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A History of the Water Resources Division

U.S. Geological Survey: Volume VIII, 1979–94

A HISTORY OF THE WATER RESOURCES DIVISION U.S. GEOLOGICAL SURVEY: VOLUME VIII, 1979–94

By James F. Blakey, James E. Biesecker, Herman R. Feltz, Irwin H. Kantrowitz, Loren E. Young, *and* others

U.S. DEPARTMENT OF THE INTERIOR
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PREFACE

This volume is the eighth in the series of reports on the history of the Water Resources Division of the U.S. Geological Survey. The first four volumes were written by Robert Follansbee, and each is entitled "A History of the Water Resources Branch of the United States Geological Survey." The periods of Follansbee's reports are as follows:

Volume I: from 1866 through June 20, 1919

Volume II: from July 1, 1919, through June 30, 1928

Volume III: from July 1, 1928, through June 30, 1939

Volume IV: from July 1, 1939, through June 30, 1947

Later volumes are entitled "A History of the Water Resources Division, U.S. Geological Survey."

Volume V: from July 1, 1947, through April 30, 1957, by George Ferguson

Volume VI: from May 1, 1957, through June 30, 1966, by Hugh H. Hudson and Joseph S. Cragwall, Jr., and others

Volume VII: from 1966 through 1979, "Integrating the Disciplines," by James E. Biesecker, James F. Blakey, Herman R. Feltz, John R. George, and others

Volume VIII may well be the last of the WRD histories. Reorganization of the USGS has eliminated the Divisions as organizational units. It is hoped that a well-educated, well-trained, highly motivated team of hydrologists and technicians will continue to support the water users and water managers of our Nation as we have done for more than 128 years.

About 100 authors wrote the 80-plus chapters in Volume VIII, but thousands of dedicated employees contributed to the success of the Division's programs from 1979 to 1994. The report was made possible by the support of Robert Hirsch, Cathy Hill, Alice Dilandro, Barbara Gunderson, Isabelle Halley des Fontaines, Linda Fritchie, Bill Carswell, and many others. The report is a reality because of the editorial skills and hard work of the Colorado District staff, especially Mary Kidd, Alene Brogan, Carol Anderson, John Evans, and Bob Olmstead.

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CHAPTER I – INTRODUCTION AND OVERVIEW

Quoting from Volume VII:

> The mission of the Water Resources Division (WRD) of the U.S. Geological Survey (USGS) is to provide the hydrologic information and understanding needed for the optimum use and management of the Nation's water resources for the overall benefit of the people of the United States. This is accomplished, in large part, through cooperation with other Federal, State, and local agencies, by:
>
> 1. Collecting, on a systematic basis, data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources.
> 2. Conducting analytical and interpretive water-resource appraisals describing the occurrence, the availability, and the physical, chemical, and biological characteristics of surface water and ground water.
> 3. Conducting supportive basic and problem-oriented research in hydraulics, hydrology, and related fields of science to improve the scientific basis for investigations and measurement techniques and to understand hydrologic systems sufficiently well to quantitatively predict their response to stress, either natural or manmade.
> 4. Disseminating the water data and the results of these investigations and research through reports, maps, computerized information services, and other forms of public releases.
> 5. Coordinating the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground water.
> 6. Providing scientific and technical assistance in hydrologic fields to other Federal, State, and local agencies.
>
> The Water Resources Division investigates the occurrence, quantity, quality, distribution, and movement of surface and underground water that constitute the Nation's water resources. Its activities include the systematic collection, analysis, and interpretation of data relating to the evaluation of national water resources and investigation of water demand for industrial, domestic, and agricultural purposes; research and development to improve the scientific basis of investigations and techniques; and reporting the results of these investigations through publications or other forms of public release. The Division provides scientific and technical assistance in appropriate fields to other Federal agencies.
>
> The water-data collection, resource investigation, and research activities are carried out in areas where the Federal interest is paramount. These include bodies of water in the public domain, river basins, and aquifers that cross State boundaries and other areas of interstate or international concern. Activities include operation of surface- and ground-water quantity and quality measurement stations throughout the Nation, the Survey's Central Laboratories System, hydrologic research and analytical studies, and a variety of supporting services.

Few will read this report in its entirety, but hopefully many will read the "Overview" that follows by Hal Langford and Jack Fischer. The 15-year period from 1979 to 1994 was challenging and exciting, and Langford and Fischer provide an excellent summary.

