In April 1950, Whetstone transferred to Anchorage as district chemist for Alaska. The next month, J.G. Connor arrived from Lincoln, Nebr., to replace him as district chemist for Virginia. Because of the increasing number of chemistry students needing laboratory space in the Cobb Chemistry building, Connor's first task was to move the QW lab to a small building (1541 Jefferson Park Avenue), known as the "Bug-House," on the south side of the University grounds. The entire QW crew, assisted and advised by SW personnel, completed the monumental job of refurbishing and moving into the new space within 2 weeks.

In 1951, Wallace (as Chief Engineer, VCC) allocated about $10,000 for additional sediment work. In June, K.H. Kroll, engineer, arrived from the Worland, Wyo., QW office to help plan and operate this program. R.N. Pollard and L.C. Stallings, part-time engineering aids, were soon added to help him. After the untimely death of Kroll in September 1952, the whole staff supported Pollard and Stallings in conducting the sediment program until W.H. Chadwick, engineer, was hired to take charge.

At the time that McAvoy left early in 1952 to join Whetstone in Alaska, the chemical-quality workload was increasing because of requests from the Armed Forces, Corps of Engineers, and other Federal agencies. S.F. Kapustka was hired from the Civil Service Register, reporting in July 1952. He was soon named assistant district chemist.

The daily maximum-minimum water-temperature station on the James River at Scottsville was started about 1953, but did not work very well until steps were taken to reduce the effects of bridge vibration on the recorder. In July 1953, Connor transferred to Salt Lake City, Utah, as district chemist, replacing C.S. Howard, regional chemist. M.E. Schroeder, assistant district chemist of the Columbus laboratory, succeeded Connor as district chemist. Again the laboratory had to be moved, this time to space used jointly with the other two branches in the new Natural Resources building on the University grounds.

Schroeder always had thought that the usual method of filtering sediment samples through asbestos mats, prepared individually in Gooch crucibles, was too time-consuming and the mats too unstable, even leading to frequent negative results on low-sediment samples. He bought some glass-fiber filter-paper circles (GFC's) and had the sediment lab test them thoroughly. The GFC's were much superior to the asbestos mats and saved considerable time and accuracy on each sample. An article by Schroeder about the experience of the Charlottesville laboratory with about 4,500 of the GFC's was published on page 26 of the *WRD Bulletin* dated February 1955. Judging from the correspondence received, practically all of the QW laboratories soon started using this time-saving, more accurate method. Personnel of QW-Raleigh and QW-Columbus found that they no longer had negative results, and Whetstone in Alaska reported even adapting

the GFC's to sulfate analyses. Nationwide, the new method improved accuracy, saved hundreds of hours, and enabled the laboratories to keep up with the many thousands of samples measured through the years.

In December 1956, when Schroeder transferred to Fayetteville as district chemist for Arkansas and Mississippi, Kapustka was named acting district chemist, QW, Charlottesville. This was about the time arrangements were being made for the end to cooperative relations between the WRD and VCC. Kapustka assumed the responsibility for closing the laboratory, transferring personnel, and packing and shipping of instruments, material, and equipment to the laboratory in Austin, Tex., and to his new headquarters in Baton Rouge, La. He left June 15, 1957, but, before he did so, he completed data reports through the date of the end of the State cooperative program in Virginia (June 30, 1957). Such elements of the Virginia program that remained were placed under the Raleigh, N.C., District.

The results of the investigations during the decade, which were published in 1957 as bulletins by the Virginia Division of Water Resources, were entitled "Chemical and Physical Character of Surface Waters of Virginia." Those for 1946–48, authored by Whetstone and McAvoy, were published as Bulletin 11. Records for 1948–51 were documented by Connor and Schroeder in Bulletin 20; for 1951–54, by Schroeder and Kapustka, Bulletin 21; and the final publication by Kapustka for 1954–56, Bulletin 22.

WATER RESOURCES COUNCIL

The Council, which was organized and gradually increased in effectiveness during the early 1950's, established an administrative services section in 1952 that handled accounting and a number of other "housekeeping" functions for the three local districts through the balance of the decade. The section, usually staffed by three persons, was under the direction of V.E. Ragland who had been handling such work for the SW District. Ragland transferred to a position in the Topographic Division's Washington, D.C., headquarters shortly after the end of the decade.

WASHINGTON

SURFACE WATER BRANCH

Condensed from documentation by Fred M. Veatch, with assistance by E.G. Bailey, G.L. Bodhaine, H.C. Broom, J.R. Throckmorton, Mrs. E.M. Smith, et al

The District headquarters remained in the Federal building in Tacoma during all of the decade. A Subdistrict office was established in Walla Walla in January 1952, but moved to Spokane in September of that year. F.M. Veatch served as district engineer throughout the decade, having been appointed to that position in 1940. From February 14, 1957, to beyond the end of the decade, Veatch was absent on an assignment to the U.S. Department of State in the Philippines, during which time J.R. Throckmorton was acting district engineer.

As of January 1948, the District staff included 14 engineers, 6 engineering aids, and 6 secretarial and clerical personnel, a total of 26. By the end of the decade (July 1, 1957, listing) there were 14 engineers, 13 engineering aids, and 5 secretarial and clerical employees, a total of 32. The three senior headquarters engineers of the District staff in 1948 were D.J.F. Calkins, E.G. Bailey, and Throckmorton. As of 1957, the engineers included G.L. Bodhaine, Throckmorton, W.C. Griffin, F.T. Hidaka, W.H. Krabler, and H.C. Broom. Griffin was in charge of the Walla Walla and the Spokane Subdistrict offices until he was succeeded at Spokane by M.M. Miller in 1953. Mrs. E.M. Smith was district clerk and accountant during the decade. Beginning in 1951, a separate field unit headed by Bailey was established in Tacoma to represent the Branch chief in the preparation of special reports and investigations for the Pacific Northwest, Alaska, and Hawaii.

The predominant activity of the District staff during the decade consisted of the collection of streamflow data and the publication and analysis of basic streamflow records, largely in direct fund-matching cooperation with State, county, and municipal agencies. Normal procedure was to design each program in collaboration with the cooperator, often with a joint field reconnaissance, so as best to plan and program the water information needed. The major cooperator in this State was the Department of Conservation, which in fiscal year 1958 (data for earlier years not readily available) contributed $60,000 that was matched by the Geological Survey. Continuing with fiscal year 1958 as an example, the total amount of direct matching funds (both sides) was $243,443 contributed from the following cooperating agencies: State Department of Conservation; State Department of Fisheries; State Department of Game; State Department of Highways; city of Seattle, Departments of Lighting and Water; city of Tacoma, Light and Water Divisions (both in the Department of Public Works); city of Aberdeen; city of Bremerton; city of Spokane; Walla Walla County; and town of Waterville. A considerable amount of study and analysis of the basic data by District personnel was necessary in many of the above programs.

Funds provided by the Department of Conservation for matching by the Survey included contributions to the Department's "Stream Gaging Trust Fund" established by the State legislature for that purpose. The nearly 40

contributors to the fund included not only cities and counties, but also private corporations. The funds provided by the corporations were used strictly in the public interest.

Basic-data collection and analysis programs were also conducted for the following Federal agencies during the decade (the total amount for fiscal year 1958 was about $50,000): Corps of Engineers' Seattle, Portland, and Walla Walla districts; Bureau of Reclamation; Bonneville Power Administration; Bureau of Public Roads; Bureau of Indian Affairs; Soil Conservation Service; Fish and Wildlife Service; 13th Naval District; Larson Air Force Base; and Lummi Indian Tribe.

Each year, the Washington District staff implemented a varied program financed only by an allotment of Geological Survey Federal program (unmatched) funds which, for 1958, amounted to $26,502. More than half of this sum was earmarked to conduct special projects described elsewhere in this statement, including the regular preparation of current, prepublication records for the immediate use of cooperators, which were published and disseminated each month by a special WRD office in Portland.

Another source of funds consisted of the payments that were made by ten licensees of the Federal Power Commission for providing streamflow and certain water levels at existing powerplants or at new sites under consideration and study. For fiscal year 1958, these programs totaled $30,672 in the District. During the decade, funds were supplied by the following licensees: Seattle City Light; Crown Zellerbach Corporation; Washington Water Power Company; Pacific Power and Light Company; Puget Sound Power and Light Company; Tacoma City Light; Washington Public Power Supply System; Grant County Public Utility District No. 2; Snohomish County Public Utility District No. 1; and Chelan County Public Utility District No. 1.

The several categories of funds spent by the Washington District, which are described in the preceding paragraphs, amounted to a grand total of $350,794 for the 1958 fiscal year (July 1, 1957, to June 30, 1958). By the end of each fiscal year, every item of the budget was reviewed and either renewed without change, revised to satisfy projected needs, or cancelled if completed.

At the beginning of the decade, records for a large proportion of the 274 gaging stations then in operation were being used by the Corps of Engineers in a comprehensive stream-development report to Congress. Records for more than 50 of the stations were used almost constantly in the operation of existing projects, including Grand Coulee Dam and reservoir, Bonneville Dam, and many others throughout the State. Data from more than 200 of the stations were useful to the State in processing applications for water rights for irrigation, power, and other uses. Data also were useful to parties submitting the applications. Other uses of streamflow records, somewhat unique to nationwide practices, included the design of navigation locks, the study of international water problems, the management or expansion of fish-propagation facilities, and some special investigations such as a study of the effects on streamflow of changes in forest cover. In some areas, the surface-water data were useful in analyzing ground-water regimes and problems.

The so-called small streams program that began in the early 1940's, mainly in cooperation with the State Department of Fisheries and the State Department of Game (game fish), continued to expand in this decade. The runoff-relation technique, developed in this District for making estimates of low flow and minimum discharge for miscellaneous sites on many streams, was believed to be original. Coverage by this long-term network-type of program on small streams was accomplished in western Washington in about 10 years, followed by similar coverage in a few parts of eastern Washington. Data collection from key stations was continued for a number of years and, at some, indefinitely. In addition to collecting and publishing streamflow information, the District was conducting a number of special projects as described in the following paragraphs.

Many streamflow records in Washington were sufficiently long by the late 1940's to permit a calculation of the frequency of various flood discharges and levels. The results of these were widely disseminated to State, county, and private engineers, and they were used extensively in bridge, culvert, and highway design and in land-use planning. The Washington, D.C., staff was of much assistance in training District personnel in these studies, as well as in the field surveys and computations of peak discharges and levels of greater floods. The frequency curves varied so appreciably between basins, however, that District specialists in this field began to identify some of the characteristics of the drainage basins that caused such variations. W.D. Simons reported on such variations and probable reasons for them in the *WRD Bulletin* for May 1948.

A compilation of surface-water basic data for the State of Washington, from the beginning of each station's record to September 30, 1950, was prepared for Survey publication by drainage basins in the 14-part Water-Supply Paper series, under the direction of Bailey who was assisted by Broom. A sequel to this publication, prepared in later years, covered the remainder of the 1947–1957 decade in this drainage-basin format. Part 12 (Washington coast and Columbia River basin above Snake River) was published in 1955, Part 13 (Snake River basin) in 1956, and Part 14 (Columbia River basin below Snake River) in 1958. Bailey, as a representative of the branch chief, also had general supervision of similar compilations for Oregon, Idaho, Montana, Hawaii, and Alaska.

A similar but single-volume compilation of surface-water basic data for the State of Washington was arranged to be published by the State Printing Office through the cooperator, the Department of Conservation. Compilation was prepared for each station's entire period of record through September 1953 by Broom who was assisted by M.L. Hollander. In compliance with the wishes of the State, this publication included many low-flow records on small streams that were not included in the above-described Federal volumes.

Annual runoffs in the Columbia River basin were compared by C.C. McDonald and H.C. Riggs for the 1928–45 period (Circ. 36, 1948). The description of the Hamma Hamma, Duckabush, and Dosewallips Rivers relative to water-resource potential was published in 1952 as USGS Circular 109. The evaluation of streamflow records in the Yakima River basin by H.B. Kinnison is documented in Circular 180 (1952). The State Department of Conservation also published hydrologic-data summaries.

Investigations of major floods included those of May–June 1948 in the Columbia River basin by S.E. Rantz and Riggs (WSP 1080, 1949); those of 1956 in Esquatzel Coulee area by D.G. Anderson and Bodhaine (open-file); and flood of February 1948 in the Palouse River basin (open-file). Past floods were also analyzed. Those in the Puyallup and Chehalis River basins were studied by I.E. Anderson in the late 1940's (WSP 968-B, 1948). Past floods in the Skagit River basin were documented by J.E. Stewart and Bodhaine (WSP 1527, 1961). Bodhaine and D.M. Thomas catalogued the magnitude and frequency of floods in Washington (open-file, 1960). Highway engineers of the State and the counties made much use of these reports, largely for designing bridges and culverts to withstand probable floods.

Rantz, on detail to Tacoma from the San Francisco District from October 1946 to September 1947, made a study of flood frequency in the Columbia River basin. In 1949, Bodhaine, working with flood specialists Hollister Johnson, S.D. Breeding, and J.M. Terry, verified roughness coefficients in stream channels in the Columbia River basin. In 1951, Bodhaine was designated flood specialist for the Northwest area.

Cooperative snow surveys, begun in this District in 1944, were continued and expanded during the decade. They were limited to western Washington, because those in eastern Washington were being conducted by the Soil Conservation Service and Washington Power Company headquarters personnel in Spokane. Snow surveys, which consist of the measurement of snow depth and water content at various locations in the mountains, are used for forecasting low-season water supplies, which is helpful to agriculture interests and for the management of reservoir storage.

In the 1940's and 1950's, snow surveys and mountain stream gaging were conducted mainly by two-man parties who snowshoed or skied to the sites (although a few sites were reached by helicopter), and some overnight stops had to be made at either the Survey's own shelter cabins or those maintained by the U.S. Forest Service. The cabins were maintained and stocked with food during summer, which was frequently brought in by pack horse. For a number of years, the District used 16 such cabins. The winter work was quite arduous and somewhat hazardous and, for that reason, the policy of stocking the cabins with "the best food money could buy" seemed worthwhile. A few anecdotes about this type of field work follow. A field party unable to find the cabin after dark and in a snowstorm had to spend the night under a tree. Next morning they found the cabin just a short distance away. A man carrying a heavy pack slipped off of the narrow trail on a steep hillside and rolled and bounced several hundred feet, badly injuring his neck. His companion snowshoed several miles for help, and received an Interior Department award for this. Occasionally, when reaching the cabin at night, a field party would find that a bear had broken in and ravaged the place, leaving little that was edible. An inexperienced young man, in a field party of two, was told to build a fire in the cook stove while the older experienced man went to a stream to get a bucket of water. He returned to find that a badly smoking fire had been built in the oven. A man snowshoeing with a heavy pack slipped and fell into a deep melt hole that had formed around a tree. He fell headfirst and became wedged between the snow wall and the tree trunk, with his showshoes above him. He said later he doubted he could have gotten out alone. His companion laughed for a while at his predicament before helping him out. The men sometimes had to share a cabin with rats. Once, in the night, one of the men, hearing a rat on a rafter nearly overhead, shot at the sound with his revolver. Next morning, the rat's neatly severed tail was found lying on the floor below.

In 1947, the District acquired some surplus property from the Navy at the Naval Base just south of the Tacoma city limits. The property consisted of 5.5 acres of fenced, mostly paved land on which three permanent buildings had been built. This property made an excellent facility for the District's construction personnel who stored their supplies and power tools there, and prefabricated gage houses, wells, cableway cars and towers, and small shelter cabins, some of which had to be packaged for pack-horse transport. The facility was also used for the repair and reconditioning of field equipment and minor structures. The Base, as it came to be known, also provided storage space as needed by the District. The Base was managed by L.V. Jacobs who was responsible for maintaining adequate stocks of necessary construction tools, supplies, and materials, and stocks of prefabricated structures and parts.

GROUND WATER BRANCH

By Maurice J. Mundorff

At the beginning of the decade, the Washington State program was a part of the Oregon-Washington District with headquarters in Portland, Oreg. R.C. Newcomb was in charge. In February 1949, M.J. Mundorff transferred from the North Carolina District to Portland. On July 1, 1949, the Portland office furniture was divided, and Mundorff and J.E. Sceva drove a truck with the Washington State share of furniture, equipment, and supplies to establish the District office of the GW Branch in Tacoma. There was no space available in the Federal building where the other WRD offices were located, so three "cubbyholes" were found in the SW Branch warehouse at the Naval Supply Annex in Lakewood (just south of Tacoma). A year later, the office moved to 21 South 38th Street, Tacoma, where it remained for the balance of the decade. By summer 1951, the staff had increased to nine technical and two clerical personnel. M.J. Mundorff was district geologist until his transfer to the Idaho District in July 1956. J.E. Sceva was Mundorff's principal assistant until 1955 when he resigned to take a position with the State of Oregon. B.L. Foxworthy served as acting district geologist until the appointment of A.A. Garrett in January 1957. Garrett's senior professional staff as of the end of the decade included Foxworthy, J.M. Weigle, and D.H. Hart. Other personnel who made important contributions during the decade included D.J. Reis, B.A. Liesch, Earl Johnston, R.L. Washburn, D.E. Wegner, G.D. Holmberg, and Ms. M.A. Hillyer.

Ground-water investigations in Washington were supported primarily by a cooperative program between the State Department of Conservation and Development and the U.S. Geological Survey. The biennial amounts contributed to the cooperative program by State agencies increased from $15,600 for the 1947–49 biennium to $38,400 for the 1955–57 biennium, according to a table prepared by Garrett and Kenneth Walters. Other sources of funding included direct Federal expenditures, and transfers from the Bureaus of Reclamation and Indian Affairs. Some small cooperative programs were also conducted for local public agencies (cities, counties, et cetera).

In western Washington, the State and county cooperative programs were aimed chiefly at delineating aquifers, making quantitative appraisals, and identifying problems, including those of water quality. In these rapidly growing urban and suburban areas, ground water was important for community supply. Studies of this type included western Whatcom County (R.C. Newcomb, J.E. Sceva, and Olaf Stromme, open-file, 1949); southwestern Skagit County (Sceva, open-file, 1950); Snohomish county (Newcomb, open-file, 1949; WSP 1135, 1953); Kitsap county (Sceva, open-file, 1954; WSP 1413, 1957); Northwest King County (B.A. Liesch, open-file, 1955; Liesch, C.E. Price, and K.L. Walters, open-file, 1959, later published as State of Washington Water Supply Bulletin 20); Central Pierce County (Sceva and D.E. Wegner, open-file, 1955); and Lewis County (J.M. Weigle and R.L. Washburn, open-file, 1956; and Weigle and B.L. Foxworthy, State Water Supply Bulletin 21). An investigation of the availability of ground water for irrigation in the Fourth Plains area of Clark County was begun in 1949 with funds transferred by the Bureau of Reclamation. The study was expanded to a county-wide investigation with Federal-State cooperative funds (M.J. Mundorff, open-file, 1959; WSP 1600, 1964). Other investigations relative to irrigation in western Washington were in the Yelm area, Thurston County (Mundorff, Weigle, and G.D. Holmberg, USGS Circ. 356, 1955), and in the Grayland watershed, Grays Harbor and Pacific counties (Wegner, open-file, 1956). Investigations in western Washington of local supplies for community use included South Bar area, Grays Harbor County (R.C. Newcomb, open-file, 1947); Earl Sound area, Orcas Island, San Juan County (R.L. Washburn, open-file, 1954); and the Lummi Indian Reservation, Whatcom County (R.L. Washburn, open-file, 1957).

In eastern Washington, area-wide ground-water investigations were chiefly related to irrigation, either as to the availability of ground water, or to the effects on the water table and water quality of large-scale irrigation with surface water. Several local studies related to the availability and quality of water for community and municipal supply.

Ground-water studies in the Walla Walla area, concerning conflicts in water rights and possible overdraft of the aquifers and conducted intermittently since 1933, extended into the 1947–57 decade. Reports released during the decade included one by Newcomb (open-file, 1951, later published as State Water Supply Bulletin 21) and by Donald Hart (open-file, 1957).

Ground-water studies in the Columbia basin project area begun earlier by G.C. Taylor continued through the decade. These studies were chiefly concerned with the effects that large-scale importation and application of surface water would have on the quality of the ground water, the rise of the water table and consequent waterlogging, and the quantity and locations of the major return flows. Because of the extensive pre-irrigation investigations, the effects of the great change in water regimen over an area including nearly 500,000 irrigated areas are well documented. Reports released during the decade include open-file reports by G.C. Taylor, 1948, and by M.J. Mundorff, D.J. Reis, and J.R. Strand, 1952. As chairman of a work group, Columbia Basin Interagency Committee, Technical Subcommittee for Operating Plan, Mundorff prepared a report on estimated return flows for

the Columbia basin project area. This report was restricted to administrative use only.

Studies of the Spokane Valley aquifer, one of the most transmissive aquifers known, were continued on a small scale. Reports released during the decade include a data report by Weigel and Mundorff, and on seismic profiles across the valley by R.C. Newcomb and others.

A study of the limitations on the quantity of ground water available from the deep basalt aquifer in the Pullman area was conducted by B.L. Foxworthy and R.L. Washburn and published as WSP 1655 in 1963. Ground water for irrigation in the Wenas Valley, near Yakima, was studied by J.E. Sceva, F.A. Watkins, Jr., and W.N. Schlax, Jr. (open-file, 1949).

In response to a Federal court order in connection with a dispute between the Yakima Indian Tribe and non-Indian land owners over water rights, B.L. Foxworthy conducted a quantitative investigation of ground water in the Ahtanum Creek basin, Yakima County, published as WSP 1598 in 1962. Local studies included the Kennewick area by Newcomb (open-file, 1948) and the Wellpinit area of Stevens County by Foxworthy (open-file, 1956).