This period is well known as the "Cohen Years," and in his brief "Postscript," Cohen shares his thoughts.

OVERVIEW AND REFLECTIONS, WATER RESOURCES DIVISION, 1979–94
The Early Years, 1979 through 1985

By R. Hal Langford

The last 18 years of my 37-year career with the Geological Survey (Survey) were spent on the senior staff of the Water Resources Division (WRD) as Chief, Office of Water Data Coordination (OWDC) from 1968 through 1979 and as Associate Chief Hydrologist from 1980 through 1985. Philip Cohen had been named Chief Hydrologist in August of 1979, the year the Survey celebrated its 100th anniversary. He had served since December 1978 as Assistant Chief Hydrologist for Scientific Publications and Data Management (SP&DM), having served for several prior years on the Director's staff in the Land Information and Analysis Office.

Cohen and I had a very close working relationship over the 6 years we served together supervising the Division. Although we disagreed on some matters, we were in accord on most and addressed all concerns openly and frankly.

In essence, Cohen believed strongly that he had inherited from predecessor Chief Hydrologists an organization second to none in the Federal Government, and that he should "first, do no harm" (a part of the Hippocratic oath) in carrying forward the work of the Division. In this I heartily concurred.

In January 1980 the senior WRD staff consisted of Phil Cohen, Chief Hydrologist and Hal Langford, Associate Chief Hydrologist, supported by Les Laird, Assistant Chief Hydrologist for Research and Technical Coordination (R&TC), and by Tom Buchanan, Assistant Chief Hydrologist for Operations. The position of Chief, OWDC, was vacant as was that of Assistant Chief Hydrologist for SP&DM. The Regional Hydrologists, who rounded out the senior staff, were Jim Biesecker, Northeastern Region; Bob Dingman, Southeastern Region; Al Clebsch, Central Region; and Bill Robinson, Western Region.

Other key personnel at Headquarters were Gerald Meyer, Jack Pickering, and Harry Barnes, who continued as Chiefs of the Ground Water, Quality of Water, and Surface Water Branches, respectively. J.R. ("Digger") Jones was Chief, Office of International Hydrology, Francis Sessums the Program Officer, and Ed Like the Administrative Officer. John Bredehoeft, the Deputy Assistant Chief Hydrologist for Research, had recently returned to scientific research.

The senior staff at Headquarters met each morning to discuss current or impending issues. This practice was a carryover from previous administrations, and it continued to provide an excellent forum for open and above-board exchanges of information and views.

Several changes in the senior WRD staff occurred during these 6 years as follows:

- Porter Ward replaced Hal Langford as Chief, OWDC, in 1981; Ed Imhoff replaced Ward on his retirement in 1985.
- Gordon Bennett replaced Les Laird as Assistant Chief Hydrologist for R&TC in 1982 (Laird left Headquarters to become District Chief of the Washington District).
- Bob Dingman replaced Phil Cohen as Assistant Chief Hydrologist for SP&DM in 1980. Dingman was replaced, following his retirement, by Jim Biesecker in 1982, and he by Jim Daniel in 1984. Biesecker was named Assistant Director for Information in 1984.
- Stan Sauer replaced Jim Biesecker as Regional Hydrologist, Northeastern Region, in 1982.
- Jim Cook replaced Bob Dingman as Regional Hydrologist, Southeastern Region, in 1980.
- John Bredehoeft replaced Bill Robinson, following his retirement in 1980 as Regional Hydrologist of the Western Region. John Conomos replaced Bredehoeft in 1985.

Only four members of the senior staff served in their positions throughout the full 6-year span: Cohen, Chief; Langford, Associate Chief; Buchanan, Assistant Chief, Operations; and Clebsch, Central Regional Hydrologist.

Changes in other key personnel at Headquarters were as follows:

- Roger Wolff replaced John Bredehoeft as Deputy Assistant Chief Hydrologist for Research in 1980.
- Gordon Bennett in 1980, and later Eugene Patten in 1983, replaced Gerald Meyer as Chief, Ground Water Branch.
- Jack Pickering moved in 1984 from Chief, Quality of Water Branch, to the newly created position of

Chief, Office of Atmospheric Deposition Analysis.

- Marshall Moss replaced Harry Barnes as Chief, Surface Water Branch in 1982.
- Della Laura replaced James Jones as Chief, Office of International Hydrology, in 1980.
- Paul Beauchemin replaced Francis Sessums as Program Officer in 1983.
- Tom Davis replaced Like as Administrative Officer in 1982.

The above summary of changes in the senior staff and other key positions in WRD illustrates the degree of flux in personnel occupying those positions. Yet despite this, the management of the Division moved ahead smoothly, due largely to the emphasis on management and technical training of Division personnel over the years and to the organization of the Division that provided opportunities throughout for personnel to develop management skills. I can recall a conversation with Rupert Southard, Chief, National Mapping Division, soon after I became Associate Chief. I expressed to him some of my concerns about the rather large number of changes in key positions that we in WRD were facing. He responded by saying "I can't feel sorry for you and Cohen because the WRD has potential high-level managers stacked up like 'cordwood' in your District offices. No other Division in the Geological Survey is so blessed."

Total appropriated funds for water-resources investigations during the 6-year period ranged from $115 million in fiscal year (FY) 1981 to $134 million in FY1986. Compared to total USGS appropriations, the water-resources program ranged from 29 to 33 percent, essentially one-third of the entire Survey's program.

As shown in table 1, except for a dip in FY1982, the total funds for the Division (expressed in constant dollars) reflect relatively stable to slightly increasing overall program support. However, reprogramming to accommodate changing priorities was really the "only game in town" during those 6 years. The start or buildup of the water-resources assessment, toxic substances hydrology, acid rain, nuclear waste hydrology, scientific and technical publications, and national water-quality assessment programs came with the demise or reduction of the supporting services, environmental affairs, water-resources scientific information center, subsurface waste storage, flood hazard analysis, ground-water recharge, and energy hydrology programs.

As a backdrop to many of these changes in program emphasis, one cannot overlook the changes in administration at departmental and bureau level that occurred. James Watt was appointed by the newly elected President, Ronald Reagan, to be Secretary of the Interior early in 1981, and he named Donald Hodel (formerly Administrator of the Bonneville Power Administration) as his Undersecretary. Watt was a determined Secretary who had very strong opinions about how the Federal Government's water-related activities ought to be organized and managed, and he was determined to learn directly about the various departmental programs for which he was responsible. For example, he and Hodel, accompanied by their wives, scheduled several Saturday morning briefings in the WRD Headquarters to obtain firsthand knowledge of some of the Division's critical activities. These briefings were often highly technical, but they always elicited good questions from Watt and Hodel (and occasionally from their wives). Never in recent memory had a Secretary paid so much attention to the WRD.

Table 1. Sources of funds

[$, in millions; FY, fiscal year]

Category	FY–81	FY–82	FY–83	FY–84	FY–85	FY–86
Water Resources Investigations (appropriated)	$115	$109	$116	$129	$133	$134
State part of Federal-State Cooperative Program	45	47	48	53	57	57
Other Federal Agency Program	33	31	38	41	48	57
Total WRD budget (actual dollars)	193	187	202	223	238	248
Total WRD budget (in constant 1982 dollars)	210	189	197	210	215	218

Soon after becoming Secretary of the Interior, James Watt took a series of actions that affected the WRD. First of all he abolished the U.S. Water Resources Council (WRC), which had been established in the 1960's by the Water Resources Planning Act, and stated that the USGS could henceforth conduct the periodic assessment of the Nation's water resources—formerly the responsibility of WRC. As a result, the Division's water-resources assessment program was begun under David Moody's leadership, and in 1984, work resulted in publication of the first National Water Summary and initial distribution of 8,000 copies.

Second, in 1982 Secretary Watt transferred the Water Resources Scientific Information Center (WRSIC), which had been created in 1966 as a result of the Water Resources Research Act of 1964 (P.L. 88–379), from the Department's (OWRT) to the WRD where it would complement the Division's programs for disseminating water information to others. The WRD placed responsibility for the WRSIC program and its staff under the Assistant Chief Hydrologist for SP&DM, who had responsibility for the Division's publications, Distributed Information System, National Water Data Storage and Retrieval System (WATSTORE), and National Water Data Exchange (NAWDEX) programs.