Because of the concern of local citizens about leakage from a large inverted siphon at the south end of Soap Lake on the water level and quality of water in the lake, a quantitative investigation was conducted, at the request of the Bureau of Reclamation, by a joint GW-SW team (M.J. Mundorff and G.L. Bodhaine, open-file, 1954). Other activities of the District staff during the decade included maintenance of a network of observation wells under the supervision of G.D. Holmberg and answering numerous requests from the public for information on ground water.

An interesting episode resulted from the desire of the Navy for a deep freshwater body where they could do underwater sonic testing. When the citizens of northern Idaho protested the use of Pend Oreille Lake for this purpose, Senator Magnuson invited Navy personnel to use a Washington lake. This resulted in a telegram from the Senator instructing the ground-water office to sound Okanogan Lake. A fisherman friend of the Senator had reported that he could not reach bottom with 1,000 feet of line. Profiles measured by District personnel showed the lake to have a maximum depth (as I recall) of 380 feet. Subsequent telegrams suggested Lake Keechelus and Spirit Lake, neither of which proved to be more than 300 feet deep.

TECHNICAL COORDINATION BRANCH

By Charles C. McDonald

A TC District office was established in 1946 to assist in the coordination of regional programs of the Division, and to participate in studies relative to the joint U.S. and Canadian plan for the development of the Columbia River basin for flood control and hydropower. Its headquarters was in Tacoma, and assigned personnel varied from one to four persons. C.C. McDonald, who had been assistant district engineer, Boston, Mass., District, was in charge. Subsequently, he was appointed by Paulsen to the International Columbia River Engineering Board (of which Paulsen was a member), under the direction of the International Joint Commission. The project for the development of the Columbia River basin continued until the final report in 1957.

McDonald transferred to Washington, D.C. in 1955 to become chief of the Branch and was succeeded by W.D. Simons who had joined the staff in 1949. F.W. Kennon was assigned to the District for a period of 3 years, M.F. Meier joined the staff in 1946 for glacier studies, and John Savini was assigned for about a year in 1954.

INTERBRANCH ACTIVITIES

The WRD Council was established and became increasingly active during the decade. One of the significant contributions by the Council was its establishment of a 5-month series of evening classes on hydrology in 1953–54 using the facilities of the College of Puget Sound (WRD Bull., Feb. 1954, p. 20).

Interbranch reports during the period included a study of the water resources of Vancouver by W.C. Griffin, F.A. Watkins, and H.A. Swenson (Circ. 372, 1956), and an investigation of the water resources of the Tacoma area. This study, by W.C. Griffin, J.E. Sceva, H.A. Swenson, and M.J. Mundorff, was published as WSP 1499-B in 1962. M.J. Mundorff and G.L. Bodhaine jointly investigated the rise in the level of Soap Lake (open-file, 1954).

West Virginia

SURFACE WATER BRANCH

Condensed from documentation by L.B. Holland and A.A. Vickers

District headquarters was in Charleston during the decade, first at 408 Union building and, beginning in 1952, in the U.S. Court House. The headquarters staff varied in size from about 7 to 11 or more persons. A field office also was maintained in Elkins to provide better access to the gaging stations in the northeastern part of the State. From three to six persons were headquartered there.

H.M. Erskine was district engineer from 1941 to 1949 when he was designated to head the Bismarck, N. Dak.,

District. He was succeeded by A.A. Fischback from the Georgia District. William Kessler, who established the District in 1929 and continued as its district engineer until 1941, remained on the staff until his retirement in 1955. W.L. Doll moved from Elkins in 1951 and succeeded Fischback as district engineer in summer 1957. K.A. MacKichen, who served as acting district engineer for most of 1949, transferred to the TC Branch in Washington, D.C., in 1951. Other members of the headquarters senior staff included H.G. Hinson, until 1949; G.C. Goddard, 1949–53; A.A. Vickers, from 1950; W.S. Bush, from 1950; and E.D. Bresee, from 1953. Mrs. C.K. Jones served as district clerk.

L.B. Holland was in charge of the Elkins office from 1942, except for the period 1948–51 when W.L. Doll served as resident engineer. R.B. Scott, F.R. Green, and C.R. Showen were also among those on the staff.

The composition of and changes in the District's data-collection program on West Virginia's streams are partially revealed in Fischback's report of July 1951 and a later schedule compiled by Doll for fiscal year 1958. The 1958 values shown parenthetically after the 1951 statistics in the next paragraph may vary from those of fiscal year 1957 because of program changes.

Of the 103 (90) locations for which daily discharge was published, 41 (35) were supported under cooperative programs, 9 (11) were under the Federal program, 52 (43) were financed by other Federal agencies, and 1 (1) by permittees and licensees of the Federal Power Commission. Locations at which periodic discharge measurements were made increased greatly from 19 to 85. Daily temperature was recorded at 11 (11) stream locations.

The West Virginia Water Commission was the primary State cooperating agency, and the Public Service Commission also provided support. The State Highway Department cooperated in the operation of a number of crest-stage gages, data from which were of value in the design of highway drainage structures. Cooperative programs with Kanawha County and the city of Clarksburg also provided funds for the data network.

The Corps of Engineers furnished support for 41 gaging stations as of 1958. They needed the discharge records for the planning and design of the proposed Rowlesburg Dam on the Cheat River, and for another dam under study on the Little Kanawha River near Brownsville. They also needed inflow and outflow data for the control of reservoir levels above the dam at Grafton, as well as for other purposes. The Soil Conservation Service supported two gaging stations.

Vickers recalls that the total funds available annually to the District in 1951 or 1952 amounted to only about $65,000, and the fact that those funds supported a sizable staff was a tribute to the management skills of those in charge. In retrospect, "it is amazing that so much was accomplished with so little."

Streamflow and other surface-water data were used largely in public and industrial water-supply projects and to plan for storage on tributary streams to augment low flow and reduce flood damage. The District reported in 1950 (McGuinness, Circ. 114, p. 122) that "a recent request for data on quantity and duration of flow at 34 localities could be answered definitely for only 7 and by rough estimates at others." The implication was that the streamflow data was inadequate to meet current needs.

Vickers states that, because only about 40 percent of the gaging stations were equipped with cableways, aluminium car-top boats were standard equipment. (Hinson described the newer and lighter boats on page 46 of the May 1946 issue of the *WRD Bulletin*.) Several stations were accessible only by foot trails as much as 4 miles in length. Radio-transmitting equipment was installed at the gage on Bluestone River near Pipestem in 1950 to permit prompt transmission of data. Vickers also recalls that the computations of daily discharge for the five slope-type stations on the Kanawha and Ohio Rivers were particularly time-consuming, usually requiring 35 to 40 percent of the equivalent effort applied to the total network of about 90 stations. He states further that the most severe flooding during the decade was in the southern part of the State during spring 1957.

The rigors of stream gaging were well known to the West Virginia personnel, especially during winter months. Holland recalls wading measurements at near-zero temperatures when the meter would quickly freeze when taken from the water and that the ice near the bridge piers was too thick to break. He states that the Elkins staff not only operated the station network, but also computed daily-flow records. They also made a survey of the discharge of springs within their operating area, the findings from which led State officials to locate a new fish hatchery at Bowden near Elkins instead of near Wardenville as originally planned.

The water resources of the Wheeling-Steubenville area in West Virginia and Ohio were studied by an interbranch team in the early 1950's and the findings were published as USGS Circular 340 in 1955. Doll was the District's participant.

GROUND WATER BRANCH

By Gerald Meyer

Merely about three percent of the water used in West Virginia (not including that used for water power) was derived from ground-water sources during 1947–57, but the resource's importance was much greater than that small percentage implies. Ground-water resources supplied 75 percent of the public water systems, most of which were owned by coal-mining companies, and

virtually the entire requirements of the State's rural population. Of the State's population of 1.8 to 2 million during the period, more than 1 million people depended on ground water for their water supply. In addition, many hundreds of commercial and industrial establishments were self-supplied with ground water, pumping a little more than half of the approximately 130 million gallons per day of ground water withdrawn for use.

Appreciation of the value of the resource and the rising level of concern for the contaminating effects of coal mining and petroleum production stimulated a formal but modest cooperative program of ground-water studies in 1941 between the U.S. Geological Survey and the West Virginia Geological and Economic Survey (WVGES). Funding totaling $5,000 annually—sufficient to support one geologist and a part-time Federal or State-supplied clerk—remained unchanged through fiscal year 1947. Funding rose to $6,400 in fiscal year 1948; to $8,400 in 1949, of which $1,000 was direct-expenditure credit to the State cooperator; and to $15,761 in 1954, which included $12,200 of matched cooperative funding and $3,561 from carryover funds and special Federal project funding. Funding continued at approximately the 1954 level until July 1957 (fiscal year 1958), when financial support increased sharply as the result of joint efforts of Dr. Paul H. Price, State geologist and director of the WVGES, and C.W. Carlston, district geologist for the U.S. Geological Survey. Total funds that year amounted to $37,830, of which $30,000 was provided by the regular cooperative program, $7,200 by a new matching arrangement with Kanawha County, and $630 of Federal funds for observation-well measurements under the collection of basic records (CBR) program. The Kanawha County project was the first formal interdisciplinary water-resources study initiated in the State, with full funding for the joint participation of SW, QW, and GW Branch personnel amounting to $12,200 in the first year of the study.

Programs and accomplishments during the period are best documented by a chronological summary of personnel, their activities, and the publications they produced. In 1947, H.F. Johnston, resident geologist, who had transferred to Morgantown from the Baltimore, Md., District office 2 years earlier, prepared a brief journal paper (1949) assessing the State's ground-water problems, the availability of ground-water supply, and chemical character of the resource. A paper prepared in 1945 by R.M. Jeffords, Johnston's predecessor, described ground-water supplies available for mining communities (USGS open-file, 1949). Jeffords wrote that probably about 400 million gallons per day of ground water was drained or pumped as waste from coal mines, about three times the rate of statewide withdrawal for use at the time.

Johnston was under the general supervision of R.R. Bennett, district geologist for Maryland. Bennett and the Maryland staff continued the West Virginia operation after Johnston resigned in October 1947 until the arrival of R.L. Griggs from Albuquerque, N. Mex., in March 1948.

As was the case with their predecessors, both Johnston and Griggs were called on to conduct brief, local ground-water investigations from time to time to provide water-resources information to assist towns, cities, and other public entities in the resolution of their water problems. By 1957, several dozen such brief reports on investigations had been completed, some of which were published in journals or State series and 17 of which were placed in the open-files of the Survey for ready public access. Collectively, these small reports constituted an informative sampling of ground-water conditions throughout the State at a time when little of the State's ground water had been investigated with any degree of thoroughness.

Griggs returned to the Albuquerque office in June 1949 and was replaced by R.C. Smith who transferred to Morgantown from the Ohio GW District in September 1949. Smith was geologist-in-charge of the Morgantown field office, and apparently the office remained under the general supervision of the Baltimore District. Smith was assisted by H.V. Tucker, Jr., a geologist who was employed in October 1949, and who served in Morgantown until January 1951 when he transferred to Salt Lake City, Utah. Tucker went on military furlough there and resigned in February 1957. Smith authored an open-file report (1952) on water-supply conditions of the carbonate-rock terrane in the area of White Sulphur Springs, Greenbrier County, and collaborated with W.L. Doll and Garland Stratton in the preparation of USGS Circular 340 (1955) on water resources available to the steel-manufacturing Wheeling-Steubenville area of West Virginia and Ohio. V.T. Stringfield, a Branch research geologist stationed in Washington, D.C., co-authored a report with Smith in 1956 on the relation of geology to the large floods and landslides that accompany some heavy rains in mountainous areas of eastern West Virginia. This report was based on their investigation of a massive mountain slope slide near Petersburg in Grant County (WVGES, Inv. 13).

Tucker was replaced by G.D. Graeff, Jr., who was hired in January 1951. Graeff prepared a brief open-file report (1953) on ground-water occurrence and availability in the vicinity of Inwood, Berkeley County, an area underlain by carbonate-rock aquifers typical of the Eastern Panhandle of West Virginia. C.W. Carlston transferred from the New York District's area office in Albany in July 1953 to replace Smith who resigned in March 1953. Carlston was the first supervisor of the Morgantown office to be titled district geologist, and West Virginia apparently became an official GW Branch District coincident with his assignment to the State. Carlston described the status

of knowledge of the State's ground water in an open-file appraisal report (1954). In 1955, he and Graeff collaborated in the preparation of a detailed report on the State's most prolific and most economically important aquifer system, the Ohio River valley alluvium. The comprehensive volume (WVGES, v. 22, pt. 3, 131 p.) constitutes the most orderly description and cataloging of hydrogeological data collected in the Ohio River valley since the start of the Federal-State cooperative program 14 years earlier. Carlston subsequently prepared a manuscript on the ground-water resources of Monongalia County, one of the first two in a planned series of county reports for the State.

Graeff transferred to the Alexandria, La., field headquarters in September 1954. P.P. Bieber was reassigned to Morgantown from the Geologic Division headquarters in Washington, D.C., in June 1956, and his first project was to update for publication a manuscript on the ground-water resources of Harrison County, started in 1941 by the first GW Branch representative in the State, R.L. Nace. B.M. Wilmoth, Jr., transferred to the District from the Geologic Division in November 1956, and was stationed in Charleston, Kanawha County, to begin an investigation of the water resources of that county in association with W.L. Doll, district engineer, and G.W. Whetstone, district chemist for Ohio.

Continuity of statewide ground-water-level observations throughout the period were made possible by cooperative program project funds and by Federal CBR funds of a few hundred dollars. The maximum was $630. The measurements were recorded in WSP's 1097, 1127, 1157, 1166, 1192, 1222, 1266, 1322, 1405, and 1538. The records include data for several large springs in the carbonate-rock regions of eastern West Virginia whose discharge was gaged by SW personnel. H.M. Erskine, district engineer in Charleston, published (W. Va. Cons. Comm., 1948) records of discharge of the principal springs of the State and described their flow characteristics. He listed 208 springs with estimated minimum discharge of 100 gallons per minute or more; more than half of these were in the Eastern Panhandle of the State in the carbonate-rock valleys of the Valley and Ridge Province. The following year, W.E. Davies of the Geologic Division of the USGS, described (WVGES, v. 19, 330 p., 1949) the origin and geologic features of about 400 caverns mainly in eastern West Virginia. The elongated, sinuous channels through the carbonate rocks represent avenues of ground-water movement to points of discharge at the large springs typical of the eastern part of the State.

Clerical services during the period were provided in large measure by the staffs of the WVGES and the Baltimore District office. Records of clerical personnel are incomplete, but they include Marguerite T. Robinson from January to April 1947; Stella Dawczyszyn, a State employee, from May 1948 to an unknown date; followed by others of part-time or intermittent service until July 1957, when Anna B. Trowbridge was hired for full-time Federal service as the district clerk-typist.

QUALITY OF WATER BRANCH

The Columbus, Ohio, District was responsible for work in West Virginia. A program data sheet by W.L. Lamar, district chief, shows that daily records of chemical quality of surface waters were collected at nine locations in 1951, probably along the Ohio River or its tributaries, in cooperation with the Ohio River Valley Sanitation Commission (ORSANCO). Program statistics for fiscal year 1958 show a continuation of the ORSANCO cooperation, participation in an interbranch cooperative study of the water resources of Kanawha County, and assistance to the SW Branch in the Salem Fork demonstration project in which the District staff operated a sediment station from 1954 on. The Columbus laboratory personnel also prepared a chemical-quality analysis of well-water samples collected by the GW District staff in Morgantown.

WISCONSIN

SURFACE WATER BRANCH

By Francis T. Schaefer

F.C. Christopherson continued as district engineer with a fairly stable office force until his death in early 1954. The District headquarters was in the State office building on the shore of Lake Monona. In July 1954, F.T. Schaefer reported as district engineer, transferring from Louisville, Ky. R.H. Brigham continued to serve as assistant district engineer. L.E. Bidwell, one of the senior engineers, transferred to Columbus, Ohio, in 1947 at about the time D.L. Miller was added to the professional staff. In 1949, F.C. Dreher was appointed as a junior engineer about the same time that Miller transferred to the Washington District. Throughout the period, Brigham and D.C. Hurtgen continued to carry a major portion of the workload in both field and office. With some expansion of the workload in 1952, B.L. Kaupanger was added to the staff. In 1954, M.W. Busby and, in 1955, D.C. Conger, both recent graduates of the University of Wisconsin, were appointed, worked a short time, and then went on furlough for military duty before returning to the Survey. In 1955, J.A. Bettendorf transferred in from the District office in College Park, Md. He was detailed shortly thereafter to Hartford, Conn., to work on the New England hurricane

floods of 1955 that devastated so much of the Northeast. In 1956, he was reassigned to Trenton, N.J.

Shortly thereafter, a program to develop flood-frequency relations for Wisconsin streams was arranged with a new cooperator, the Highway Commission. The program included hydraulic analyses of bridge sites and the establishment of continuous-record stations and crest-stage gages to provide information for small drainage areas for which streamflow data were deficient. D.W. Ericson transferred from the Nebraska District and took charge of the program, which added a new dimension to the breadth of District activities. Throughout the period, the Public Service Commission continued to be the principal cooperating agency, as it had been since 1913 when the District was established under the direction of W.G. Hoyt.

Stream-gaging operations also continued in collaboration with Corps of Engineers districts in St. Paul, Minn., Rhode Island, Ill., and Milwaukee, Wis. The Milwaukee COE district eventually moved to Chicago, Ill.

During the period, the Wisconsin Department of Conservation became interested in the water quality of streams, particularly relative to sediment transport and deposition in trout streams. As a result, several stations were established, in cooperation with that agency, to start evaluating sediment characteristics. Other work with the Fish and Wildlife Service involved the determination of the water budget for Horicon Marsh, a wildlife refuge.

Work with Federal Power Commission licensees began during the period. Some such work had been incorporated in the regular program but, at this time, it was decided to request reimbursement to the District in accordance with provisions of the FPC licenses for the cost of obtaining the necessary stage and flow records at their hydropower installations.

Toward the end of the period, a small program with the Madison Metropolitan Sewerage District was arranged to measure the effects of its diversion of treated effluent to a small stream that drained into the Madison chain of lakes below Lake Monona. A modest program with the Committee on Water Pollution, an independent State agency, also continued. Its primary interest was related to stream pollution from the numerous paper manufacturing industries. Other work was conducted on a reimbursement basis with the Soil Conservation Service relative to rates of sediment deposition in several of its small detention reservoirs.

At the end of the decade, there were in operation approximately 100 daily-discharge stations, four daily-sediment and temperature stations, and six stage-only stations. Periodic measurements of discharge were being obtained at 32 additional sites, and water temperatures were being measured periodically at 69 stations. One daily-reservoir-stage recorder was in operation, and about 27 lake gages were being maintained. Duration tables for all streams were continued and updated every 2 years for use by the Public Service Commission in the determination of allowable surface-water diversions.

GROUND WATER BRANCH

By William J. Drescher

The basic ground-water program in Wisconsin during the decade consisted of continuing investigations of the deep aquifers in the eastern part of the State, and investigations in the central irrigation districts and in the southwest mining area. The studies in the Milwaukee, Green Bay, Outagamie County, and Fond du Lac areas were reported in WSP's 1190 (1953), 1229 (1953), 1421 (1957), and 1604 (1962), respectively. The rapidly increasing use of shallow ground water for irrigation in the sand plains was studied from 1948 to 1951 and was reported in WSP 1294 (1955). Another study was begun in Portage County where ground water was pumped for irrigation and surficial water drains and dams were used in an effort to control water levels. An investigation of water entering the zinc-lead mines of southwestern Wisconsin was started in 1951.

Because of its relative proximity and because there was no USGS ground-water program in Illinois in 1947, the Wisconsin District took over the ground-water studies at Argonne National Laboratory (ANL) southwest of Chicago. This work consisted primarily of aiding the laboratory in developing its water supply, but also included studies of dewatering and foundation stability of some of the buildings and reactors, and a study (in retrospect) of the original waste-disposal site for the Manhattan Project. An interesting aside to this study is that a former Survey employee criticized W.J. Drescher's advice to the ANL and predicted total failure of the water supply by the early 1960's. Two decades have passed without a problem!

In the early part of the decade, 1949–50, Cecil Spicer and George Edwards (Geologic Division) came to Wisconsin. They brought electrical resistivity equipment and extensively studied the Marshfield, Neillsville, Fond du Lac, and Antigo areas to define the depths and extent of shallow aquifers.

In 1949, F.C. Foley, district geologist, was sent to France on assignment to the Defense Department to advise on water supplies available for maintenance of the grounds of cemeteries of American war dead. In his absence of 4 months, the District continued and expanded despite a near total lack of experienced direction. In 1951, Foley resigned to become the ground-water chief for the State of Illinois; he later went to Kansas as State Geologist and never lost his place as a leader among cooperators with the Survey.

W.J. Drescher succeeded Foley and continued as district engineer until 1956 when he was designated branch area chief for the Mid-Continent Area; his headquarters remained at Madison. C.L.R. Holt, who had been assistant district geologist, acted in that capacity until he was appointed district geologist in 1958. Others who served in District activities for periods of 2 or more years included G.E. Hendrickson (through 1948); Eugene Daniels (1948–50); A.H. Harder (1949–53); V.T. McCauley (1951–54); K.F. Anderson (1953–55); T.G. Newport (from 1953); E.F. LeRoux (from 1954); and W.K. Summers (from 1955). The District staff was located in space in Science Hall, University of Wisconsin, during the entire period.