Finally, the Water Resources Research Act of 1984 (P.L. 98–242) established in the Department of the Interior responsibility for the State Water Research Institutes and National Water Resources Research Grants Programs. This Act modified and expanded on the similar Act of 1964 (P.L. 88–379), which had been assigned to the Department's OWRT, and on a grants program of the Bureau of Reclamation established in 1978. Responsibility for implementation of the provisions of the Act was given by Secretary Watt to the USGS. In order to assume the responsibilities called for by P.L. 98–242, the Division underwent a major reorganization at Headquarters, creating a new position of Assistant Chief Hydrologist for Research and External Coordination with responsibility for activities under the new Act, the National Research Program, and the OWDC. A summary of the program management structure for USGS accommodation of the 1984 Act was presented by Langford to the Annual Meeting of the National Association of Water Institute Directors on November 8, 1984 (see WRD memorandum 85.18). Marshall Moss, who was instrumental in developing the Division's plans for responding to P.L. 98–242, was named the first Assistant Chief Hydrologist for Research and External Coordination.

Another change in administration, this one at Bureau level, also affected the Division. Bill Menard had been named Director, replacing Vince McKelvey, in April 1978. He appointed Joe Cragwall in March 1979 to the position of Associate Director and named Milt Hackett as Acting Chief Hydrologist. Menard resigned in January 1981 when the Reagan administration took office, and in September 1981 Dallas Peck was sworn in as the eleventh Director of the U.S. Geological Survey. Formerly, Peck had served as the Survey's Chief Geologist, and as such, was Chief of its Geologic Division. When Cohen and Langford were first in office, Cohen arranged for them to meet monthly with Peck and his Associate Chief Geologist, Gordon Eaton, to discuss issues involving the two Divisions, develop approaches for joint programs, and address any inter-Division problems. These meetings were helpful in the opinions of all four.

Cohen had served directly on Menard's staff for about a year prior to moving to the WRD, so he had firsthand knowledge of Menard. This familiarity with Menard and Peck helped in dealings with the Director's Office, although at times we were frustrated with some of the programming decisions rendered. Peck continued to serve as Director during the 6-year period and was supported by Doyle Frederick as Associate Director. Frederick was formerly Associate Chief, National Mapping Division.

A number of significant events and actions occurred during the early years. At the outset, the Department imposed strict travel ceilings on its agencies. The 8-percent reduction hit WRD especially hard, and on March 12, 1980, the Chief Hydrologist announced that the National Meeting of the WRD scheduled for San Diego, Calif., in July was canceled; the joint meeting of our two Advisory Committees was canceled; activities at the National Training Center were suspended; all training at other Federal agencies, and at public and private facilities, that involved travel were suspended; all technical and management reviews were suspended; all WRD committee meetings involving travel were canceled; foreign travel was reduced and attendance at domestic technical meetings was limited; the Graduate School program was markedly reduced; and safety inspections involving travel (except emergencies) were canceled. All of this was done in the hopes that essential field work could be carried out. The Division met this challenge and

weathered it despite the hardships it caused and showed that WRD had a resilience second to none.

Another event, more challenging, albeit not of national scope, occurred on May 18, 1980, when Mount St. Helens erupted near Vancouver, Wash., with profound impacts on the area, particularly Washington, Oregon, and Idaho. WRD personnel in the area responded immediately and conducted field studies to document the hydrologic significance and impact of the resultant mudflows, ashfalls, floods, and water-quality changes. The Division came through famously and again showed its ability to respond effectively to catastrophic events. On September 2, 1980, the Chief Hydrologist transmitted a detailed four-page program of Hydrologic Investigations and Research that WRD was conducting in FY1980 and would conduct in FY1981 in the vicinity of Mount St. Helens. Funding in FY1981 for volcanoes totaled $4.5 million.

I remember (amusedly) representing WRD at a meeting called by the Director the day after the eruption to obtain proposals from the Divisions on needed studies in the Mount St. Helens vicinity. The proposal for WRD exceeded that presented by the Geologic Division. This caused such concern that the Director immediately scheduled a second meeting for the following day so the Divisions could "refine" their estimates. As I recall, the WRD's proposal was essentially unchanged for the second meeting, but the Geologic Division's proposal was considerably "enhanced" to a funding level above that of WRD.