During this decade, E.F. Bean, a most supportive and capable cooperator, was succeeded by George Hanson as State geologist. Hanson also proved to be very strong supporter of the cooperative program.

In September 1951, the District was host to the first of the series of 12 short courses conducted by the Branch throughout the country. The University of Wisconsin at Madison provided classroom space, food, and lodging. The fifth of the short courses was also held at the University of Wisconsin in 1953.

QUALITY OF WATER BRANCH

The program in Wisconsin was small and was conducted by personnel from the Columbus, Ohio, District. The actual operation of the three or four stream stations, at which fluvial-sediment discharge-data were collected from 1954 on, was by the SW Branch staff and samples were sent to the Columbus laboratory for measurement and computation. The work was in cooperation with the Wisconsin Department of Conservation through its Committee on Water Pollution. The Columbus laboratory staff also analyzed the well-water samples collected by personnel of the GW Branch. C.R. Collier, the District sediment specialist, prepared a report on the sediment movement in small streams in Wisconsin during 1954–59 that was released to the open-files.

WYOMING

SURFACE WATER BRANCH

By Harold P. Eisenhuth and Mervin S. Petersen

The surface-water investigations in Wyoming continued under the direction of the Denver, Colo., District during the entire decade. Two area offices were maintained until near the end of the period, one at Riverton and the other at Sheridan. The Riverton and Sheridan staffs varied from one to four people. Three field headquarters were also maintained: the one at Worland was used until 1955, the Kemmerer location was reopened in 1948 and continued beyond the end of the decade, and the Douglas headquarters was used from 1946 to 1956.

The Sheridan headquarters was under the direction of H.P. Eisenhuth from July 1947 until February 1951 when he began a detail to Washington, D.C., followed by a transfer to the Denver District office. He was succeeded by G.L. Haynes, Jr. About 35 gaging stations in the northern part of the State were operated out of the Sheridan office. In July 1956, Haynes transferred to Casper to be in charge of the newly established area office at that location, which, as of July 1957, had a staff of nine employees. Later, the activities of the other Wyoming offices of the Branch were consolidated at Casper. Haynes was assisted by R.I. Smith.

The Riverton office, which was not maintained continuously during the first several years, was under the direction of M.S. Peterson who had transferred from the Logan, Utah, office in May 1949. Peterson remained until May 1954, when he began a 4-month detail to review records in Washington, D.C., prior to a transfer to Rolla, Mo. He was succeeded by R.I. Smith. The Riverton staff, which included personnel from the QW Branch, worked primarily on studies of the Wind River project, but maintained all stream gages from Dubois to Boysen Dam.

W.P. Fulton maintained the Worland headquarters until 1950. W.H. Krabler was in charge during 1950, followed by C.W. Browne until 1952. C.F. Obert was in Worland during the final 3 years it was open. Personnel from this office maintained stations in the Yellowstone River basin from Boysen Dam to Lovell.

A.S. Sollid maintained headquarters at Rock Springs until he transferred to the Montana District, leaving the office vacant. Thereafter, the stations in the Great Basin near Cokeville and those of the Green River basin near Daniel were operated from the Denver office until L.F. Hanks transferred from Lincoln, Nebr., to Kemmerer in September 1948. C.E. Keliher transferred to Kemmerer from Denver about the same time. Hanks died in June 1949 and E.R. Jereb transferred from Denver shortly thereafter to succeed him. In 1950, Jereb transferred to another government agency and Keliher transferred to Lamar, Colo. Apparently the Kemmerer office was vacant until W.R. Scott transferred from Riverton in 1952 to take charge of the office. J.O. Ragsdale transferred from Denver to Kemmerer in July 1952. Scott transferred to Pennsylvania in 1956, but Ragsdale continued the operations at Kemmerer until 1962 when Wyoming became a District under L.A. Wiard.

H.E. Hodges transferred from Denver, Colo., to Douglas in April 1946 to conduct an investigation on the

North Platte River to determine the loss in transit of water released from the Bureau of Reclamation's Seminoe-Pathfinder-Alcova reservoir system. This water flowed to Guernsey Reservoir and then to the Tri-State Dam in Nebraska, a total of 232 miles.

Federal-State cooperation during the decade was primarily with the Wyoming State Engineer (nearly 90 percent as of fiscal year 1958), and the remainder was with the National Resources Board. Major funding also was received from the Bureau of Reclamation through the MRB program. The Bureau also contributed other funds for assigned work, as did the Corps of Engineers. The total annual budget, all funds, as of the end of the decade, was in excess of $150,000.

Several well-defined construction programs relative to the development of Wyoming's most valuable natural resource—its water—were begun during the decade. Boysen Reservoir on the Wind River, Glendo Reservoir on the North Platte River, and the Keyhole Reservoir on the Belle Fourche River were completed during this decade, and the Owl Creek project had reached the construction stage.

GROUND WATER BRANCH

Condensed from documentation by H.M. Babcock

The Federal-State cooperative program in Wyoming continued under the direction of the Denver District until September 1951 when H.M. Babcock was designated district engineer. He continued in charge through 1957. At the beginning of the decade, D.A. Warner was resident geologist at Cheyenne, followed by C.C. Williams and (in 1948) by R.T. Littleton as geologists-in-charge. Initially the office was located in the State Capitol building. In 1949, it moved to a leased Federal building located about two blocks from the Capitol building.

That portion of the MRB program that included northern Wyoming was initally under the Billings, Mont., District. This began with a study of the Heart Mountain project near Cody by F.A. Swensen in summer 1946. During summer 1947, Swenson, assisted by Kenneth Bach, conducted a study of the Paintrack irrigation project near Manderson. In 1948, the Billings District was established, and district geologist Swenson opened a field office in Riverton, Wyo., placing D.A. Morris in charge. Studies were begun on the Riverton irrigation project and its extensions with the assistance of O.M. Hackett and later of K.E. Vanlier. In 1951, F.A. Kohout of the Terry, Mont., field office, conducted a study of the Kaycee project near Kaycee, Wyo. By 1954, MRB program funds were greatly reduced, and that part of the program formerly under the Billings District was transferred to the Cheyenne District.

In 1949, activities under the MRB program were extended to include a portion of the North Platte River basin in Wyoming and western Nebraska, and H.M. Babcock transferred from Phoenix, Ariz., to Cheyenne to supervise this work. Babcock was designated as engineer-in-charge and reported to the district geologist in Denver. Investigations by the Cheyenne staff under the MRB program continued in Wyoming until 1953. As that program began to phase out, the Federal-State cooperative activities expanded, and some of the personnel from the MRB program were assigned to the cooperative work. During 1947–1957, the number of professional personnel ranged from one in 1947 to a peak of seven in 1953, and declined to three in 1957. F.N. Visher and J.R. Rapp joined the Cheyenne staff in the latter part of 1948. Visher moved to Torrington when that office opened in 1949. Rapp's initial efforts were in the Egbert-Pine Bluffs-Carpenter area (WSP 1140, 1953) and on MRB program reconnaissance projects. In 1951, he began a detailed study of an irrigation project in the North Platte River valley (WSP 1377, 1957). Several short municipal water-supply studies followed, which were in cooperation with the State Engineer. Rapp transferred to the Minnesota District in 1953. D.A. Morris joined the Cheyenne District headquarters when the Riverton office closed in 1953, as did D.W. Berry. During the following 3 years, the staff conducted a series of investigations to determine the availability and quality of water for irrigation, municipal, industrial, and domestic uses from a wide variety of hydrologic environments. H.A. Whitcomb and C.J. Robinove replaced Morris and Berry in 1956.

The Torrington headquarters was established because of its proximity to projects in southeastern Wyoming under both the State cooperative program and the MRB program, the latter including some work in Nebraska. The Goshen County study (Circ. 238, 1953) was an example of projects under the State cooperative program. The water-availability investigation on the North Platte River, under the MRB program, started under the Denver District and was taken over by Babcock on his arrival in Cheyenne. The staff was augmented by hydrologists from Cheyenne on temporary detail. Visher transferred to Montana in 1952, the year that E.A. Bradley and L.J. Bjorklund arrived. Bradley conducted a reconnaissance of the Niobrara River basin in Wyoming and Nebraska (WSP 1368, 1956), and Bjorklund collected data for the Upper Lodgepole valley study (WSP 1483, 1959). The Torrington office closed in fall 1953.

With the exception of the long, continuing, ground-water-level monitoring program and studies in the Pine Bluffs and the Platte County area, investigations under the State cooperative program were general areal studies and site studies for individual cities. Ground-water development for irrigation and other large uses had not

progressed very far, and there were no areas of serious ground-water depletion. Hence the funds available were used to conduct reconnaissance-type studies to identify aquifers in areas that had a potential for later development.

The study of underflow in the Niobrara River basin by H.M. Babcock and C.F. Keech (open-files, 1957) was of special significance as it provided ground-water-flow measurements used in the assignment of water according to the provisions of the Niobrara River Compact. This was the first time that combined surface- and ground-water flow was made a part of a river basin compact dividing the water between two States.

QUALITY OF WATER BRANCH

By Russell H. Langford

The Lincoln, Nebr., Regional office staff conducted the program in Wyoming through an area office in Worland and a field headquarters in Riverton. The staffs of these offices operated the stations for collecting sediment and chemical-quality data primarily in the Bighorn, Tongue, and Powder River basins of north-central Wyoming. The area office staff also operated several streamflow stations in the vicinity of Worland. The area office was headed throughout the decade by T.F. Hanly who transferred from Charlottesville, Va., in 1946. He was assisted by W.L. Haushild, G.C. Lusby, B.H. Ringen, H.B. Fabricius, and D.W. Brownell in Worland, and by R.C. Williams in Riverton. A laboratory was established in Worland to conduct sediment-concentration and particle-size analyses. L.R. Petri later joined the Worland staff.

The Regional office staff in Lincoln also particpated in investigations in Wyoming. Chemical-quality sections of ground-water-resources reports were prepared for the Kaycee irrigation project by F.H. Rainwater (WSP 1360-E, 1957); Riverton irrigation project by W.H. Durum (WSP 1375, 1959); Goshen County by W.H. Durum (WSP 1377, 1957); Upper Lodgepole Creek by R.A. Krieger and E.R. Jochens (WSP 1483, 1959); Platte County by R.H. Langford (WSP 1490, 1961); Greybull River-Dry Creek area by R.H. Langford (WSP 1596, 1963); and Crook County by R.H. Langford (WSP 1698, 1964).

In addition, two distinctive reports on the geochemistry, chemical-quality of surface water, and sediment characteristics of streams in the Wind River basin were prepared by the Lincoln staff. The first, WSP 1373 (1956), covered drainage of the Wind River and its tributaries; the second, WSP 1535-E (1961), described chemical degradation on opposite flanks of the Wind River Range. C.H. Hembree, F.H. Rainwater, and B.R. Colby conducted the studies and prepared the reports.

Part V—Research, Methodology, and Instrumentation

Although funds specifically identified as being for hydrologic research had been requested for a number of years, Follansbee (v. IV, p. 21) reported that it was not until fiscal year 1947 that Congress appropriated $37,000 for that purpose. The Water Utilization Branch was assigned the responsibility for formulating the program and allocating those research funds to the three operating branches. The District offices were asked by a Division Circular dated March 2, 1950, to suggest studies that "seek to develop new principles, techniques, or equipment of general application to hydrology and the work of the Water Resources Division." In his Circular dated October 16, 1950, the CHE made a field survey of research scheduled or underway and declared research to be "one of the fundamental objectives of the Water Resources Division and . . . inherent in nearly every investigation." The Washington, D.C., office personnel had found that they did not have enough information about the actual extent of current research activities to enable them to make the required presentation to the Bureau of the Budget, to Congress, and to defense agencies such as the Research and Development Board. The replies received in response to the October 16 Circular revealed that there were 110 research projects underway, about one-half under the Federal-State program. The replies also revealed that viewpoints varied as to what actually constituted research. Current research activities were inventoried annually during most of the balance of the decade.

The CHE's report to the Director in October 1955 referred to steps the Division had taken to further strengthen its research program. The report stated that "in recent weeks five particularly qualified men have been officially moved into new positions wherein their efforts may be more exclusively devoted to research subjects . . . ." The report for December 1955 stated that because the "production of fundamental knowledge in hydrology is not keeping pace with the needs, a significant new program has been proposed in the 1957 budget . . . ." Throughout the decade, the water-resources research program had been given high priority, first by Director Wrather and later by Director Nolan. The Geologic and Topographic Division's programs had long carried a higher portion of total effort in research than had the Water Resources Division, although water-resources research increased rapidly during the period.

The Survey's concept of research, however, was not applicable to all situations. The author recalls that during the decade, at least four inquiries were made to Federal agencies by Congressional committees or Government commissions as to what portion of their appropriated funds were used for research. Unfortunately, the definition of research used in each request was somewhat different in interpretation. In some instances, the Division, guided by the Director's interpretation of the inquiry, reported all of its activity as research. The Division's work and perhaps that of the entire Survey could indeed be visualized as research, especially relative to the Nation's overall economy. Former Director Nolan recalls (written commun., 1985) that the difficulty of ascertaining the segments of programs that could he classified as research was felt throughout the Federal government and that the President's Science Advisory Committee also spent several years attempting to develop definitives of basic (fundamental), background, and "applied" research.

Except for those projects that were scheduled specifically as research, the program staff found it difficult to determine the extent to which other investigations contributed to the Division's record of research achievements until the work was complete and reported on. Some investigational projects yielded significant research-type findings. On other occasions, research potential of a project had been largely determined by the imagination and perception of the project leader or staff members. Specific examples of achievements during the decade, not only in water-resources research but also methodology and instrumentation, are presented below, first from the Columbus Equipment Development Laboratory and then from the branches, each of which conducted much of its own activities in these fields.

Equipment Development Laboratory

By Arthur H. Frazier

Prior to 1947, much of the pioneer development work on new stream-gaging equipment was conducted by the Ohio SW District personnel, first under the supervision

of district engineer Lasley Lee and later under his successor C.V. Youngquist. H.E. Cox and some helpers did most of the actual shopwork. In 1947, however, it was decided to relieve the District of that activity and to establish a separate Equipment Development Laboratory that would provide services for the Survey's other Divisions as well. The laboratory headquarters remained in Columbus because most of the employees who were familiar with the work were in residence and because the best shop facilities were located there. At first, a building on High Street was rented to house the newly expanded facility but, after several months, the unit moved into a new building a short distance west of the Olentangy River and south of Fifth Avenue.

A.H. Frazier was placed in charge of the laboratory in November 1948. Frazier, who had left the WRD 7 years before to assume charge of the Survey's Division of Field Equipment, was uniquely familiar with instrumentation needs for water-resources investigations. He had used his mechanical engineering talents advantageously in improving flood-measuring equipment during earlier service with District offices in Madison, Wis., and St. Paul, Minn. On another occasion, he greatly simplified the method of preparing rating tables for the current meters rated at the Bureau of Standards' National Hydraulic Laboratory.

With its enlarged staff of about a dozen full-time employees, the laboratory expanded its equipment research and development work. Laboratory personnel also wrote specifications and served as consultants in letting Federal Schedule of Supplies contracts for instruments not commercially available to help replenish District inventories depleted during the years of World War II. Its personnel repaired or rebuilt instruments damaged by field use, and maintained a central stock that District offices ordered from catalogs that were periodically issued and updated.

The laboratory was organized so as to be financially self-supporting, except for the salaries of the chief and his administrative staff that were paid from Washington, D.C., office funds. District offices supplied the balance of needed funds from the prices that were charged for stock items, for renovating field equipment, and for constructing experimental models. With more adequate centralized assistance in instrument developments now available, many Districts referred their special equipment needs to the Columbus laboratory rather than attempt to perform such work with their own limited local facilities. In some instances, District personnel were detailed to the laboratory to work on items.

Motorized gaging vehicles were designed and built for use at some of the measuring sites on the Columbia and lower Mississippi Rivers. Articles by laboratory personnel in various WRD Bulletins on design and performance of new or special equipment stimulated District procurement and use.

To acquaint more Districts with newly conceived items of equipment, Frazier organized the "Gadget Club." Each participating district paid $10 annually to receive some newly developed or improved small item of equipment for trial use. The name was later changed to "IDEA Club" because of the unfavorable connotation of the word "gadget." "IDEA" was the acronym for "Instrument Development Extension and Acceptance."

Because of the limited amount of storage space available in the Washington, D.C., office and to simplify field procurement, the stock of stream-gaging cables, reels, and related equipment located there was transferred late in 1950 to the Columbus laboratory (WRD Circular dated October 5, 1950). Early in 1952, the Survey's Service and Supply Branch began stocking supplies and equipment formerly stocked by the Division. In January 1951, using its new computer facility, the Administrative Division took over the preparation of annual inventories of nonexpendable property.

By 1951, strains on the economy imposed by the Korean conflict threatened to restrict purchases of critical materials by laboratory and District office personnel. An inventory of items needed through 1952 was sent to the National Production Authority, but the Division failed to receive the "Defense Order Number" from that agency that would enable it to make purchases of critical items. Efforts were then made to purchase the needed items through some of the Federal cooperating agencies, such as the Atomic Energy Commission. Still, some shortages threatened to curtail the Division's field activities and makeshift methods were put to use. For example, the supply of rolls of water-stage recorder paper became so scarce in some Districts that they were rerolled and used a second time—on the back side. By mid-1951, equipment inventories were at such minimum levels that resales to other agencies were made with reluctance.

The Price current meter was used in making streamflow measurements throughout the decade. Frazier, who took the lead in studies of current-meter performance, gave preference to the Price design over other meters, none of which were currently commercially available. In 1948, he revised a pamphlet he had written in 1941 on the care and rating of current meters.

Cutting holes with an ice chisel through thick ice on wide, frozen streams so a current meter might be lowered into the flowing water was a cold, strenuous, and time-consuming task. In the late 1940's, personnel of the Nebraska District (closely followed by South Dakota personnel) tried to expedite that operation by developing a gasoline-driven ice drill. The Equipment Development Laboratory staff joined in that effort beginning in 1957, and furnished a few such drills to some of the northern field offices.

During 1950 and 1951, a considerable number of the Survey's manually-operated sounding reels were

converted to battery-powered operation. A sizable number of special cranes and cable cars were also designed and built in the laboratory during that time and the following decade. The reels were used for suspending the current meters and heavy sounding weights from highway and railway bridges and cableways. Each reel had to be of a different design to meet the local conditions. A 500-foot-capacity well-exploration reel was built in the laboratory for use by field personnel of the GW Branch.

Because the cleaning, repair, and adjustment of recorder clocks by local jewelers was not always done promptly and (or) satisfactorily, personnel of the Equipment Development Laboratory set up a facility to conduct this service for the Districts at their option. As of late 1950, two or more experienced clock repairmen were on the laboratory payrolls.

Late in 1955, Frazier, at his request, was reassigned as a research specialist to the TC Branch. In spring 1956, K.S. Essex, a hydraulic engineer with about 12 years of experience with the Denver District (SW), was appointed to succeed Frazier as supervisor of the Columbus Equipment Development Laboratory (WRD Memos dated November 29, 1955, and May 9, 1956). Frazier's headquarters remained in Columbus through the end of the decade.

Surface Water Branch

Although equipment was being developed for the measurement, by current meter from bridges or cableways, of ever greater rates of discharge, peak flood discharges frequently went unmeasured because of impassable access roads, darkness, short response times, and inadequate manpower. A means of calculating recent maximum discharges from channel depths and hydraulic gradients, revealed by channel debris, had been used for some time. This so-called "slope-area" technique was dependent also on an estimation of channel roughness. H.W. Barnes recalls (written commun., 1987) that "one of the earliest research efforts of the 1947–57 decade had to do with the need to verify the slope-area methodology for computing flood discharge in general and the channel-roughness coefficient, Manning 'n', in particular. The initial efforts were under the technical leadership of Hollister Johnson. However, it has always been my understanding that Tate Dalrymple was responsible for organizing and directing the roughness-verification program. The product was a library of photographic slides in three-dimensional color with a summary description of the channel geometry. The stereo slide sets proved to be very useful to engineers and hydrologists concerned with the hydraulics of natural streams. The photo slides became so popular it was necessary to make arrangements with a major film processing firm to make duplicate sets to fulfill requests from private consultants, universities, and governmental agencies here and abroad. It was this sustained popularity that led to the justification of WSP-1849 (1967). I believe this was the first Water-Supply Paper ever published using three-color photography. As I recall, the initial printing order was for 5,000 copies (2 times the normal printing for a WSP). A second printing was made in 1977."

About 1950, the Branch staff began seriously thinking about the possibilities of making use of recent developments in high-speed electronic computers to do some of the routine computing required in Division operations. It was obvious that such efforts could be applied most advantageously to computation of streamflow records. Contracts for a study of the problem were negotiated with three firms, and their findings were scrutinized in 1953. Late in 1954, a contract was let for the development of a device that would visually "read" the gage height from the automatically recorded line on the strip charts, compute the discharge, and record the results on punch cards, which could be used, in turn, for a variety of "printouts." Such a step must have required courage at a time when experience with electronic computers, and the Division's financial resources, were both very limited. W.L. Isherwood, in a progress report on the venture, stated "that perhaps this whole plan sounds rather visionary, but considering the overall basic data, the possible savings, expressed either in dollars or in release of engineer's time for other important work, is tremendous" (WRD Bull., Nov. 1953, p. 108).

The computer was delivered to the Washington, D.C., office about 1955 but, after a year or two of testing by Isherwood and his staff, it was found to be incapable of sensing, with reliability and accuracy, the often indistinct and watery gage-height lines of varying width and intensity on recorder charts that were often spotted by insects. Isherwood recalls also (oral commun., 1981) that the computer's 200 to 300 vacuum tubes, each with a limited life span, were rarely all functioning at the same time. The experience nevertheless was beneficial because it led to a more successful alternative, that of recording water-level data at gaging stations on punched digital-type paper tapes. During the transition period, the mechanical discharge integrators, long used at many District offices to calculate the daily discharge from gage-height charts that showed wide fluctuation, remained in use. In fact, new integrators were still being built on order by the Survey's Division of Field Equipment as late as 1949 and perhaps later (WRD Circular dated April 8, 1949).

A procedure for calculating peak water discharges through contracted openings in the absence of current-meter measurements was developed and verified during the decade by C.E. Kindsvater, R.W. Carter, and

H.J. Tracy. The procedure was applied to river channels at abrupt contractions, usually bridge openings. The research was conducted and reported on at the hydraulic laboratory at the Georgia Institute of Technology and included verification of coefficients on the basis of actual current-meter measurements (Circ. 284, 1953). Barnes recalls that this new methodology "became the inspiration and foundation for substantial cooperative highway programs in most WRD districts" and "eventually had application to the present backwater techniques used extensively in virtually all floodplain-management activities."

Other research by Carter resulted in a treatise on the hydraulics of flow-through, conventional, highway box and pipe culverts (Circ. 376, 1957) that yielded benefits far beyond the design of highway drainage. Barnes states that considerable research had been conducted prior to Carter's work that dealt mainly with the hydraulic capacity relative to design. However, much of the prior research was limited in scope to the capacity and resistence characteristics of standard pipe sizes. On the other hand, the work conducted in the Georgia Tech hydraulics laboratory was probably the single most comprehensive investigation of culvert flow (for any objective) ever undertaken. The research provided a basis for the development of theoretical ratings for culverts operating under virtually any field condition. As a result of Carter's research, the USGS was able to establish small-stream data-collection programs, statewide and in urban areas, in many Districts, which in time evolved into a national program funded by and coordinated with the Federal Highway Administration.

Barnes also recalls the comprehensive analysis of previous research on the discharge characteristics of broad-crested weirs during the decade by H.J. Tracy. His analysis, published as Circular 397 in 1957, is of lasting importance to the USGS, Corps of Engineers, and other government engineers, and has been recognized by the International Standards organization.

By the end of the decade, researchers Kindsvater and Carter had developed new formulas by which sharp-crested weirs could be used with greater accuracy as water-measurement devices. They demonstrated for the first time that viscosity had a definite effect on the relation between head and discharge. The refined methodology has since been adopted internationally.

The mid-section method of computing river discharge was officially adopted in fiscal year 1950 after a comparative study was made between it and the mean-section method used earlier. This was accomplished by a special committee of branch engineers in 1949. K.B. Young, a special assistant to the branch chief, assisted the committee by making most of the computations and analyses and preparing the report.

In 1954, E.G. Barron of the Kentucky District transferred to Columbus, Ohio, to head a new instrumentation and research unit for the Branch, primarily to give greater attention to the further development of a "bubbler gage." Such gages, which sensed and recorded river stages by pressure, could be installed in much less costly structures than the float-type recorders that required gage wells of heights equal to the full-stage range of the river. In late 1955, the first improved bubbler gage was installed at a Survey gaging station and, by mid-1956, some experimental models were assigned to a few of the Districts for field trials. Numerous other projects were also underway during the decade, some of which were at District level and are noted in the District activity statements in Part IV.

Ground Water Branch

Condensed from documentation by E.P. Patten and R.H. Brown

According to O.M. Hackett, ground-water research from World War II to the mid-1950's "became progressively smaller in proportion to the total effort" of the Branch (USGS Circ. 527, 1966, p.3). This was due largely to the pressures by industry and all levels of government for hydrologic data that would help resolve immediate water problems without adequate regard for long-range needs. Research findings thus continued to occur mainly as by-products of problem-oriented investigations until near the end of the 1947–57 decade. In 1956, R.R. Bennett, who had been selected to head the new research section, "drafted a statement identifying five major areas of research vital to an understanding of hydrologic systems" (Circ. 527, 1966, p. 4). This was a major contribution to the planning of research projects in the years that followed and well beyond the decade.

The more significant achievements in research, methodology, and instrumentation during the decade included the following:

- What was probably the most advanced device yet developed for taking undisturbed samples of earth materials from outcrops and test pits was perfected by W.O. Smith during 1950. Each sample was taken in a lucite tube that was transferred to a permeability-measuring instrument without disturbance of the material. The permeameter, also of the most advanced design, was perfected during the year.
- A set of compact, lightweight, electrical well-logging instruments, developed by R.R. Bennett in the previous few years, was adapted for truck mounting in fiscal year 1951. Included in the set was an adaption of a sensitive temperature-measuring instrument that

indicated direction and velocity of movement of water in drilled wells. An improved electric-tape gage was developed to measure depth of water in wells.

- Research was extended in 1951 on the use of underground saline-water reservoirs for waste disposal, including radioactive materials and spent brines, particularly in the design and operation of recharge wells and the determination of possible long-range deleterious effects.
- A technique was devised in fiscal year 1952 by J.G. Ferris and D.B. Knowles that provided quantitative data on the value of wells as indicators of water levels in aquifers and of aquifer productivity. This was accomplished by introducing measured volumes of water into the wells and observing how quickly the original water level was regained.
- An electrically-operated water-stage recorder was developed in fiscal year 1952 for wells too small or too deep for the use of standard floats. Also, 8-day recording gages were converted to 30–day operation by means of a battery-operated clock escapement.
- Research on ground water in Arctic regions was continued in fiscal year 1953 through cooperative studies with the Corps of Engineers. This included aerial-photo interpretation of permafrost terrane.
- A working model of an electric slide rule was constructed for quick determination of theoretical drawdowns caused by pumping.

Substantial progress was made during the decade toward analog simulation of ground-water systems that became a much-used tool in the 1960's in the solution of complex ground-water problems. H.E. Skibitzke and G.M. Robinson, with the encouragement of C.V. Theis and R.R. Bennett, designed and reported on (unpub., 1954) an analog resistor-capacitor network that gave a sound base for later advanced models used in the solution of ground-water flow problems. Gerald Meyer described experiments by Bennett in the early 1940's with continuous field-resistance-type analogs (''Scientific Advances in Geohydrology,'' a paper presented at the 1976 Geological Society of America meeting, Denver, Colo.). Theis was a pioneer in this field, as was R.W. Stallman who developed mathematical models to describe aquifer flow-fields in detail, and applied methods of numerical analysis to compute solutions.

Quality of Water Branch

Four field research centers were established by the Branch during the decade. The first was at Minneapolis, Minn., in 1948; the others were activated during 1953–57 in Denver, Colo.; in Menlo Park, Calif.; and in Fort Collins, Colo. (Durum, 1978, p. 149).

Laboratory technology in the chemical analyses of water samples advanced during the decade, both in greater production efficiency in making analyses and in the accuracy of results. The improvement of laboratory methods in the determination of boron was reported in 1948 (WRD Bull., May 1948, p. 47), as was the determination of nitrate by the use of the Devarda method as described by Burdge Irelan (WRD Bull., May 1949, p. 22–24).

The laboratory determination of sodium and potassium, a time-consuming task in earlier years was, by 1951, expedited by the purchase of a flame spectrophotometer, several types of which had been developed after World War II. W.W. Hastings, then district chemist for Texas, in a statement in 1947 stressing the need for research, had recommended that this equipment be tried by the Branch (WRD Bull., Feb. 1947, p. 57). The first one was used in the Washington, D.C., laboratory. R.A. Krieger reported that laboratory time was cut about in half by the new equipment (WRD Bull., Feb. 1951, p. 2). Simultaneously, L.L. Thatcher, who was in charge of research on methods in the D.C. laboratory, reported that the flame photometer was also applicable in the determination of lithium (WRD Bull., Feb. 1951, p. 3). Durum (1978, p. 154) stated that the adaptation of the flame photometer ''heralded a new age in water chemistry.''

R.H. Langford, who was in charge of the Lincoln, Nebr., laboratory, reported the successful use of newer laboratory techniques for the determination of total hardness, calcium, and magnesium (WRD Bull., Aug. 1951, p. 53). Durum (1978, p. 155) stated that the introduction of new analytical techniques in its laboratories caused Branch chemists to reestablish standards and quality-control criteria.

The preliminary edition of ''Methods of Water Analysis'' that branch chief Love had issued in January 1950 (superseding W.D. Collin's WSP 596–H, 1928) to assure uniformity in analytical procedures, was soon being updated to incorporate the new procedures. Prior to 1950, the analytical methods used were monitored by the Washington, D.C., office. Thereafter, standard procedures evolved in rapid succession. The Geological Survey segment of the Secretary's annual report for 1952 stated that ''improved analytical and instrumental techniques for analyzing water were emphasized in 1952. The slower gravimetric and volumetric methods of making analyses are giving way to the fuller utilization of electronic laboratory equipment like the spectrophotometer, flame photometer, and potentiometer.''

Although field measurements of the specific conductance of water samples had been made earlier at various locations on waterways, it was during this decade that the usability, limitations, and potential of the field-conductivity meter were determined. Once a relationship

was established between the specific conductance and the concentration of a specific dissolved-mineral constituent (or total dissolved solids) in the waters of a stream, the relatively simple measurements of specific conductance revealed variations in water quality during intervals between the more time-consuming chemical analyses (WRD Bull., Feb. 1955, p. 1).

A new type of analytical balance was tested late in 1948 by C.F. Lindholm and found to increase the speed and accuracy in the WRD water-quality labs (WRD Bull., Feb. 1949, p. 16). Known as the Gramatic Balance, it had a single pan and knobs by which the operator applied the various weights without directly handling them.

J.D. Hem described a new method for determining the sodium concentration in water samples using uranyl-zinc acetate (WRD Bull., Aug. 1948, p. 80). The method saved both time and money. Chemists L.L. Thatcher, F.H. Rainwater, and H.A. Swenson of the Lincoln, Nebr., District reported that the newer spectrophotometric method that used an organic dye had advantages over the single precipitation method in the determination of magnesium in natural waters (WRD Bull., May 1948, p. 47).

The rapid expansion of investigations of sedimentation in river and reservoir systems was accompanied by a sizable effort in the development of methodology and instrumentation as well as research of the behavior of sediments of different types in flowing water. The Branch, together with the Corps of Engineers, continued its role in the development and testing of equipment for the measurement of fluvial sediments for the Interdepartmental Committee, which was created in 1939 to achieve more uniform and improved instrumentation and methodology. During the decade, the work was conducted largely at the University of Minnesota's St. Anthony Falls Hydraulic Laboratory. B.C. Colby represented the Branch during the period, having succeeded P.C. Benedict in 1946. Accomplishments included evaluation of the bottom-withdrawal tube method, development and calibration of the visual-accumulation tube, and a report on fundamental guides to particle-size analysis (Durum, 1978, p. 132).

Refinements in the procedures for measuring the amounts of sediments moving along stream channels included efforts to determine sediment movement along the channel beds as well as suspended sediments, samples of which were more readily collected for measurement. One of the more ambitious efforts to measure the total sediment moving in a channel took place in the late 1940's. After tests were conducted on a model in the Colorado A&M College hydraulic laboratory, a structure was built on the Middle Loup River at Dunning, Nebr., that would create sufficient turbulence to put bed load sediment also into suspension so that it could be sampled in the normal manner (WRD Bull., Nov. 1949, p. 68–76).

H.A. Swenson states that of historically significant accomplishments in the Missouri River basin program, 1947–1957, the work of the late Survey hydrologists Bruce R. Colby and his twin brother, Byrnon C. Colby, merit special honor. Bruce introduced new principles in the understanding of sediment transport, including bed-load discharge, and devised simplified methods for computing total sediment discharge with the modified Einstein procedure. He made significant contributions to interpreting changes in chemical quality of streams and lakes. Byrnon specialized in basic research on sediment behavior in alluvial channels with application of these findings to the practical design, development, and production of sampling equipment for suspended-, bed-load, and particle-size sediment measurements. Through a series of well-prepared, carefully documented reports, he enriched the literature of sediment assessment by no small degree.

S.G. Heidel (WRD Bull., Feb. 1955, p. 11) reported on studies of relations between suspended-sediment movement and streamflow. He urged caution in attempting to estimate sediment discharge from streamflow data.

Technical Coordination Branch

All of the Branch projects were entirely or largely under the Division's research category. They have been described primarily under the Branch segments of the Division's role and structure (pt. I, TC Branch), under the Federal program (pt. II, the Federal program), and within Part III, under Regional, Interstate, and Foreign programs; Soil and Moisture Conservation program; River and Land Morphology; and Lake Mead Sedimentation Survey.

Part VI—Management Techniques and Facilities

Those responsible for the management of the Survey's water-resources investigations underwent numerous changes in administrative and management procedures during the decade, as did officials at the Bureau level and in the other Divisions of the Survey. New regulations originated at all levels, from Congress, the White House, and Bureau of the Budget on down. With an ever bigger Federal establishment coping with ever more complex problems, Federal administrators at all levels sought more complete, expeditious, and uniform reporting systems as a basis for planning budget and management.

The impact of these changes on the District chiefs of the several branches was especially severe. Their independence as administrators, relatively great until the mid-1940's, steadily decreased during the decade. District accounting systems were centralized, automobile purchases and space rentals became the functions of the newly created General Services Administration (GSA), and clearance for new projects and project funding was subject to ever more review by each operating Branch and by the Division's newly formed Program Control (PC) Branch.

Those in overall charge of administrative management functions of the Division have already been identified. Others, in charge of specific administrative functions, will be identified later in this section.

Program Formulation and Fund Allocation

The decade brought many attempts, and some progress, in the revision of traditional program-formulation techniques so that projects would be designed to reflect the full potential of the Division rather than to continue the more limited ranges of abilities available when project boundaries were confined to those of the individual branches. Suggested changes were proposed primarily by G.E. Ferguson who earlier (1940–47), as district engineer (SW) for Florida, had found that, although many water investigations in the State required the talents and experience of personnel from all three branches, the projects designed and approved within a single Branch frequently avoided this approach. What was so clearly observed in Florida, where few boundaries existed between surface and ground water, would inevitably be increasingly apparent in other States where water-resources investigations were also becoming broader in scope.

In his new position as a senior member of the CHE's immediate staff (and later as chief of the newly formed PC Branch), Ferguson sought Paulsen's approval of various ways to shift greater responsibility for program planning and balancing and for project review to the Division, but with full participation by Branch-level officials. Some of these steps brought a reaction from some having Branch responsibilities. This was to be expected. For many years, each Branch had used techniques that had met its own needs. To abandon this for new and untested methods over which they would have only limited control was a traumatic experience.

The objections to changes in programming techniques, usually discussed privately, placed a burden on Paulsen. He had made good progress in strengthening interbranch harmony and mutual confidence between himself and each Branch chief. It was understandable that Paulsen decided to defer some revisions in programming techniques. He favored the committee-type approach, which was more democratic in nature, and this approach was used both at the National Headquarters and at field levels by the State WRD Councils. There is little doubt that the members of such committees and councils, in gaining greater familiarity with the investigative potential of the Division, were later much better prepared to accept and to assume positions of responsibility at Division level under the later reorganization of WRD.

Many of the additional responsibilities in programming that the Division assumed during the late 1940's and early 1950's were because additional program data were required for the annual budgets in keeping with increased standards established by the Bureau of the Budget. Such budgets were prepared under the direction of the PC Branch and its predecessor staff.

The procedures used in planning, negotiating, and financing cooperative and Federal program projects are described earlier in part I, "Program Control Branch." Long-range planning procedures were neither specified nor formalized by the Division during the decade, although such planning did exist between mutually interested District chiefs and their major cooperators at State

level. By memo dated March 24, 1955, the CHE asked the Water Resources Councils (composed of local District chiefs of each Branch) to give greater attention to long-range planning and to work toward a better balance of programs within each State. The Councils, essentially committees, could often do little more than provide a time and place for open discussion of such measures or objectives, and then only if its members were willing; however, even under such unfavorable conditions, their progress in program planning and project formulation was remarkably good.

Nationwide progress in balancing programs did not come until 1958 and later when the four newly appointed area hydrologists were given control of the funding of programs. The fact that they had not yet been given line authority actually was beneficial to the development of a better program structure. Control of the funds gave them adequate influence, and freedom from supervisory burdens provided the time for program review and improvement.

Prior to and during the early years of the decade, each Branch chief or his designated representative developed and essentially approved the use of funds allocated to the Branch following congressional appropriations. The Branch chief would consult with the CHE in situations where problems were known to exist. Formal notice of fund allocations, at least for the SW Branch, were received annually by the District offices on a single nationwide schedule sheet. This was the only formal program document that the writer recalls—one project on each line. It was prepared by H.F. Hill, Jr., who for many years was the senior member and a highly efficient part of the Division's administrative staff. By about 1946, this once simple and adequate method was obviously overloaded. The schedule for that year was still on one sheet, but the number of projects had increased to the point that it was a multifold document. Fund allocations continued to be approved by each Branch chief until after the end of the decade when they were issued instead by each of the division hydrologists.

Fiscal Management and Accounting

Many changes in fiscal procedures were begun during the decade because of rapid growth in the number of allotments, the introduction of electronic (punch-card) accounting systems, and the establishment in the late 1940's of a Division of Administration in the Survey headed by G.J. Mowitt. Each change usually involved greater centralization. The greatest burden of these changes was likely borne by those responsible for keeping accounts in the District offices (see Summary of proceedings, 1954 conference, WRD, May 24–27, 1954, Chicago, Ill., p. 30–37, unpub.).

Until fiscal year 1948, the Districts had maintained separate accounts for funds made available under cooperative agreements, for allocation of monies from the Federal program, and for transfers from other Federal agencies. Allocation notices were usually received annually from the Washington, D.C., headquarters. District supervisors managed their funds through these field accounts. The Survey's Branch of Accounts also performed allotment accounting on bookkeeping machines, and these were considered the official ledgers. Reconciliation between District and Headquarters ledgers was by correspondence, usually an "end of year" operation (C.W. Morgan, oral commun., 1975).

By 1948, the allotments had become so numerous and subject to so many changes that a coding system was specified so that the field and Washington office ledger statements could be more readily reconciled. The first listings of allotments under the code were transmitted to the Districts by a WRD Circular dated May 21, 1948, a product of the new punch-card machines.

The Administrative Division then used the new equipment to maintain account ledgers, copies of which were forwarded monthly to the Districts with the expectation that they would eliminate the need for ledgers prepared locally. By 1955, the punch-card-produced "A-16" ledgers "were believed to be sufficiently accurate and complete to be used effectively for district as well as central use" (WRD Circular dated February 4, 1955). However, the Districts were asked to maintain an "obligation register" for field verification of the A-16 and for day-to-day control of field finances. Since 1948, accounting had also become more complex because of a requirement by the House Committee on Appropriations that each charge on account ledgers be classified by "object of expenditure" (WRD Circular dated March 8, 1948).

Expansion of the program in combination with problems with the new accounting system caused a serious backlog of unanswered correspondence in the Washington, D.C., office (WRD Circular dated February 10, 1948). A series of WRD circulars, particularly in fiscal year 1948, indicates the extent of the problem. Beginning with fiscal year 1951, District offices stopped sending their expenditure vouchers directly to the Treasury Department's regional disbursing offices for payment. They were, instead, sent to the Survey's Branch of Accounts for auditing and payment (WRD Circular dated May 19, 1950).

New language in the fiscal year 1955 Appropriations Bill made it mandatory that both sides (Federal and State) of the cooperative accounts be in balance by the end of each year. This eliminated the occasional and convenient practice of carrying over small balances of local funds in States where a fiscal year ended after June 30

(WRD Circulars dated March 15 and April 27, 1955). In January 1955, eight fiscal and organization-management type positions in the WRD were transferred, with salaries, to the Administrative Division, which would henceforth perform those functions.

Beginning July 1, 1955, terminal leave was paid from a central account financed from the Washington office service charge. A Government Accounting Office audit team had raised a point of concern regarding the practice of transferring funds between Districts to cover the value of accrued leave for employees moving from one District to another (WRD Circular dated September 21, 1955).

The practice of supporting the general administrative costs of the Washington, D.C., office through assessments against appropriated and transferred funds continued during the decade. Smaller assessments against the same funds were used to meet similar needs of the Director's office and other bureau-level facilities.

C.E. Staudte joined the staff in 1947 to take charge of the fiscal control section. He was assisted by C.J. Wack who entered on duty in 1948 and later (1951) transferred to the Department of Justice. C.W. Morgan, who had transferred from the Survey's Branch of Printing and Engraving to the CHE's staff in 1949, succeeded Staudte in 1950 when Staudte transferred to the Navy Department. In 1956, Morgan was placed in charge of an expanded administrative section, which included the fiscal management activities. Fiscal control was under the general direction of Frank Barrick, Jr., administrative officer, beginning in 1950.

Personnel and Careers

Personnel management at the operating level was the responsibility of each Branch during the decade, but the criteria, limitations, and problems were so similar that they can be described under a single heading. There were few, if any, periods in the decade when there was an adequate number of qualified personnel available to fully meet program commitments. Shortages were caused largely by legislative and executive measures intended to contain the size of the Federal establishment; an inadequate supply of graduate engineers, geologists, and chemists to meet national needs; a diversion of manpower to the military and to defense industries during the Korean conflict; higher salaries paid to college graduates by private industry; and the resignation or retirement of a number of senior ground-water hydrologists who joined or established private consulting firms.