Since shortly after becoming Chief Hydrologist in the fall of 1979, Phil Cohen had become aware of the fact that many of WRD's research personnel and some of its senior staff were deeply concerned about the Division's National Research Program (NRP) and its place in the overall program of the Division. Also, numerous uncertainties and questions existed regarding how the NRP was being managed and how it should be managed in the future. Cohen took it upon himself personally to interview most of the researchers privately to obtain their views. He also solicited the views of senior staff, and, on March 3, 1981, announced to the entire Division his conclusions about how the NRP would henceforth be managed to "... enhance the scientific capabilities of the Geological Survey." Included in the changes he promulgated (WRD memorandum 81.46) were:

- Reducing the number of Research Advisors and establishing supporting positions of Deputy Research Advisors.
- Changing the role of Regional Research Hydrologists to directly supervise research personnel in their respective Regions, and to report directly to the Deputy Assistant Chief Hydrologist for Research (rather than the Regional Hydrologist). Cohen expected the Regional Research Hydrologists to work closely with their counterpart Regional Hydrologists to assure effective linkage among the NRP and the other Division programs. Regional Hydrologists were to continue to provide administrative support to NRP personnel in their Regions.
- Enhancing the flow of information and transfer of technology among the Division programs by developing formal procedures for strengthening the linkage between Regional Discipline Specialists and Regional Research Hydrologists.
- Implementing the use of the Research Grade Evaluation Guide on a Divisionwide basis.

These changes were met with varying degrees of enthusiasm by members of the staff who were directly affected; but in my view, the overall result was good for the Division as a whole and improved the interaction of the "research" element with the rest of the Division's programs.

Following his March 3, 1981, directive, Cohen issued specific instructions on June 4 (WRD memorandum 81.82) for strengthening the Research Advisor System, and on July1 (WRD memo 81.81) for implementing the Research Grade Evaluation Guide for Divisionwide review and classification of research positions. These three actions substantially altered how the NRP was managed and how its personnel were evaluated.

Several other events in 1981 were significant: the national meeting of WRD, which was canceled earlier in the year due to travel restrictions, was held in October in Ocean City, Md.; the Cascades Volcano Observatory was established in Vancouver, Wash.; the National Water Resources Assessment Program was started; the Hydrologic Instrumentation Facility (HIF), opened in 1980 at Bay St. Louis, Miss., became fully operational; a new format was established for the Survey's Water-Supply Paper series—an effort that Cohen personally undertook to enhance that series;

and the name and scope of the Division's Office of Radiohydrology was changed to the Office of Hazardous Waste Hydrology to coordinate research and investigations related to all types of wastes—radioactive and toxic chemical. Jack Robertson was named its Chief, succeeding George DeBuchananne.

During the early years the WRD broke free from reliance on mainframe computing and established a decentralized information system by installing more than 70 large minicomputers at Headquarters and in each of its Regional, District, and large project and Subdistrict Offices. These minicomputers were connected by leased telephone lines and satellites to form a true "Distributed Information System" that revolutionized many of the ways we had formerly conducted our work and that greatly improved our computational capability. The minicomputers were accessed initially by more than 1,500 terminals and microcomputers. This major shift in WRD's program was accomplished without special congressional appropriations by utilizing operational program funds.

One evidence of this greatly improved information system was the superb exhibit developed, installed, and manned by WRD personnel at the Louisiana World Exposition in New Orleans, whose theme was "The World of Rivers: Fresh Water as a Source of Life." The exhibit, "Measuring U.S. Water Resources," included a display of satellite telemetry that allowed visitors to obtain a real-time computer-graphics streamflow display of one representative stream in each State. It was one of the highlights of the exposition. The number of sites providing real-time water data by satellite increased from 350 in 1982 to 1,600 in 1986.

Another breakthrough accomplished during this early period was the consolidation of the two main water-quality laboratories in Doraville, Ga., and Denver, Colo., into a single, highly sophisticated and automated central laboratory in Denver. This laboratory was a state-of-the-art facility, and its development and management was headed by Bob Averett, who was named a Special Assistant to the Chief Hydrologist for this purpose.

WRD involvement in international activities continued throughout the 6-year period. In 1981 Phil Cohen was named a member of the Bureau of UNESCO's International Hydrology Program (IHP). As such, he worked with other representatives of member nations on priorities for undertaking work under the IHP. Beginning in about 1982, Hal Langford served as the USGS representative (and leader) of the U.S. delegation to planning meetings of IHP in Paris. Representatives of the National Weather Service and the U.S. Army Corps of Engineers served as members of the U.S. delegation. Langford also served on the U.S. delegation to World Meteorological Association (WMA) meetings in Geneva; the U.S. delegation to WMA was led by the National Weather Service representative, Robert Clark. Langford also served as the USGS member of the U.S. delegation working with its Canadian counterpart on the International Joint Commission program for the Souris and Red River Basins.