For the 10 years prior to the beginning of the decade, the size and activities of the Division's Washington, D.C., office had been seriously restricted by the limitation placed on expenditures for personal services in the District of Columbia. When the limitation was first imposed on the "gaging streams" appropriation 21 years earlier, it nevertheless allowed for headquarters salary costs that were about 44 percent of that appropriation and 14 percent of the total funds available. The limitation was not subsequently adjusted to allow for program growth. For example, during the 1947 fiscal year, the limitation ($235,000) restricted D.C. salary costs to about nine percent of the "gaging streams" appropriation. For this reason, an increase of $115,000 (to a total of $350,000) was included in the fiscal year 1948 budget requests to Congress. A total of $265,000 was allowed by the Congress. This was increased to $300,000 in 1949. The limitation later was removed. (From fiscal year 1948 Budget Estimates, p. 246; fiscal year 1948 Budget Justifications, p. 121; 1949 Budget Estimates, p. 162.)

At the District level, personnel shortages led to the wide use of overtime (WRD Circular dated June 9, 1948). By 1951, the use of overtime had become so extensive that the Director established a policy wherein overtime could be used only where "time pressures exist to meet specific deadlines or objectives." Bureau-level approval was needed in advance for overtime scheduled for more than 90 consecutive days. Permission after the event was required to meet unforeseen emergencies such as floods (WRD Circular dated March 26, 1951).

In his Personnel Announcement No. 9 dated January 5, 1951, the Director stated that the anticipated mobilization of armed forces during the Korean conflict could have an adverse impact on the Survey's program. He delegated to Division chiefs the authority to contact the military for the purpose of delaying calls to active duty of Survey employees who were both military reservists and on "critical" assignments.

An amendment to the supplemental appropriation act of 1952 carried limitations on rates of promotion of classified employees. For example, a GS-5 (usual starting grade for a recruit with a BS degree) employee could not be promoted to the next salary step (GS-7) until after a year of service (WRD Circular dated November 23, 1951).

Early in 1953, the new administration's Secretary of the Interior "froze" the filling of all vacancies. He justified the action as an aid in reducing Government expenditures and promoting greater efficiency. Appointments were to be approved by the Secretary's office (WRD Circular dated February 10, 1953). The order was rescinded late in the following year except for appointments to new or previously unfilled positions (WRD Memo dated November 1, 1954).

The Division attempted to maintain an adequate workforce in the face of such obstacles, each of which fortunately was of relatively short duration. The Division greatly strengthened its recruiting program. Perhaps its

greatest success toward optimum achievement was in the use of technical aids to do a major portion of the work formerly assigned to the professional staff. A number of the appointees to the subprofessional positions were graduate geologists who had not yet passed the Civil Service examination. District supervisors who had a relatively adequate supply of personnel attempted to assist other less fortunate Districts through transfers and recruitment. Listings of personnel needs, District by District, were updated and distributed frequently.

In his memo dated February 9, 1956, to District offices, Paulsen dealt again with the "major problem" of staffing, estimating that 200 additional employees would be needed by the next summer if program plans materialized. He suggested greater delegation of responsibilities to employees without professional ratings, greater use of student trainees, and interbranch details for promising employees. In summary, he asked for "a more aggressive and effective personnel program." At the end of the decade, the Division listed the need for an additional 55 employees that included 30 engineers, 6 geologists, and 2 chemists (WRD Memo dated March 13, 1957).

IN-SERVICE TRAINING

Training of personnel during the decade was accomplished almost entirely within the branches. One exception was that the Division coordinated the fellowship program with Harvard University, and several WRD hydrologists were given fellowships in the Graduate School of Public Administration at Harvard during the decade. These fellowships were made possible by a grant from the Conservation Foundation in about 1950. WRD attendees were selected each year from a group of about eight candidates from government agencies and included R.B. Vice (QW, 1951–52); C.W. Reck (SW, 1952–53); G.C. Prescott (GW, 1953–54); L.E. Newcomb (SW, 1954–55); and William Back (GW, 1955–56) (see WRD Circulars dated July 7, 1952, through February 1, 1957).

Surface Water Branch

Training of new personnel in the standardized field and office methods used in the streamgaging program continued at the District and Subdistrict levels by temporarily placing the new personnel with experienced career people. This was supplemented by details of selected employees for periods of several weeks or months to the basic records section at Branch headquarters. Training in indirect methods of measuring floods, developed earlier by Hollister Johnson, was accomplished largely by at-the-site surveys by District personnel working with the regional flood specialist.

Steps toward encouraging self improvement came early in the decade. For example, the August 10, 1947, issue of the *WRD Bulletin* (p. 133) carried a listing of titles of 43 books that were recommended for purchase by District offices of the SW Branch for use in informal study by personnel.

C.H. Hardison, who joined the special reports and investigations section in 1952 and was in charge from 1954, recalls that, in the early 1950's, a number of headquarters personnel attended courses in the new field of statistics given by the Department of Agriculture. They adapted this new tool to the analysis of streamflow data, prepared informal notes on their findings, and began training selected detailees to the basic records and the special reports and investigations sections. Short indoctrination sessions in statistics were also given by these headquarters specialists in the District offices.

In 1953, the first of a series of courses in fluid mechanics was held in Atlanta for a group selected from the District offices. These courses were conducted by C.E. Kindsvater, a member of the Georgia Tech faculty and consultant to the Branch. From 1949 until the end of his stay in Lincoln, Nebr., R.E. Oltman was in charge of a special studies office for training field engineers in hydraulic engineering within the 10-state area adjacent to Nebraska. Following his transfer to Washington, D.C., as chief of SW training in 1955, Oltman developed and directed training courses for both hydrologists and technicians. A series of 2-week advanced short courses in surface-water hydrology and hydraulics was launched in 1956, and continued semiannually for several years beyond the end of the decade.

Ground Water Branch

This Branch had by far the most extensive formal training program within the Division. Its many new professional employees, almost entirely graduates in geology or engineering, needed more training than could be given on the job. The following description of the origin and development of the ground-water training program was written almost entirely from information provided by J.G. Ferris in 1983 and G.G. Parker in 1989.

In 1951, G.H. Taylor, in charge of the Survey's ground-water investigations under the recently established Missouri River basin program, enlisted the assistance of J.G. Ferris, district engineer, GW Branch, Michigan, to conduct a training session in ground-water hydraulics primarily for a number of recently recruited geologists and engineers. The need for such in-service training was acute. Until 1949–50, neither college courses nor textbooks in ground-water hydraulics were available and few articles on the subject had been published in scientific journals. This initial training session, referred to as a

''workshop,'' was held from February 26 to March 6, 1951, at Lincoln, Nebr. A second workshop, arranged by R.H. Brown and E.M. Cushing, was held at Nashville, Tenn., from June 18 to 23, 1951.

In March 1949, G.G. Parker, district geologist for south Florida, transferred to Branch headquarters in Washington, D.C., as assistant chief, ground-water geology section. His duties, which included hiring new employees and assigning them to field offices, strengthened his awareness of the need for in-service training. Parker developed a plan for a career-development program that was accepted by the Branch chief, the CHE, and later the Director.

In May 1951, when the manpower and training section was established with Parker as chief, he organized the series of ground-water short courses, which were more comprehensive than earlier training courses. He expanded the course structure to include geology, water chemistry, and geophysics, and recruited the best qualified lecturers from senior members of the Branch as well as specialists from other branches. Parker also enlisted the cooperation of several universities with two principal objectives in mind: to take advantage of their academic atmosphere and facilities, and to apprise academe of the rapid growth of technology and its correspondent demand for training in the developing field of ground-water hydrology. D.W. Berry, a member of the Wyoming staff, transferred to Branch headquarters in 1956 to assist Parker. Parker moved to Upper Darby, Pa., in fall 1956 to take charge of a project in the Delaware River basin and was succeeded by Berry.

During the balance of the decade under Parker's direction, 13 short courses were held at the following locations and times: University of Wisconsin at Madison, September 3–15, 1951; Louisiana State University at Baton Rouge, March 10–22, 1952; University of New Mexico at Albuquerque, August 4–16, 1952; University of Texas at Austin, March 9–21, 1953; University of Wisconsin at Madison, August 16–29, 1953; University of Arizona at Tucson, April 12–24, 1954; University of Michigan at Ann Arbor, August 16–28, 1954; University of Oklahoma at Norman, February 28–March 13, 1955; Michigan State University at East Lansing, August 1–13, 1955; Louisiana State University at Baton Rouge, January 29–February 11, 1956; University of New Mexico at Albuquerque, August 6–18, 1956; and University of Oklahoma at Norman, March 3–16, 1957. In August 1957, a University of Wyoming ''Science Summer Camp'' was held in the Snowy Range of the Medicine Bow Mountains.

Attendance at the short courses usually ranged between 40 to 50 persons including perhaps 10 to 15 instructors. A number of the instructors lectured in their specific fields of expertise and audited other portions of the course that were beneficial to their careers. Among the regular lecturers were J.G. Ferris, H.H. Cooper, R.W Stallman, and M.I. Rorabaugh (ground-water hydraulics); S.W. Lohman, H.E. Thomas, A.M. Piper, and J.F. Poland (ground-water geology); H.E. Skibitzke and P.H. Jones (geophysics); W.W. Hastings and J.D. Hem (water chemistry); A.I. Johnson (soil mechanics laboratory); R.R. Bennett (hydrologic modeling); C.L. McGuinness and Mrs. F.G. Thompson (reports); G.G. Parker (history and management); and D.W. Berry (training coordination). A few of the attendees were from the SW and QW branches, an arrangement that aided interbranch liaison and rapport.

Quality of Water Branch

Although the Branch usually had access to an adequate supply of graduate chemists during the decade, orientation and in-service training were required for many recruits. H.A. Swensen (oral commun., 1985) recalls that many of the new employees, although well versed in general chemistry, had only limited training in water chemistry, which was an elective rather than a required course in some universities and colleges. He also recalls that few of the newer personnel were trained to relate the analyses to the environment from which the water samples were collected, and that proficiency in this came gradually as they gained experience on project investigations.

For the new employees already trained in water analysis, W.F. White (oral commun., 1985) recalls the need to indoctrinate them in analytical procedures that were highly standardized so that the resulting analyses of water samples from the various Branch laboratories would have nationwide uniformity. Although deprived of day-to-day flexibility in routine procedures, employees were not discouraged from seeking improved techniques that might later be adopted as standard practice. Such improvements have been described earlier under Branch research and methodology. Rapid change in the technology of collecting, analyzing, and interpreting fluvial-sediment samples also required in-service training on the part of both field engineers and laboratory staffs of the Branch. According to Durum (QW Branch history, 1978, p. 157), the Branch held its first technical training school in Charlottesville, Va., in May 1956 and, a year later, held a second in Albuquerque, New Mex. In addition to specific aspects of water-quality studies and techniques, general coverage of surface- and ground-water activities were presented by lecturers from their respective branches.

ENTITLEMENTS, SALARIES, AND TRAVEL

Federal employees group life insurance became available in the mid-1950's (memos dated August 27 and

September 21, 1954, executive officer to division chiefs). Health insurance legislation was not enacted until after the end of the decade. Other "entitlements" of the decade included a clarification of the nondiscrimination policy in Executive Order 9980 (July 26, 1948) and the designation of the head of each field office as a deputy fair employment officer (WRD Circular dated September 16, 1949). By memo dated June 16, 1954, to Survey employees, the Director provided guidelines by which "special clothing" (special footwear, parkas, hard hats, and rain clothing) could be purchased at Government expense for the protection of those engaged in a hazardous occupation for a short time.

Beginning in the late 1940's, a growing number of employees of the Division were conducting Atomic Energy Commission and other projects that were classified because of national security. Regulations were developed to ensure that the resulting correspondence, carefully marked "confidential," was not viewed by unauthorized parties. The term "confidential," long used in a more general way in Division administration, had to be confined to this particular usage (see WRD Circular dated September 13, 1950).

Travel costs increased steadily during the period and government allowances ("per-diem" rate) were increased from time to time. According to Survey Order No. 180, the $4 flat per-diem rate ended on June 30, 1949. The new rate approved by the Congress allowed a $9 maximum domestic rate. The Division specified (WRD Circular dated July 19, 1949) that heads of principal field offices would be allowed $9; assistant chiefs, $8; and other professional employees, $7, all on a "not-to-exceed" (claim only what you actually spend) basis. Subprofessionals received a flat per-diem rate of $6.50 and hydrologic field assistants $6.

In 1951, the Comptroller General decided that travelers were to use the fully authorized per diem. Authorizing officers were required to determine in each case what a proper amount or limitation should be. A WRD Circular dated June 23, 1952, announced per-diem rates for routine field work that varied from $7 for most States to $8 for California. A memo dated June 22, 1956, announced, for fiscal year 1957, rates of from $8 to $9 for actual field travel predominantly in rural areas, and from $10 to $12 for travel that required frequent stops in larger cities.

On October 28,1949, under the new "Classification Act of 1949," the separate professional and scientific service (P-1 to P-8 in WRD), subprofessional service (SP), and clerical, administrative, and fiscal service (CAF) grades were abolished and a single general schedule (GS-1 to GS-18) for all employees was established. Division professional personnel did not lose identity with this change as some feared because their background discipline, such as chemist, engineer, and geologist, had been extensively used in titles and personnel listings under the earlier and separate series. Under the new system, the professional employee did not use all of the numbered steps in the new series. One began at the GS-5 level and skipped the GS-6, GS-8, and GS-10 steps as he or she progressed upward. The new Act also provided for periodic step increases for employees whose service and conduct were satisfactory and for more rapid advancement as an award for those achieving superior accomplishments (see WRD Bull., Nov. 1949, p. 65–66).

Basic pay rates increased several times during the decade. The annual entrance salary for professionals (P-1 until 1949, GS-5 thereafter) increased from $2,644 to $3,670. The annual pay for those in charge of the larger Districts offices, typically a grade of P-5 (later GS-12) was $5,905 at the beginning and $7,570 at the end of the period. However, by 1957, many District chiefs had been promoted to GS-13, the starting pay for which was $8,990. In the late 1940's, many of the engineering aids were at the SP-5 level with a salary of $2,394. The District clerical staffs at that time were usually at grades CAF-2 to CAF-5, the annual salary for which ranged from $1,954 to $2,644 per year in 1947. Equivalent GS grades in 1957 ranged from $2,960 to $3,670 (from Federal Personnel Manual Supplement 990.2).

Gage readers, observers, and samplers who were traditionally considered Survey personnel and paid as such, were reclassified as contractors beginning on January 1, 1951. This action, requested by the Division and approved by the General Accounting Office, eliminated the preparation and certification of special payrolls and the withholding of Federal income and Social Security taxes (memo dated Jan. 3, 1951, Executive Officer to WRD field offices).

At the beginning of the decade, the processing of personnel actions at headquarters was under the direction of Ms. Helen Kiesel, chief clerk, and her principal assistant, Ms. M.E. Allen. In 1947, E.A. Erdmann, Jr., was placed in charge of a newly established personnel unit. Erdmann went on military furlough in 1948 and did not return to the Survey. Mrs. M.A. Lafon succeeded Erdmann and, as of January 1950, had four assistants. Mrs. Lafon resigned in 1952 and was succeeded by Ms. L.M. Landgren who, in turn, was succeeded by Ms. K.T. Iseri later in 1952. In 1954, the unit was disbanded because the personnel function was taken over by the Administrative Division.

Space, Records, and Property Management

The transfer of responsibility for securing office and storage space, and for records and property management, from the District offices to the General Service

Administration (GSA) began about 1951, and was a traumatic experience for the Division during the balance of the decade. GSA was established by Congress on July 1, 1949, as the Federal custodial agency. Justification was based on reports of many instances of poor performance by many agencies, but no reports are known to have originated in WRD or the Survey. The most difficult period occurred following the time of the actual transfer of responsibility for the lease of office and storage space from the local District chief, who was usually well informed as to local conditions, to the designated GSA field official. The GSA field official, newly appointed and often with headquarters in another city, was frequently without experience. In the years following 1949 and beyond the end of the decade, GSA personnel gradually gained experience, and displayed increasing skills that finally equalled and perhaps surpassed the pre-1951 performance of the Districts in these specialized fields.

WRD Circular dated February 4, 1951, announced that GSA's Public Buildings Service (PBS) would henceworth take over all arrangements for office, automobile, and equipment storage space. Another such circular, sent out on August 20, 1951, listed leases selected by the PBS that would henceforth be taken over by them. The total annual rental costs were transferred from the Geological Survey to the GSA budget.

The accumulation of original field data at District offices had grown to the point that, in 1948, the Nebraska District (SW) was asked to explore the practicability of microfilming such records prior to their disposal. D.D. Lewis, district engineer, reported that the results were good; however, it was determined that the disposal of the original records would require the approval of the U.S. Archives (WRD Bull., Feb. 1948, p. 19–23). In fall 1948, the Archives requested information regarding the volume of all administrative material in WRD files (WRD Circular dated October 20, 1948).

In 1950, in compliance with the Federal Records Act of that year, the Division established a records-management program under which noncurrent records were to be moved out of high-cost office space and into records centers. The SW District offices were most heavily involved in this activity. Gage-height recorder charts, discharge measurements, and supplemental data for thousands of station-years of record were catalogued and scheduled for proper disposition, mostly to the nearest of the GSA's 14 record centers or annexes (WRD Bull., Aug. 1955, p. 68).

A circular dated January 29, 1951, announced instructions from the Secretary that all records that were indispensable to the Survey would be identified, inventoried, and placed in categories, and that a plan would be developed for their protection. It was determined that few of the Division's records were vital to the military effort of the Nation (Category I) and that none were in field offices. Inventory of records or documents valuable or irreplaceable for nonemergency administrative or research activities of the Survey were then inventoried on a less stringent time schedule.

For a period of about a year (1950–51), the Division was faced with a critical shortage of supplies because of their diversion to the military and industrial build-up relating to the Korean conflict. Although the Survey was designated as a "defense agency" relative to personnel actions, it had no defense order number by which to purchase office supplies. During that period, it was not uncommon to use the reverse side of discarded sheets of used paper for final drafts of new circulars and manuscripts (WRD Circular dated March 8, 1951).

In 1953, a standard filing system for correspondence records was developed and used on a trial basis in the Washington, D.C., office. By WRD memo dated January 11, 1955, a description of the system was sent to the District offices with a request that it be used.

The inventory and control of nonexpendable property was also placed under more centralized authority during the decade. WRD Circular dated January 11, 1951, announced that the traditional annual inventory prepared by the District offices would be ended in favor of an annual verification of a machine-tabulated list prepared by the Survey's Administrative Division. In 1952, the stock of supplies and equipment formerly administered by WRD was placed under the control of the Administrative Division's Service and Supply Branch (WRD Circular dated February 27, 1952).

The Division maintained a procurement unit until 1954 after which its functions were transferred to the General Services Section. Mrs. C.K. Nonamaker was in charge of the unit until 1948 when she was succeeded by H.J. Rhatigan. In 1952, Rhatigan was succeeded by H.G. Carty who continued to serve as supply clerk under the General Services Section. Ms. J.A. Romack became supply clerk in 1955.

Transportation

It is likely that few public agencies made as much use of automobiles and light trucks in the pursuit of program objectives as the Survey. The operation of the nationwide streamgaging and observation-well networks required by far the greatest amount of travel, but other field personnel conducting investigative projects were also highly mobile. When World War II ended, the Division's fleet was in generally poor condition. According to testimony given by Paulsen at the House hearings on the fiscal year 1948 supplemental appropriation, the Division owned 362 passenger cars and 408 trucks as of February 16, 1948. Of the passenger cars, 290 were "light weight"

and 72 were "medium weight." (By 1982 standards, they all might well be classed as "large.") More than half (245) were purchased before World War II and the rest were surplus vehicles from other Federal agencies. Of the trucks, 279 were pre-World War II purchases and 129 were surplus vehicles. Practically none of the surplus vehicles were new and most required costly reconditioning. Only one of the vehicles was based or used in Washington, D.C. The statement by Paulsen was necessary because Congress placed limitations on the number and type of cars that could be purchased under each appropriation. For example, a car purchased in fiscal year 1949 could not exceed a cost of $1,400 (WRD Circular dated March 31, 1949).

Traditionally, each District purchased its own new vehicles with District funds under Federal contract and within the annual authorized limits for the Division. Districts would often increase or decrease the number of vehicles on hand by the number of used vehicles put up for trade-in. This was changed, however, by a rental system developed by the Division to discourage the retention of little-used vehicles in the Districts, a target for criticism throughout Government. (The General Accounting Office investigators had recently discovered a "fleet" of vehicles that had allegedly been in storage for a year or two, apparently forgotten during the past one or more field seasons. They were not Water Resources Division vehicles.)

Under the new rental system announced and described by WRD Circulars dated July 7 and 13, and August 4, 1953, each District was charged a flat daily rental fee for each vehicle. The proceeds, placed in a single nationwide account, were used to replace vehicles and for repairs, maintenance, and gasoline. The system was refined beginning in fiscal year 1955 (WRD Memo dated September 22, 1954). Greater recognition was given to the cooperator's equity in certain vehicles with devices that would provide a transition to single ownership. Rental rates were 80 cents per day for vehicle replacement plus 4 cents per mile for maintenance and gasoline.

The Survey's authorization for car purchases in fiscal years 1955 and 1956 permitted the Division to replace 50 of its vehicles in 1955 and 95 in 1956 (WRD Memos dated July 15, 1955, and July 23, 1956). The July 23 memo mentions "localities where GSA motor pools have been established" and refers also to GSA surveys for motor pool needs. The Division eventually had to rely on the GSA motor pools for its transportation needs, but this did not happen until after the close of the decade.

One other use of the Division's fleet, unique and apparently ending in the late 1940's, was during the Christmas season mail rush. It was customary for District offices to make some of its vehicles available to the local post offices when their own fleets were inadequate to meet needs.

Until fall 1952, the Division's cars were identified only by the dignified oval gold and black seal of the Geological Survey placed on each of the front doors. WRD Circular dated September 4, 1952, announced a decision by the USDI that the Survey decal must be placed below a new "U.S. Government Shield." (Many field personnel felt handicapped. As Survey employees, they had been permitted a discreet amount of travel on private land to read gages, et cetera. Now their cars bore markings similar to those of Federal enforcement and action agencies that were not always held in respect by local landowners.)

The vulnerability of drivers of Government vehicles involved in accidents, and of the Government itself from unfair damage claims, was eased following Interior Order No. 2528 dated June 27, 1949. Claims against the Government for damages were referred to the appropriate U.S. Attorney who was also asked to provide legal assistance to drivers of Government vehicles who were charged with violations in connection with such accidents (WRD Bull., Feb. 1950, p. 30).

When locations were beyond the capabilities of the automobile and the highway system, other and newer forms of transportation were used aggressively and often dangerously in the continuing battle against terrain and weather to reach a gage or measuring site at the required date and hour. One of the earliest vehicles for over-snow transport was purchased by the Portland office in January 1949 for use in streamgaging and for traversing snow courses during the winter months. The Tucker Sno-Cat, weighing about 0.76 pounds-per-square-inch of the supporting snow surface, gave satisfactory performance but had high gasoline consumption. Compared with the snowmobiles of the 1970's, it was a large, cumbersome, four-passenger vehicle that weighed 2,600 pounds empty. Its average speed was about 5 to 7 miles per hour, with a maximum of 15 to 20 miles per hour in open country. The body was that of a small automobile (WRD Bull., Nov. 1949, p. 89–90.) In a later article, W.V. Iorns, who was stationed at Logan, Utah, and was reporting on snow tractors, said that "commercial vehicles now available are doing a satisfactory job" (WRD Bull., Aug. 1950, p. 66–68).

The Utah District (SW) may have been the first to use a helicopter in servicing gaging stations when, in May 1956, three engineers were shuttled among 13 gaging stations that were spread over about 30 miles of the west rim of the Wasatch Plateau in central Utah at elevations between 9,500 and 10,500 feet (WRD Bull., Aug. 1956, p. 44). In spring 1957, the Colorado District (SW) hired what was at that time the most powerful commercial helicopter available to take hydrographers to eight remote gaging stations at elevations ranging from 8,200 to 9,100 feet in southern Wyoming. E.J. Tripp reported that the

venture was largely unsuccessful because of poor weather conditions and inadequate power for high altitude lift-offs with equipment, but that valuable experience was gained to assist in planning for future use of helicopters for inspection of remote gaging stations (WRD Bull., Aug. 1957, p. 51). With regard to transportation over water, H.G. Hinson reported that, by the late 1940's, aluminum boats had already come into use because of their portability, and that rubber rafts, usually from Army surplus, were safer than other vessels for flood work (WRD Bull., May 1948, p. 46).

By 1948, thousands of water samples collected by the QW Branch were being shipped annually by railway express to the nearest or the most appropriate water-quality laboratory. The great majority of these shipments in glass containers were by railway express and the returned cases of empty bottles were accepted at a special low rate. Although many of the local residents hired to collect the samples lived on rural routes distant from railway express facilities, transportation by parcel post was impractical because mailings of more than 4-pounds weight were subject to postage, and the problems associated with the samplers holding and affixing stamps seemed too formidable for adoption. However, the Oklahoma District officials made a successful case for the Survey before local postal authorities, which led to an arrangement for the use of special labels and monthly payment of accumulated charges (WRD Bull., May 1948, p. 71–72).

Communication—Liaison

Despite the increasing use of the long-distance telephone, the United States mail continued to be the major means of communication between District offices and the Washington, D.C., headquarters during the decade. Western Union telegrams had been used for more urgent messages, but their use declined because of the telephone. The WRD Circular series continued to be used to convey information to the District offices. Unnumbered, these Circulars were identified by date and subject. Beginning on January 1, 1953, the term "Memorandum" was used instead of "Circular." The frequency of such issuances did not change greatly during the decade, varying perhaps from 4 to 12 or more per month. Each of the Branch chiefs also issued memos to his District offices on intrabranch matters.

Extensive use has been made of these WRD Circulars (memos) in the preparation of this history. They have been referred to by date because they are preserved by the Division in chronological form, with each calendar year in a separate binding. On the basis of past practice, the 3-foot stack of these volumes for the 1947–57 decade likely will, in time, be transferred to the U.S. Archives.

The quarterly *WRD Bulletin* continued throughout the decade, having begun many years earlier as a newsletter. Composed of articles typically reporting on new or improvements on existing hydrologic techniques or equipment, the *Bulletin* helped District staff keep abreast of the technology underlying each activity. All employees were eligible contributors. Although not specifically identified as such in the issues, it appeares that C.H. Pierce, a senior hydraulic engineer on the Headquarters staff (SW), was editor for an extended period. He also updated the index to the *Bulletin* through 1947 (WRD Bull., Feb. 1948, p. 32–33).

Formerly mimeographed, the May 1948 issue and subsequent issues of the *Bulletin* were reproduced by the newer offset process, which permitted a photographic reduction of the original manuscript and the use of two columns of text per page. Some delays were apparent. The August 1948 issue was not available until the following March because of a printing backlog in the Department's miscellaneous services section. The number of field copies increased during 1949 so field personnel could have better access to it. By memo dated February 8, 1954, the CHE announced the appointment of a special committee to review the general pattern, content, format, and distribution of the *Bulletin*, the first review since 1938 (WRD Bull., May 1954, p. 25). By memo dated November 26, 1956, prepared and signed by R.L. Nace, an effort was made to devote more space to "airing new ideas, research problems, and problems in practical hydrology." He hoped that the *Bulletin* could become a "preliminary outlet" for younger writers.

In an age of manual typewriters, carbon paper, and mimeograph stencils, considerable time was spent in preparing letters and memorandums. Secretaries skilled in transcribing dictation into a grammatically correct letter in one operation were usually on the rolls not only at Headquarters but in the larger District offices as well. The electrostatic copying process was being developed during the decade, but none were known to be in use in the WRD. Typed carbon-backed originals on thin paper could be reproduced legibly on ozalid or blueprint machines and many documents preserved from the decade were made using this process.

By 1948, program growth and problems associated with new accounting procedures resulted in a backlog of unanswered correspondence in the Washington office, according to a WRD Circular dated February l0 of that year. (The surge in correspondence is indicated by the fact that a WRD Circular dated March 8, 1948, reported that the allotment limit for field stationery was exhausted!)

By 1950, the volume of mail received at the National headquarters from the field had grown to the point where a mail code was adopted for use in outgoing correspondence. WRD Circular dated January 30, 1950, specified

that field replies to memos, formerly all addressed to the CHE, were to be directed instead to the head of the subordinate unit in which the correspondence originated.

In October 1953, the Interior Department unilaterally decided to use commercial postage on its correspondence, rather than to maintain the records and inventories required in the use of penalty indicia. In compliance, the Division's outgoing correspondence was sent to a central mail room under the Survey's Administrative Division where postage (commonly 3 cents for a letter) could be affixed. Parcel post mailings under stamp were already in effect (WRD Circular dated October 29, 1953). Frank Barrick recalls that the use of postage stamps continued through the end of the decade (written commun., 1983). During 1954, the Division transferred its mailing facilities to a new centralized mail room under the Survey's Administrative Division (WRD memos dated February 28 and March 9, 1955).

By 1953, the convenience and effectiveness of the long-distance telephone was well recognized. However, its increasing use brought a reaction from Headquarters. WRD Circular dated August 19, 1953, discussed the matter of the relatively high cost of telephone calls and the absence of a record of the business transacted. Better planning was suggested to reduce the length of telephone conferences and a greater use of memos in lieu of or in connection with calls. (A comparison of relative costs, then and now, between a phone call and the preparation of a memo, is interesting. John Treicis of AT&T Long Lines has advised orally that in 1953, a 3-minute call from New York to San Francisco cost $2.50 plus 60 cents for each additional minute. In 1983, such a call at a commercial rate would have cost $1.48 plus 43 cents for each additional minute. The Federal Telecommunications System, established in 1963, provided even lower costs. Regarding the cost of preparing a memo, the annual starting salary of a GS-4 stenographer was $3,175 in 1953 and $11,949 in 1983. The economic forces were all in favor of the telephone.)

FIELD CONFERENCES

Division- and Branch-level conferences, both national and regional, had served for many years to help keep field and headquarters officials in touch with one another and informed of the latest techniques, and usually were documented as proceedings for later internal reference. Follansbee (v. IV, p. 22–25) describes the conferences of the previous decade, all after World War II and regional in nature because of the growth of the organization.

Only one Division-level conference was held during the 1947–57 decade, at the Morrison Hotel in Chicago, Ill., during May 24–27, 1954. It was in response to a petititon requesting a SW Branch conference and signed by 32 district engineers of that Branch. By memo dated December 3, 1953, the CHE advised the field officials of all branches of his approval, with the Director's concurrence, of a Division-level conference to be arranged by a committee composed of six District chiefs from the three branches and under the chairmanship of L.C. Crawford. Conference Secretary Burdge Irelan, in his summary of proceedings, refers to it as "the first national administrative conference of the Water Resources Division." Although originally scheduled for about 30 persons, nearly 125 were present (see group photos, figs. 5, 6 and 7). The conference was declared a huge success in terms of information exchanged among the many who had never met and those who had not been together recently. Perhaps best remembered of the many statements made at the conference was that by guest speaker and internationally renowned sanitary engineer Dr. Abel Wolman, who stated that "the Survey should publish more promptly material which interprets and synthesizes the vast amount of basic data accumulated." Most agreed that this was timely advice. Other conferences were held for all WRD officials in certain States or regions, such as the Pacific Northwest conference in Portland in April 1952 and the California conference in Los Angeles in October 1952. Regional conferences were also arranged within the three operating branches.

Publications and Report Preparation

TYPES OF PUBLICATIONS

Of the five established series of formal book-type publications used by the Survey, the Division continued to make the greatest use of the Water-Supply Paper series during the decade. From 1896, when the first one was published, to 1947, nearly 1,000 WSP's had been printed, and about 400 more were added during the decade. Fourteen or more of these reports were used annually for publication of daily-streamflow records. Others documented annual records of ground-water levels, chemical analysis of water samples, and sediment-discharge data. A sizable number reported on flood stages and discharges. The balance was devoted largely to findings from project investigations. The Division made only occasional use of the Professional Paper series, which carried a larger page size and was used extensively by the Geologic Division.

Of the Circular series established in the 1930's for less permanent and relatively simple reports, fewer than 20 had been published at the beginning of the decade. Circulars proved to be a practical outlet for Division manuscripts, and a large portion of the nearly 400 published before 1957 pertained to water resources. Unlike the WSP's, the Circulars were furnished to the public without charge.

Figure 5. Attendees at WRD Conference, May 23–27, 1954, Chicago, Ill.; Group 1.

Figure 6. Attendees at WRD Conference, May 23–27, 1954, Chicago, Ill.; Group 2.

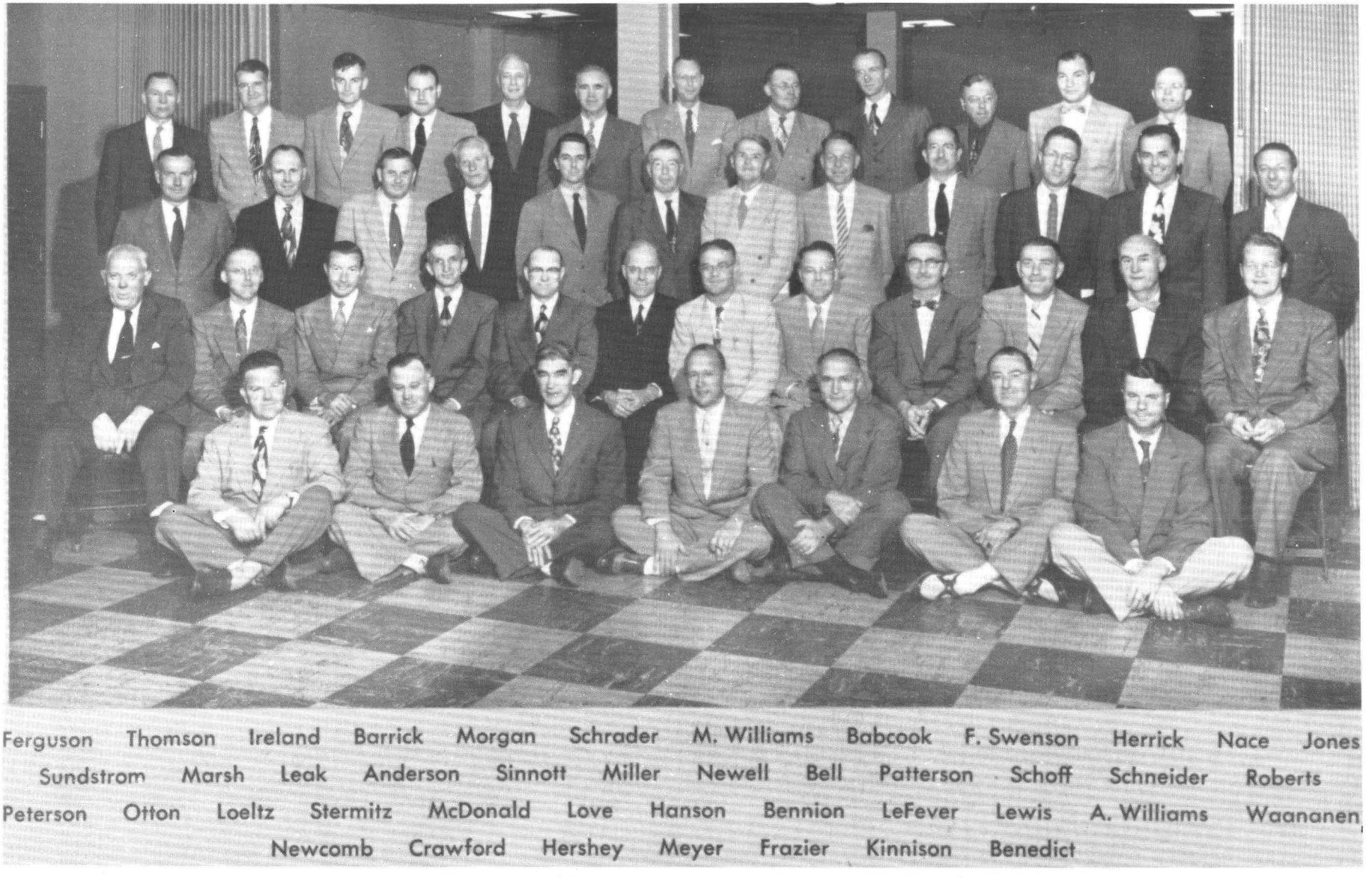


Figure 7. Attendees at WRD Conference, May 23–27, 1954, Chicago, Ill.; Group 3.

A Hydrologic Investigations Atlas (''HA'') series was first used in 1954 for hydrologic information that could be most effectively presented with greater reliance on graphics and less on text. For such a format, sheets measuring 22 by 27 inches were specified. W.B. Langbein recalls that the establishment of the ''HA'' series was stimulated by the Division's need to respond in a positive manner to two unrelated situations (written commun., 1975). H.C. Troxell, a hydraulic engineer and senior member of the Los Angeles, Calif., Subdistrict staff, had prepared in the late 1940's numerous manuscripts of findings from the cooperative water-supply study of the San Bernardino area. Although the voluminous text was repetitive and would have been costly to publish, Troxell's maps, diagrams, and charts were designed with considerable skill. Paulsen, in considering what to do with this ''shelf full'' of report material, was also mindful of the desire of an official of the Bureau of the Budget to have WRD make greater use of map formats in its reports. Robert Randall, a mapper by profession and in charge of the Bureau of the Budget's map coordination, sat in on the annual hearings on the Survey's budget. Paulsen conferred with Langbein on the matter and, to test the merit of the proposal, Langbein reconstructed the groundwater study of Lodi, Calif., so that it ''became a folio of maps rather than a book accompanied by folded maps in a pocket.'' Langbein concludes: ''We wrote Troxell sending him the Lodi sample and asked him if he would be willing to take the necessary time to prepare his report in atlas form. Troxell jumped at it and the result is HA No. 1 (1954). This was issued in fancy library folio form with covers. The change in form to letter-sized folio followed in 1959 with HA-14, the first of the flood series which George Edelen and I prepared.''

The greater use of maps in the reporting of station data networks and boundaries of study areas was formally proposed by J.C. Kammerer in 1946 (Proceedings, Southern Branch conference, WRD, December 5–7, 1946, Montgomery, Ala.). Kammerer described a format that likely helped provide a design base for the first series of ''Water-Resources Investigations of (State)'' published in 1962.

The Water Resources Review (now National Water Conditions), a monthly press release of hydrologic conditions, started in 1940 and continued with a widening distribution during the decade. A sampling of the list of about 3,000 mailees in 1952 indicated that about 29 percent of the copies went to other Federal agencies, 25 percent to business corporations, 23 percent to non-Federal agencies, and 12 percent to colleges and libraries (WRD Bull., Aug. 1952, p. 78). WRD Memo dated March 13, 1956, specified several changes in terminology in the Water Resources Review, including the ''complete abandonment of the term 'normal'.'' Because of confusion as to the meaning of that term, ''median'' or ''average,'' as appropriate, was used instead.

A plan for a new series of special reports of the water resources of each State was announced in a WRD Memo dated April 24, 1957, a few days before the end of the decade. They were to be prepared in popular style and directed to ''everyone concerned with water.''

A number of reports by WRD personnel were published commercially during the decade. Among them was ''Hydrology,'' edited by O.E. Meinzer (WRD Circular dated April 7, 1949); ''The Conservation of Ground Water'' by H.E. Thomas (WRD Circular dated October 1, 1951); ''The Flood Control Controversy'' by L.B. Leopold and Thomas Maddock, Jr.; and ''Floods'' by W.G. Hoyt and W.B. Langbein. The last two were announced by WRD Memo dated April 29, 1955.

Many other manuscripts were unpublished but were made available for public inspection as ''open-file'' reports at locations conveniently close to the parties most interested. The ''open-file'' category had been developed in the previous decade largely by O.E. Meinzer for use in the GW Branch. He was very specific concerning the need to keep manuscripts confidential until they were approved and publicly announced as open-file items. This was to assure that no single interested party could, through preview, gain unfair advantage over others regarding findings in situations where local ground waters as a resource were controversial or in litigation. WRD Circular dated October 30, 1950, carried the latest instructions from the Director's office, which specified that, although basic data without interpretive statements could be open-filed under blanket authority, other reports must have the Director's approval and public notice, such as press releases. Many reports, initially open-filed to provide early public access, were later published (pt. II, ''Annual Budgets and Congressional Appropriations, 1954 Fiscal Year''). By the end of the decade, the standing of open-file reports was clarified by a memo dated February 28, 1957, from the Associate Director to the Chief, Publications Branch. They were to be a form of publication that could and often should be cited among the list of references in other reports.

Numerous manuscripts that reported results of local investigations were published by cooperating agencies at the State level, often at the request of those agencies. Whether printed by the Survey or the local cooperator, publication costs were borne entirely by the publishing agency and outside of the cooperative funding.

Reports prepared during the decade by the Division under the various series, including Open-File and cooperator-published types, are listed in the ''Water Resources Investigations for (State)'' folders, edition of 1962. These are available for reference at the library, U.S. Geological Survey National Center, Reston, Va.,

and at other Survey libraries and District offices. More detailed descriptions of each publication series are given in "Suggestions to Authors, U.S. Geological Survey, 5th edition."

Numerous articles by non-Survey writers on the Nation's water resources were published during the decade in response to increasing public interest. WRD personnel were usually contacted by the writers in the preparation of the material. Copies of two such publications were transmitted to the District offices by a WRD memo dated April 12, 1954: *Fortune Magazine's* March 1954 article on "How Are We Fixed For Water?" and the American Water Works Association's booklet "The Story of Water Supply."

REPORT PREPARATION AND REVIEW

Problems encountered in the preparation, review, and publication of accurate, well-written reports during the decade did not vary greatly from either earlier or later efforts. Two earlier obstacles, however, were largely overcome. The backlog of WRD reports held for review in the Survey's section of texts during the first 2 years of the decade was being steadily reduced, according to an item in the *WRD Bulletin* dated May 1949. In fiscal year 1950, Congress approved the elimination of a specific item in the annual appropriations for printing and binding. An amount of $75,000 was transferred from that item to the "gaging streams" appropriation. This permitted the Division to use its funds, without specific limitations, to meet its publication needs (pt. II, Annual Budgets, 1950 Justifications).

Reports that contained "interpretive statements" were given the traditional special scrutiny by the Division staff and required specific approval by the Director or his assigned representative. The preparation of manuscripts on subjects crossing Branch jurisdictional boundaries also required special treatment. WRD Circular dated February 21, 1949, specified that "a report prepared by one branch containing information within the field of competence of other branches, should be referred to those branches . . . for review . . . ." WRD Memo dated June 11, 1956, further specified that interbranch reports were to be assigned to one particular Branch for further processing.