One of the most significant international activities during the early years was the direct involvement of WRD in the protocol between the United States and the People's Republic of China (originally instigated by President Nixon). WRD's involvement was in the field of surface-water hydrology, specifically flood hydrology. Marshall Moss headed the technical work, which also involved many other members of the WRD staff, both at Headquarters and in the field. The initial work under the protocol consisted of visits by Chinese hydrologists to the United States and to various units of WRD at Headquarters and in the field. Reciprocal visits by WRD hydrologists to China resulted in developing mutual understanding of the water resources and water problems of the two countries.

The first visit by WRD hydrologists to China took place in 1981. The team was led by Cohen and included Marshall Moss, Don Thomas, Bill Emmett, and Dick Paulson. These exchange visits culminated in 1985 in a seminar on flood hydrology held in Nanjing, People's Republic of China. The U.S. delegation to this week-long seminar consisted of 22 representatives of WRD, other Federal agencies, State agencies, and universities. The U.S. delegation was led by Langford with principal technical direction by Marshall Moss. The seminar consisted of 44 technical papers presented (in English) by 22 representatives of each country followed by a week-long field trip to the Yangtze River Basin, including a trip by boat through the Three Gorge area of the Yangtze River. These early exchanges broadened later to include other hydrologic issues, particularly water-quality concerns.

The activities of the OWDC continued to develop during the early years with the publication and distribution of about 10,000 copies of the "National Handbook of Recommended Methods for Water Data Acquisition." This 12-chapter looseleaf manual was

prepared and kept current by technical working groups staffed by experts of the WRD and other Federal agencies and reviewed by experts in the non-Federal sector. A companion major effort by OWDC culminated in the publication by the USGS of a map of the United States and of each State depicting codified hydrologic-unit boundaries. These efforts involved many WRD personnel throughout the Nation as well as personnel of other Federal and State agencies and technical societies.

Other significant events and actions during the early years were:

- Fully implementing the National Stream Quality Accounting Network, which built on earlier network-design efforts of the OWDC.
- Developing a mathematical model that successfully predicted the rapid retreat of Alaska's Columbia Glacier.
- Linking of the Division's WATSTORE with the U.S. Environmental Protection Agency's Storage and Retrieval System (STORET) and monthly delivery of water-quality data from WATSTORE to STORET.
- Establishing a Toxic Substances Hydrology Program in response to the rising national concern about contamination of the Nation's ground water and surface water.
- Conducting research field studies to evaluate the origin, movement, and fate of toxic selenium in the San Joaquin Valley in California.
- Publishing more than 300 reports describing scientific findings and results of Regional Aquifer-System Analysis Program investigations.
- Starting an intensive program to collect and interpret data to help formulate national policy decisions regarding the control or abatement of acid rain. Served as the lead agency in an interagency program for monitoring atmospheric deposition.
- Reorganizing the WRD Headquarters staff to address the new functions and responsibilities assigned, particularly those stemming from the Water Resources Research Act of 1984 (P.L. 98–242) and to better distribute responsibilities among senior Division managers. Jack Fischer was named the new Assistant Chief Hydrologist for Program Coordination and Technical Support, and Marshall Moss the new Assistant Chief Hydrologist for Research and External Coordination.
- Designing a National Water-Quality Assessment (NAWQA) Program—a blueprint for the first ongoing and comprehensive quality appraisal of the Nation's water resources.

Special note should be taken of the NAQWA Program. The genesis of the program occurred in August 1983 when Cohen asked Gordon Bennett to take the lead. Bennett appointed an ad hoc committee consisting of Jacob Rubin, Jim Bennett, Bob Hirsch, Sam Luoma, and Ike Winograd. Their job was to review the principles of water-quality data acquisition and utilization, as applied to WRD programs, and to develop a set of principles to guide the Division in designing and utilizing large-scale, perennial programs of water-quality data acquisition. Groundwater and surface-water quality was to be taken into account.