In 1955, with the number and size of reports increasing, the GW Branch staff formalized further the report-review process and, in so doing, specifically required that manuscripts be sent by each District to the appropriate regional staff officer for review. A more complete report routing sheet was specified (GW Memo 56.3 dated July 25, 1955). The GW Branch staff was in a leadership role during the decade in the preparation of descriptive and interpretive reports because of greater reliance on and experience with them. More detailed procedural and policy information than is covered in the foregoing may be found in GW Branch Memoranda numbers 54.25; 54.7; 55.6; 56.14; 56.2; 56.41; 56.44; 57.18; and 57.29. Copies of them are likely stored in the U.S. Archives.

PUBLIC RELATIONS

The Division enjoyed an ever stronger relationship with industry, the press, and the general public during the period. As stated in the introduction and in other earlier segments of this volume, recognition that water was a vital but limited natural resource grew rapidly during the decade. It was soon discovered, by those who sought reliable nationwide information as to the nature and extent of the resource and how it could best be used, that the Geological Survey was well qualified to furnish the data. Moreover, there were few other such sources at the time. Private industry and others also felt quite comfortable with the data because the Survey was not a regulatory or an "action" agency.

Public awareness of the WRD's activities and their value increased during the period. The presence of gage structures on river banks, and of stream gagers and their equipment on bridges and cableways, did not usually arouse the curiosity displayed by local residents in earlier years. The Survey was less frequently referred to as the "Geodetic Survey." Although familiarity with the published findings of the Division was confined largely to professional staffs of water-related agencies, there was growing evidence that the number of elected officials personally familiar with WRD reports increased steadily during the period. This was, of course, the result of local water problems and the need to become acquainted with measures required for the solution of those problems.

The U.S. Chamber of Commerce typically expressed support for the Survey in its annual policy statements. Magazine writers sought interviews with WRD officials and senior scientists. Water-oriented organizations, of which the American Water Works Association (AWWA) was the most prominent at the time, relied heavily on WRD personnel for published articles and even policy guidance. (During the decade, AWWA's major interest may well have been in water supply. In later years, its major interest shifted toward the problems of water-department management.) The American Water Resources Association (AWRA) was organized and had a healthy initial growth during the decade. Many WRD personnel joined AWRA and became prominent in the conduct of its affairs.

Attention was increasingly given during the decade to the preparation of exhibits for use at national meetings of

water-oriented organizations. One of the Division's early experiences with a large formal exhibit was at the annual meeting of the National Reclamation Association in Oklahoma City, Okla., in November 1948. Part of a Survey-wide presentation, WRD's 10- by 30-foot exhibit of field equipment publications and diagrams attracted a gratifying amount of interest (WRD Bull., Feb. 1949, p. 2–4). An earlier exhibit was set up at the Pacific Chemical Exposition in San Francisco, Calif., in October 1947 (WRD Bull., Nov. 1947, p. 185). Another was maintained at the California State Fair in September 1949 (WRD Bull., Nov. 1949, p. 76).

The quality of the exhibits greatly improved, however, after R.H. Kenah, the Survey's first exhibits specialist, entered on duty in July 1954. Kenah and his staff constructed a number of portable exhibit racks with packing cases on which photos, diagrams, and charts were mounted for exhibit as needed (WRD Memo dated September 24, 1954). Also, public knowledge of the type, breadth, and availability of WRD's publications measurably increased after 1950 when the Survey established Public Inquiries Offices in Denver, Colo.; Salt Lake City, Utah; San Francisco and Los Angeles, Calif.; Spokane, Wash.; and Anchorage, Alaska (Ann. Report, 1956, p. 142).

Instances were rare when negotiations with the public were other than harmonious and objective. The securing of permission to construct and maintain gage structures, cableways, channel controls, and observation wells was invariably handled by a simple exchange of letters with the landowner. Legal authority by condemnation did exist, however, and was tested successfully in at least one instance, as reported by C.E. Knox of the Boston District, when a new landowner demanded an exorbitant fee for past and future use of a gaging station site (WRD Bull., Nov. 1948, p. 115).

Part VII—Response to Special Situations and Events

Controversy Over USGS Ground-Water Investigations, 80th Congress Hearings

In the mid-1940's, a controversy developed between the U.S. Geological Survey in North Dakota and the Layne Western Company of Minnesota over performance by Layne Western in connection with contracts for test drilling as a part of ground-water studies by the Geological Survey in cooperation with the State geologist. Lee Rogers, president of Layne Western, already perturbed by the tendency of towns like Beulah, N. Dak., to delay contracts for drilling water-supply wells until cooperative ground-water studies were made, placed his grievances not only before a number of organizations but also before Congressional Appropriation committees. Having gained the backing of the Minnesota Well Driller's Association of which he was chairman of the legislative committee, Rogers attempted to gain the support of similar driller's organizations in other States. Rogers charged that Survey ground-water hydrologists were using well-drilling rigs purchased with public funds in direct competition with private drillers, that the Survey hydrologists were promoting ground-water studies unduly, and that the private well drillers had greater experience in developing ground-water supplies and could satisfy municipal requirements without Federal assistance.

The president of the Illinois Well Driller's Association, eager to have Association members learn both sides of the controversy, devoted a portion of the July 1946 periodical to statements from Rogers; A.G. Fiedler, assistant chief, GW Branch, Geological Survey; W.M. Laird, North Dakota State geologist; and G.E. Condra, Nebraska State geologist. Fiedler acknowledged that objections to test drilling by Survey personnel with State or cooperatively owned equipment had been raised at House Hearings on the Survey's 1946 and 1947 appropriations. He further stated that the Survey's experience in the subject had been reviewed and that its policy was to "conduct test drilling so far as practical, by contract, but that in the four States where drilling by State or cooperatively-owned rigs was in progress . . . such work would continue." Former Director Nolan recalls (written commun., 1985) that this policy statement was prepared as a result of a meeting in the Director's office with representative well drillers. He also recalled a comparable problem with aerial photography required by the Topographic Division.

The issue arose with greater force when the Survey budget for fiscal year 1948 was considered by the Congress. This has been covered in considerable detail earlier in part II, "Annual Budgets and Congressional Appropriations, 1948 Fiscal Year."

Rogers also brought his complaint to the American Water Works Association through Herbert Grove, AWWA's national director from the Minnesota Chapter. G.E. Ferguson (also an AWWA director representing Florida at the time) recalls that Grove presented Rogers' position unexpectedly but quite forcefully at the 1947 (?) meeting of the national officers and directors and that he (Ferguson) was ill-equipped for an effective rebuttal of charges on a subject with which he was not familiar. (It is perhaps noteworthy that, at a social session that evening, and with new information on Grove's background, Ferguson had the opportunity of advising Grove that his (Ferguson's) grandfather and Grove's father were fellow pioneers and lodge members and close associates in the Minnesota town Ferguson had moved from years before. Fortunately, the discussion continued the following day in a more friendly and thoughtful manner.)

Following conferences with Survey representatives and a group of well-drilling contractors, the AWWA announced in the July 1948 issue of its journal a new policy regarding test drilling. The statement, after affirming the inadequacy of water data and its support of Survey cooperative ground-water studies with municipalities when State agencies did not exist or were unable to provide the services, expressed the opinion that "neither the USGS nor the State agencies with which it cooperates should own or operate test well drilling equipment. . . ." It further held that "test well drilling should be done by competent private industry under contractual arrangements made by the driller with the Geological Survey or the State or local public agency concerned." However, AWWA then referred to the foregoing as "opinions in broad principle" and granted "that when test well drilling needs to be done—and no private contractor is willing or able to do the work—the public agency may properly do it in order that the public interest be served effectively."

This policy statement was sent to the WRD districts on November 16, 1948, with a reminder that it was similar to a statement released by the Director and published in the July–August 1945 issue of the Johnson National Driller's Journal. The GW Branch personnel continued their activities with no known recurrence of the controversy. Relations with well drillers and their associations, with this exception, have been good and mutually beneficial. In retrospect, the event—regrettable as it was—had side effects that were beneficial. Ground-water investigations that required test drilling were developing so rapidly (Follansbee, v. IV, p. 222) that a critical analysis of policy was timely. The situation also strengthened internal solidarity. District chiefs of the other branches joined in making effective representations of the importance of and requirements for ground-water studies. These included P.R. Speer and R.E. Marsh, SW district engineers for Minnesota and North Dakota, respectively.

Secretary's Survey Committee on the USGS

In 1953, newly-appointed Interior Secretary Douglas McKay, in an effort to eliminate waste from governmental operations, arranged for a number of investigating committees, each to look into the activities of one of the Department's Bureaus and Offices. (The investigative effort apparently extended beyond Interior; the Bureau of Standards also was under scrutiny.)

The Committee for the U.S. Geological Survey, established August 5, 1953, by Assistant Secretary F.E. Wormser, was under the chairmanship of J.R. Van Pelt, president of the Montana School of Mines. Other members were S.G. Lasky (Committee Secretary), H.M. Albright, D.M. Davidson, J.C. Frye, and W.B. Heroy. The Committee met at intervals for a period of about 7 weeks. A number of witnesses from WRD were asked to meet with the Committee, one at a time. (The author recalls that the atmosphere was one of friendly inquiry during which the witness was invited to make suggestions.)

Anticipating that the Committee would look into the organization of WRD, the CHE appointed a task force composed of W.W. Hastings, H.B. Kinnison, and H.E. Thomas to facilitate preparation of information that the Committee might request. A statement of program and organizational objectives had already been prepared and was transmitted to the District offices by WRD Circular dated September 24, 1953. It refined and expressed in greater detail, but did not appreciably revise, earlier statements of program goals. The statement did express, however, in Circular form for the first time, a set of guidelines to achieve a greater integration of Branch field facilities and administrative service functions. These were summarized earlier in part I.

The Committee's report dated February 12, 1954, credited the Survey with "an unsurpassed record of integrity, ability, and devotion to duty," identified "its major points of weakness," and made 46 specific recommendations (USGS Library, National Center, call numbers 207[200] Un31sn and Un31sra). Among those recommendations relative to WRD were that programming functions in each Division be under an assistant chief for plans and coordination. (This led to the abolishment of the PC Branch in 1957.) The Committee supported the continuation of the branches, but recommended that "part of the research work be taken over by a General Hydrology Branch to be created." (A new Branch by that name was established in 1957, replacing but using the staff and facilities of the TC Branch.) Joint (Federal-State) equipment ownership was criticized (and was ended a few years later). For the cooperative program, joint programming and staffing and State supervision of projects were suggested.

It was evident that many of the Committee recommendations were based on suggestions from its witnesses at Division, Bureau, and Department levels, and from other sources as well. Practically none of the recommendations were new. In retrospect, the very existence of such a Committee served as a catalyst to progress in programming and organizational changes and, through the September 24, 1953, policy statement by the CHE, the field establishment became better conditioned for the consolidation of districts in the 1960's.

Survey Advisory Committee

Although it was not associated with any specific event or situation existing in WRD during the decade, the assistance received by the Survey and the WRD from the Survey Advisory Committee is worthy of documentation. Doing so should also clarify the fact that the Secretary's Survey Committee, described in the preceding section, and the Survey Advisory Committee were separate and unrelated entities. Any confusion regarding such a relationship may have come, first, because three members of the Advisory Committee were also members of the Secretary's Survey Committee and, second, because no formal reports were prepared by the Survey Advisory Committee. Much of the following information was kindly provided from memory by former Director T.B. Nolan in a conference with the author in April 1985.

The Survey Advisory Committee was established at the recommendation of the Secretary of Interior and the National Academy of Sciences as an informal advisory group to W.E. Wrather, a petroleum geologist who was appointed Survey director in 1943 on the recommendation of the Academy. The Committee, composed of nationally

and internationally known scientists and educators, proved so helpful that it was invited to continue by Director Nolan when he succeeded Wrather in 1956, and it did so until Nolan's retirement in 1965. The composition of the committee was as follows: H.M. Albright, Director, National Park Service (1929–33) and long-time general manager (1933–56) and president (1946–56) of U.S. Potash Co.; Eliot Blackwelder, an eminent student of desert terrains and mountain glaciers, former part-time Survey employee (1916–19), and head of the Geology Department at Stanford University (1922–45); J.C. Frye, Survey employee in Kansas (1938–40), State geologist of Kansas (1952–54), and chairman, Illinois Geological Survey (1954–74); W.B. Heroy, Survey employee (1908–19), member of the firm Beers and Heroy (1946–56), and president, Geotechnical Corporation (1946–52); M.M. Leighton, chief, Illinois Geological Survey (1923–54); Major General Herbert Loper, district engineer, Corps of Engineers, in charge of work on the Missouri River and its tributaries (1935–39), chief, Military Intelligence Division, Corps of Engineers (1940–41), and later assistant to the deputy chief of staff, research and development; D.H. McLaughlin, chairman, Division of Geological Sciences, Harvard University (1930–41), Dean of the College of Engineering, University of California (1942–43), and president and later board chairman, Homestake Mining Co., Lead, S. Dak.; G.G. Simpson, curator, American Museum of Natural History (1944–59) and professor, Harvard University (1959–70); and Abel Wolman, internationally distinguished sanitary engineer and professor at Johns Hopkins University. Blackwelder, Heroy, Leighton, McLaughlin, and Wolman were the original members. Simpson succeeded Blackwelder as a committee member in the mid- or late-1940's when Blackwelder died. Frye succeeded Leighton in 1960. Albright and Loper were added later at the Survey's recommendation, Albright because of his familiarity with the work of the Conservation Division and Loper because of his mapping background. Loper, in retirement from active duty, was advisor to the Secretary of Defense on atomic-energy matters.

The committee members, without Federal compensation or reimbursement for travel costs, attended meetings called by the Director usually at the Survey's headquarters in Washington, D.C. Meeting frequency depended somewhat on the emergence of problems or situations about which the Director sought advice. Division chiefs frequently participated. Committee activities were informal, and although findings were usually not formally documented, the members usually met with the Secretary at the time of their Survey meetings. These members—each a leader in his particular segment of the earth sciences—collectively provided the Survey with advice and recommendations that stood the test of time and on occasion provided valuable support for Survey programs with industry and members of the Congress.

The President's Water Resources Policy Commission

The President's Water Resources Policy Commission was established by Executive Order 10095 dated January 3, 1950. The Commission was to study and make recommendations to President Truman "with respect to Federal responsibility for and participation in the development, utilization, and conservation of water resources . . . ." In response to a request from the Commission in March 1950, the Division prepared and forwarded to it a report entitled "Water Facts in Relation to the National Economy." The principal authors were C.L. McGuinness and A.M. Piper. The report had a brief text followed by three appendices. Required field data were prepared by local District staffs and integrated by the WRD State councils, perhaps the first nationwide effort in which the newly organized councils played a significant role (WRD Circulars dated March 7, May 8, and June 9, 1950). USGS Circular 114 by McGuinness (1951) was an adaptation of material collected for the above report.

The Commission reported its findings and recommendations in three volumes. Volume 1, the general report, was entitled "A Water Policy for the American People" (445 p., 1950). Volume 2, "Ten Rivers in America's Future," was of about equal size and also published in 1950. Volume 3 (sometime later) carried the title "Water Resources Law."

Volume 1 included (appendix 3) the report of the Commission's Committee on Standards for Basic Data, which was established in April 1950. A.H. Williams, assistant chief, SW Branch, was a committee member. The committee, in making recommendations toward overcoming "the recognized deficiencies in basic data" (p. 326), expressed a need for expanded hydrologic-data networks that included 5,800 new gaging stations, of which 3,000 would include daily temperature readings; 1,200 chemical-quality stations to be sampled daily with temperature readings; and 1,300 stations at which daily sediment loads would be measured.

Also specified were reconnaissance ground-water surveys in all areas not already covered and intensive surveys in river basins "where acute need exists in connection with projects." (Proposals for the expansion of basic-data programs also included those for topographic mapping, geology, soils, fish and wildlife, and socioeconomic activities.) No agencies were mentioned by name. The recommendations undoubtedly enhanced Bureau of the Budget and congressional support for increases in the Division programs during the balance of the decade.

H.R. Committee on Interior and Insular Affairs

During 1952 and 1953, the House of Representatives' Committee on Interior and Insular Affairs published four volumes or "parts" in a series on "The Physical and Economic Foundation of Natural Resources." Parts II, III, and IV of the series were on water resources and were prepared largely by Division scientists at the request of Committee Chairman Congressman John R. Murdock of Arizona, and Dr. J.R. Mahoney, senior specialist in natural resources of the Legislative Reference Service, Library of Congress.

Part II, "The Physical Basis of Water Supply and its Principal Uses," was a compilation of reports largely by water-oriented agencies at the Federal level, including the Survey. Part III, "Groundwater Regions of the United States—Their Storage Facilities," was prepared by H.E. Thomas. Part IV, "Subsurface Facilities of Water Management and Patterns of Supply—Type Area Studies," carried an introduction by Congressman A.L. Miller of Nebraska, the new Committee Chairman. The first chapter, in which A.M. Piper explored the national water situation, was followed by descriptions of eight selected areas prepared by other hydrologists of the Division.

The report manuscripts (requested by Representative Murdock under the rather detailed specifications set by Mahoney) were prepared on schedule, but the commitment was a difficult one for two reasons: the participants were forced to postpone other commitments, and no clearly defined allocation of funds was made in the Survey's current appropriations, although Mahoney believed that this had been accomplished. A professor emeritus of economics at the University of Utah, Mahoney was highly interested in the planning of the reports and made numerous direct field contacts with participating Division personnel.

Commission on Organization of the Executive Branch of the Government

This commission, headed by former U.S. President Herbert C. Hoover (1928–32) and most often referred to as "the Hoover Commission," was established by the 80th Congress in 1947 to explore ways to improve the efficiency of the Executive Branch and to eliminate wasteful methods of operation. The Commission, in its report to President Truman in 1949, recommended a number of sweeping changes. Although reports from the Commission's numerous specialized task groups began to be referred to the various agencies for review as early as 1949, the three-volume "Task Force Report on Water Resources and Power" was not published until June 1955 (USGS Library, National Center, call number 784[200] Ur326r).

The Division was pleased to note one particular recommendation by the task force which, in discussing the need for basic data, stated that "Congress should establish a policy of requiring, as a condition of Federal assistance, a satisfactory demonstration that each project proposal is based on adequate basic data . . . ." By memo dated March 22, 1955, the Director asked the Division to prepare the required formal review of the report. Most of the reports by other task forces were handled by the Survey's administrative offices, with the various review procedures continuing beyond the end of the decade. The implementation of those task force recommendations that were accepted by the Executive Branch had little, if any, direct effect on the substantive program of the Division during the decade.

The Princeton Report

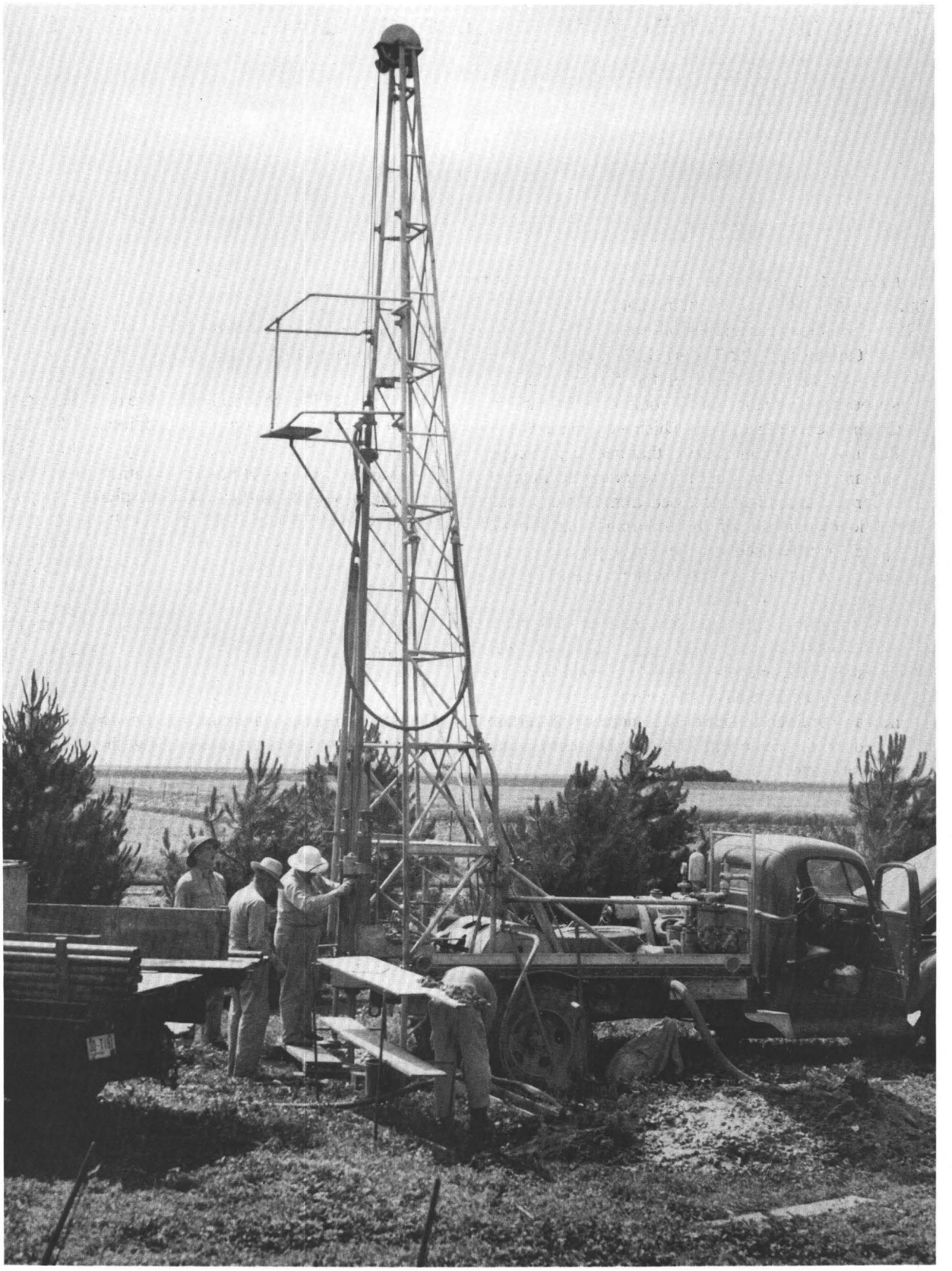
This 60-page report, "The Geological Survey," was part of an administrative history of the USDI compiled as a research project by Norman Horowitz of the Woodrow Wilson School of Princeton University. The volume in the Survey Library (cataloged as 207[200] H785g, dated June 15, 1950, and marked as a draft) is likely a review copy sent to the Survey for comment prior to plans for final publication.

The report was a frank and critical assessment of the organization and management of the Survey, as illustrated by the final sentence of its initial paragraph: "Because the Bureau treasures its autonomy and resists organizational change, it is from time to time cast in the role of a 'problem child' in the departmental family." The descriptions of the goals and performance of the individual divisions were essentially factual, and criticism was largely reserved for the large degree of independence allowed the divisions by the Bureau and the absence of a standard regional level of control. The Director's response (memo dated December 21, 1950, to the Secretary) sought to (and apparently did) give the USDI a better understanding of the Survey's operating problems and their relation to administrative management than was apparent from the report. The author is uncertain if the USDI officially sponsored the Princeton Report, but he recalls that the recommendations made by Horowitz were similar in nature to the aspirations of two Departmental organization and management specialists who used to visit WRD headquarters from time to time during that period. The report had little effect on subsequent plans or activities of the WRD, probably because of the Director's response of December 21.

Observance of 75th Anniversary of USGS

A program celebrating the 75th anniversary of the founding of the U.S. Geological Survey was held in the

USDI auditorium on April 21, 1954. C.G. Paulsen, one of the speakers, cited the pioneering work and long-time leadership of N.C. Grover who served as CHE of the Survey from 1913 to 1939. Grover, then 86 and whose attendance had been arranged, was introduced by Paulsen and given a round of applause (memo dated May 7, 1954 to District offices). (A biographical memoir of Grover, who died in 1957, was prepared by A.H. Frazier, a condensation of which was published in the May 1976 edition of *WRD Retirees* newsletter. Grover's part-time service earlier in the decade is described in pt. I.)



Drilling test holes with a rotary rig for ground-water exploration.

Part VIII—The Close of the "Paulsen Decade"

Director Nolan announced Paulsen's retirement to the Survey's division chiefs by memorandum dated April 17, 1957. The initial paragraph follows.

"On April 30, 1957, Carl G. Paulsen will retire after 11 years as Chief of the Survey's Water Resources Division and a total of 45 years in Government service, 43 of which were in the Water Resources Division. During that period the scope and amount of the Survey's work in the field of water resources has increased tremendously, and public recognition of its importance has grown apace. Mr. Paulsen can be justly proud, as the Survey is, of the accomplishment record of the Water Resources Division under his direction. We hope to profit further from Mr. Paulsen's extensive experience in the field of water-resources investigations, and plans are being made to retain him on a part-time basis after April 30. In that way he can continue to serve as a member of certain boards having to do with Canadian boundary water problems and on other similar assignments that will benefit from his broad knowledge and great skill as a moderator."

Paulsen's memorandum dated April 18, 1957, to WRD's District chiefs and staff officials is quoted below.

"The attached memorandum by the Director of the Geological Survey announces my retirement from full-time Government service at the close of this month and the designation of Luna B. Leopold to succeed me as Chief of the Water Resources Division. My most sincere best wishes are extended to Mr. Leopold for a very successful career in guiding the highly important activities of the Division. I know that you will share these good wishes and will support him to the utmost. His brilliant record and nationwide recognition as a research engineer and hydrologist will add prestige and the kind of specialized talent needed by the Division in its future progress.

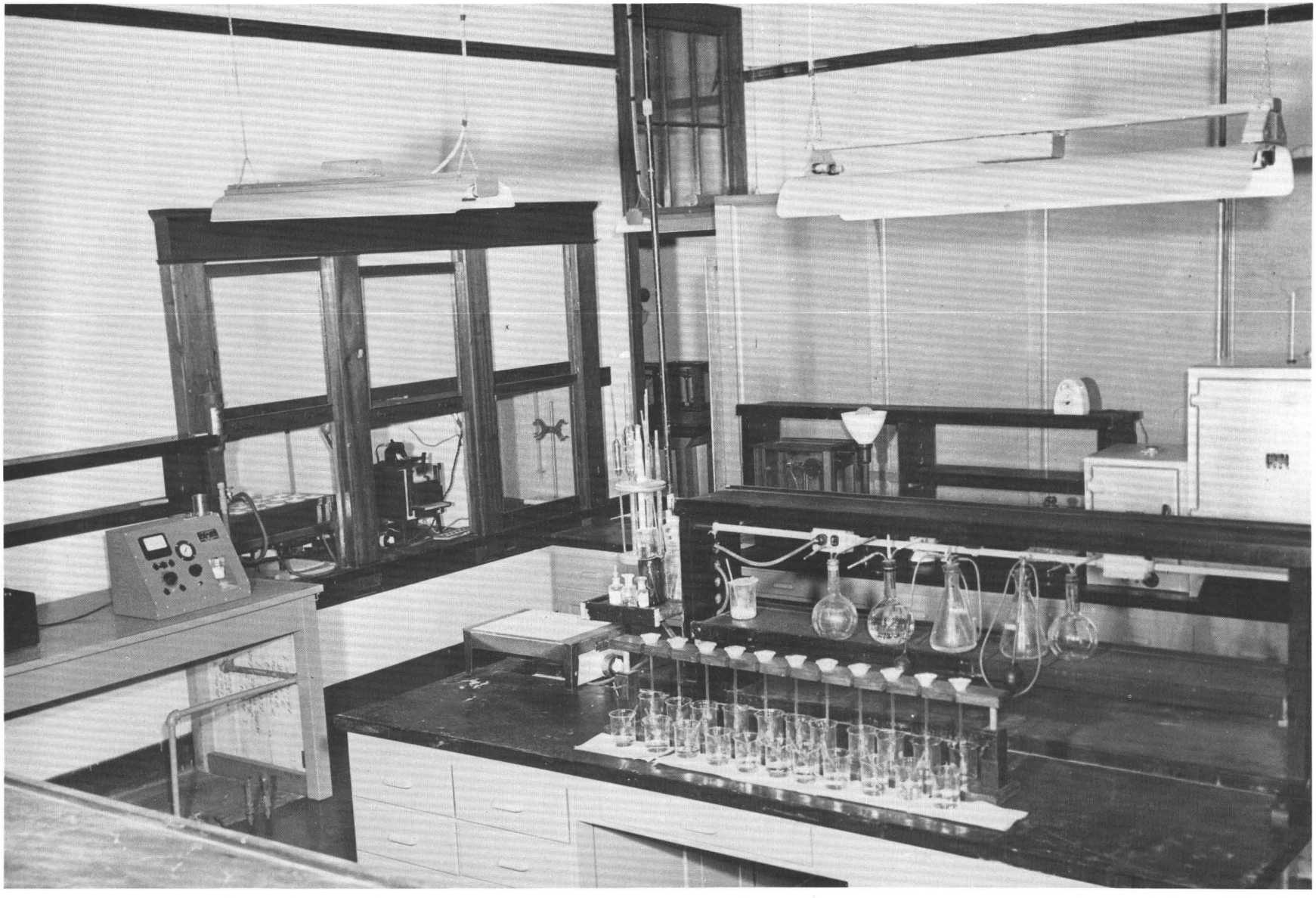
"Mr. Leopold will be ably assisted by Raymond L. Nace as Chief of Operations for the Division as well as by the branch chiefs, staff officials, area representatives, and the district chiefs throughout the country. With the support of an organization of outstanding people such as the Division and its branches represent, the Water Resources Division can look forward confidently to further accomplishments in the field of hydrology and public service even beyond our best expectations.

"It is with a great deal of sincere personal regret that I am leaving a full-time position and lifelong career in the Geological Survey. I do wish, however, to express heartfelt gratitude to all my associates in the Survey for their splendid support and loyal assistance throughout the many years we have worked together and achieved our overall objectives, despite the trials and tribulations of organizational growth. I am truly proud of our accomplishments, which could not have been achieved without your advice and constructive help throughout our many years of close association. They have been happy ones for me—thanks to you—and I am tremendously grateful.

"All of you, individually and collectively, will always have my most sincere best wishes for greater success and happiness in the future. You are well on the road to those greater accomplishments. I am happy to say that you have the full support of the Director and his staff in all of your activities. I shall look forward with keen interest and pleasure to seeing all of you from time to time in the future."

WRD personnel who had the privilege and pleasure of a close association, or even an occasional contact with Carl Paulsen during the decade, know that his references to the "years we have worked together" and "our overall objectives" came straight from his heart. One worked **with**—not for—Carl, and all who knew him—whether a junior engineer with a current meter in a swinging cable car over debris-laden floodwaters or his contemporary monitoring a pumping test on a wintry day—were aware that Carl would be proud of their accomplishments.

More than 30 years have passed since the end of the "Paulsen years," and the strong basic-data program that Carl did so much to build in cooperation with the States is still intact, strong, and vital in the eyes of budget officials, the Congress, and the public. Of equal value among his achievements were the friendly working relationships he established among Division personnel in the 1947–57 decade that conditioned them for a smooth transition to the basic organizational changes in the 1960's and the continued high morale in the years that followed.



General view of the water-quality laboratory, U.S. Geological Survey, that was housed in the Chemistry building on the campus of Oklahoma A&M College in Stillwater.

Appendix A—Selected References, Source, and Availability

[Most of the following information sources are referred to a number of times in the foregoing text]

Durum, W.H., 1978, Historic profile of quality of water laboratories and activities, 1879–1973: U.S. Geological Survey Open-File Report 78–432, 235 p.

Follansbee, Robert, 1939, A history of the Water Resources Branch of the U.S. Geological Survey to June 30, 1919: Volume 1, printed under private subscription by Division personnel, 1939 (copies later reproduced for internal use only by Water Resources Division). [V. 2 same title, extends coverage from July 1, 1919, to June 30, 1928; v. 3 from July 1, 1928, to June 10, 1939; v. 4 from July 1, 1939, to June 30, 1947.] Note: These four volumes have thus far been cleared for ''internal use only'' by Survey personnel.

Picton, W.L., 1960, Water use in the United States, 1900–1980: U.S. Department of Commerce, Washington, D.C.

Swenson, H.A., Water quality and the Geological Survey, 1960: U.S. Geological Survey, for administrative use only, 103 p.

Taylor, G.C. Jr., 1976, Historical review of the international water-resources program of the U.S. Geological Survey, 1940–70: U.S. Geological Survey Professional Paper 911, 146 p.

USGS Circular, a series of publications identified by number. See ''Publications of the Geological Survey, 1879–1961'' and subsequent catalogs for full titles. Available in USGS Library, National Center, Reston, Va. (not to be confused with the WRD Circulars that are administrative memorandums).

Secretary's Annual Reports, available for inspection at the Department of the Interior's Library, Washington, D.C.

Survey Orders were issued as needed by the Director to Division chiefs. Identified by numbers.

Water Resources Division Bulletins were published monthly for the internal use of employees of the Water Resources Division, USGS. Copies are on file in the Division headquarters in Reston, Va., and in some District offices.

Water Supply Paper (WSP), the Division's primary report series. Identified by number only because of space limitations. See ''Publications of the Geological Survey, 1879–1961'' and subsequent catalogues for listing. Available in USGS Library, Reston, Va., and in most District offices.

WRD Retirees Newsletter, issued quarterly by an organized group bearing that title. Copies available in the USGS Library, National Center, Reston, Va.

WRD Circulars were either directive or informational (or both) in nature and were issued by the CHE to District chiefs and other field officials at such times as necessary. Referred to by date. Copies on file at Division headquarters or in the U.S. Archives, Washington, D.C.

Appendix B—List of WRD Personnel by Location, January 1, 1956

Water Resources Division
General Services Administration Bldg.
Washington 25, D.C.
January 1, 1956

OFFICE OF THE DIVISION CHIEF

Paulsen, Carl G., Chief, Engr-15
Ireland, Dorothy M., Secy. (Steno)-6

Program Control Branch
Office of the Chief

Ferguson, George E., Chief, Engr-14
Barrick, Frank, Jr., Adm Officer-12
Winkle, Gertrude M., Secy (Steno)-5
Casey, Frances W., Secy (Steno)-4

Program Development Section

Young, Kenneth B., Engr-12
Albright, Dorothy M., Clk-Typ-3

Fiscal Management Section

Morgan, Charles W., Chief-9
Snyder, James J., Acct Clk-5
Elmore, John W., Acct Clk-5
Youmans, Margaret L., Acct Clk-4
Williams, Rebecca A., Acct Clk-4
Feigler, Bettie J., Clk-4
Casgrain, Mildred D., Clk-Typ-3

General Services Section
Office of the Chief

Allen, Marjorie E., Chief, Adm Asst-9
DeVito,William J., Adm Asst-7
Murphy, Frances W., Mail & File Clk-4
Nootenboom, Selma J., Clk-Typ-4
Romack, Judith A., Supply Clk-4

Technical Coordination Branch
Office of the Chief

McDonald, Charles C., Act Chief, Engr-13
Langbein, Walter B., Engr-14
Leopold, Luna B., Engr-14
Sieveka, Ernest H., Engr-13
Waananen, Arvi Olavi, Engr-13
Thiesen, May E., Secy (Steno)-5
Blankemeyer, Lorena H., Clk-Steno-4

Research Section

Wolman, M. Gordon, Geol-9
Patton, Eva M., Illus (Gen)-6
Andrews, Grace C., Secy (Steno)-4

Technical Reports Section

Eisenlohr, William S., Jr., Engr-13
Coffay, Ethel W., Engr-7
Randall, Lois E., I&E Specialist-7
Bornstein, Gloria, Edtl Clk-5
Phillips, Elsie, Secy (Steno)-4
Currie, Ruth F., Clk-Typ-3

Water Utilization Section

MacKichan, Kenneth A., Chief, Engr-13
Mussey, Orville D., Engr-12
Kammerer, John C., Geol-12
Conklin, Howard L., Engr-12
Goodrich, Addie M., Clk-Steno-4

Surface Water Branch
Office of the Chief

Wells, J.V.B, Chief, Engr-14
Williams, A.H., Asst. Chief, Engr-14
Oltman, Roy E., Engr-13
McCall, John E., Engr-12
Reck, Charles Wm., Engr-11
Sieveka, Laura M., Secy (Steno)-5
Kent, Ila, Secy (Steno)-4
Koziski, Dorothy L., WAE, Clk-Steno-4
Zervos, Kay E., WAE, Clk-Steno-3

Research Section

Carter, Rolland W., Chief, Engr-13
Brown, Bertah A.D., Clk-Steno-4

Special Reports & Investigations Section

Hardison, Clayton H., Chief, Engr-13
Bue, Conrad D., Engr-12
Searcy, James K., Engr-12
Kinnison, Hallard B., Engr-11
Richardson, Donald, Engr-9
Rostvedt, Julian O., Engr-9
Hilker, Joan M., Stat-Clk-Typ-4
Berrang, Eunice L., WAE, Clk-Typ-4
Smith, Rose Mary, Clk-Steno-3
Crain, Jean M., Clk-Typ-3

Technical Standards Section

Dalrymple, Tate, Chief, Engr-13
Benson, Manuel A., Engr-12
Cragwall, Joseph S., Jr., Engr-12
Baker, Bessie L., Clk-Typ-4
Lynch, Jane L., Clk-Typ-3

ANNUAL REPORTS SECTION

Peterson, Barney J., Chief, Engr-13
Flynn, Francis J., Engr-12
Isherwood, William L., Jr., Engr-12
Anderson, Bennie A., Engr-11
Hodges, Edward B., Engr-11
Miller, Lucy M., Edtl-Clk-5
Logan, Ethel K., Edtl-Clk-4
Reed, Mildred M., Edtl-Clk-4
Drilleau, Margery O., Flexowriter Opr-4
Jefferson, Lois M., Clk-Steno-4
Barr, Arnold B., WAE, Clk-Typ-3
Dove, Donald A., WAE, Clk-Typ-3
Emory, Jonia A., WAE, Clk-Typ-3
Fones, Rita M., Clk-Typ-3
Forrest, Winona B., WAE, Clk-Typ-3
Gascon, Barbara A., Clk-Typ-3
Miller, Marion M., Clk-Typ-3
Parker, Roger C., WAE, Clk-Typ-3
Prince, Eunice M., WAE Clk-Typ-3
Rosenbaum, Hilda Z., WAE, Clk-Typ-3
Schroebel, Elva L., WAE, Clk-Typ-3
Smith, Hazel L., Clk-Typ-3
White, James C., WAE, Clk-Typ-3
White, Jerry E., WAE, Clk-Typ-3
Wilkie, Robert C., WAE, Clk-Typ-3
Williams, Paula M., WAE, Clk-Typ-3

GROUND WATER BRANCH
Office of the Chief

Sayre, A. Nelson, Chief, Geol-15
Fiedler, Albert G., Asst Chief, Engr-14
Brown, Glen F., Geol-14
Bennett, Robert A., Geol-13
Eakin, Thomas, E., Chief, Foreign Act., Geol-13
Parker, Gerald G., Chief, M&T Section, Geol-13
Stuart, Wilbur T., Engr-13
Adamson, John H., Jr., Geol-12
Thomasson, Horace G., Jr., Engr-12
Jackson, Roy O., Geol-12
Prescott, Glenn C., Geol-11
DaCosta, Jose A., Geol-11
Broedel, Carl H., Geol-9
Bauer, Colene R., WAE, Geol-7
Gose, Charles J., Jr., Geol-5
Kfoury, Simon H., Translator-7
Berrall, Katherine S., Secy (Steno)-5
Malone, Ruth L., Secy (Steno)-5
Bowman, Frederica S., Secy (Typ)-4
Griffin, Gertrude W., Secy (Steno)-4
Ross, Joan M., Clk-Steno-4
Baker, Anne V., WAE, Clk-Typ-3
Damon, Mabel C., Clk-Typ-3
Dorf, Martha R., WAE, Clk-Typ-3
Messick, Elizabeth E., Clk-Typ-3
Humphrey, Agatha P., Clk-Typ-3
Mariano, Diana T., Clk-Typ-3

GROUND WATER GEOLOGY SECTION

Stringfield, Victor T., Chief, Geol-13
DeBuchananne, George D., Geol-12
Johnston, Paul M., Geol-12
Trainer, Frank W., Geol-11
Back, William, Geol-9
McAnallen, Louisa I., Clk-Steno-5

GROUND WATER HYDRAULICS SECTION

Brown, Russell H., Engr-13
Smith, William O., Physicist-12

GROUND WATER HYDRAULICS SECTION—CONTINUED

Stallman, Robert W., Engr-11
Hart, Rodney, Engr Aid-7
Teel, John R., Jr., Engr Drftsm-5

TECHNICAL REPORTS SECTION

McGuinness, Charles L., Chief, Geol-13
Reed, Edwin W., Engr-12
Birdsall, John M., Geol-11
Vorhis, Robert C., Geol-11
Griffin, Margaret S., Geol-9
Smith, Jean A., Phy Sci Aid (Geol)-5
Grayson, E.H., WAE, Phy Sci Aid (Geol)-5
Thompson, Frances G., Pub Edtr-7
Andreasen, Jane L., Prntg & Pub Clk-4
Montgomery, Mary F., Prntg & Pub Clk-4
Merrithew, Marion O., Secy (Steno)-4
Lane, Judith C., WAE, Clk-Typ-3

QUALITY OF WATER BRANCH
Office of the Chief

Love, S. Kenneth, Chief, Chem-14
Hastings, Warren W., Asst Chief, Chem-13
Keith, Martha L., Secy (Steno)-5
Reynolds, Anna J., Clk-Steno-4
Lichtman, Linda S., WAE, Clk-Steno-3

CHEMICAL QUALITY SECTION

White, Walter F., Jr., Chief, Chem-13
Rainwater, Frank H., Chem-11
Thatcher, Leland L., Chem-11
Scarbro, George F., Phy Sci Aid-6
Bunnell, Doris M., Secy (Steno)-4

PHYSICAL QUALITY SECTION

Vice, Raymond B., Chief, Engr-13
Guy, Harold P., Engr-11

TECHNICAL REPORTS SECTION

Durum, Walton H., Chief, Chem-12
Lohr, Edwin W., Chem-11
Iseri, Kathleen T., Edtl Clk-5
Zietz, Frances F., Secy (Steno)-4
Loadman, Jack C., WAE, Clk-Typ-3
Nowlin, Nita F., WAE, Clk-Typ-3
Truex, Joann D., WAE, Clk-Typ-3
Wolly, Janet S., Clk-Typ-3
McManus, John P., WAE, Clk-Typ-3

FOREIGN ASSIGNMENTS

SURFACE WATER

AFGHANISTAN

Snell, Leonard J., Tech Adviser
Heckmiller, Ignatius A., Tech Adviser

IRAN

Jetter, Karl, Tech Adviser

PAKISTAN

Yonker, Carl C., Tech Adviser

GROUND WATER

CHILE

Dingman, Robert J., Geol

EGYPT

Murray, C. Richard, Tech Adviser
Cushman, Robert L., Tech Adviser
Doyel, William W., Tech Adviser

INDIA

Garrett, Arthur A., Tech Adviser
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