The actual genesis of the effort goes back to the work of Langbein and Hoyt with the publication in 1955 of their book "Water Facts for the Nation's Future," the subsequent issuance in 1964 of Bureau of the Budget Circular No. A–67, the resulting national-network design activity of the OWDC, and the development by WRD of the National Stream Quality Accounting Network, the earlier Hydrologic Benchmark Network, and the National Trends Network (for precipitation). These forerunners of NAWQA (together with the Regional Aquifer-System Analysis Program, the River Quality Assessment Program, and the National Water Summary activities) were fundamental underpinnings for successful development of the NAWQA Program.

The dialogue between Congressman Sidney Yates and Phil Cohen at the annual budget hearings before the House Appropriations Subcommittee (chaired by Yates) provided added incentive for the Survey to be able to answer Yates' question: "Well, Mr. Cohen, what is the status of the Nation's water quality?"

The early years culminated in a national WRD conference in November 1985 in San Diego, Calif., at which the new program thrusts and the new organizational arrangements were thoroughly explored. Plans were proposed for future development of the Division and its programs. Plans for the NAWQA Program

were highlighted. Shortly thereafter, Bob Averett was announced as the new Associate Chief Hydrologist.

As I reflect on those early years, I realize just how fortunate I was to have played a part in shaping the Division and its diverse programs of research and investigations of the Nation's water resources. The experience solidified my belief that the men and women of the Division are persons of high integrity and superb technical competence. We were fortunate to have been led during this period by Phil Cohen, whose intellect, compassion, and vision were instrumental in enhancing the capability of the Division to address the Nation's needs for understanding its water resources.

REFLECTIONS ON THE LATER YEARS, 1986–94

By John N. "Jack" Fischer

I was the Assistant Chief Hydrologist for Program Coordination and Technical Support (PC&TS) from 1986 until 1988. From 1988 through the end of the history covered in this volume, I was the Associate Chief Hydrologist. These are my recollections of the issues on which we worked and of the events that occurred during those 8 years.

Upon the retirement of the Associate Chief Hydrologist, Hal Langford, in 1985, the Chief Hydrologist, Philip Cohen, selected Bob Averett as his replacement. Averett was a nationally prominent aquatic biologist working in Denver within the National Research Program (NRP). He was an innovative thinker and very highly regarded as a scientist and teacher. His selection as the Associate Division Chief was a natural extension of Cohen's efforts to bring the scientific expertise and intellectual capabilities of the NRP to bear more directly on the day-to-day activities of the Division.

As the Associate Chief, Averett was very successful in that specific regard. He maintained a close and supportive relationship with scientists and scientific programs throughout the Division and provided scientists, particularly those within the NRP, with a sense that they had a senior advocate within the bureaucracy. However, Averett had little patience for the multitude of nonscientific tasks involved in Division management. Budgets, personnel issues, bureau and department politics, and so forth, bored him to tears. In 1988, he returned happily to NRP.

I moved over from PC&TS to replace Averett as Associate Chief Hydrologist. Verne Schneider left his position as Chief, Office of Surface Water, to become the Assistant Chief Hydrologist for PC&TS. Bill Boning, the former Chief of the Texas District, became the Chief of the Office of Surface Water. The Office of Ground Water was headed by Gene Patten. Dave Rickert was the Chief of the Office of Water Quality. Rickert also had overall responsibility for the newly named National Water Quality Laboratory in Arvada, Colo. (The water-quality laboratory in Atlanta was disestablished in 1986 primarily for economic reasons.)

Al Clebsch retired as Central Regional Hydrologist in 1985 but continued to serve the Division in a number of voluntary advisory positions. Jim Blakey, the District Chief in Colorado, was his replacement. On the staff at Headquarters, Tom Buchanan continued as the Assistant Chief Hydrologist for Operations until 1986 when he retired to take a senior management position with CH2MHill. Bill Mann, then managing the water-use data program, was selected to take his place.

Jim Daniel was the Assistant Chief Hydrologist for Scientific Information Management. John Moore, Gene Hampton, and Gary Cobb filled the key assistant roles under him. Daniel and Cobb had the daunting task of trying to keep the Division in step with the disconcertingly fast development of new information systems. Moore and Hampton had the challenging responsibility for the quality of Division reports and their timely publication. Working with the Central Region reports staff, they initiated a "fast-track" review system available to Districts that demonstrated a high level of reliability in report preparation and review. The Montana District, under the leadership of Joe Moreland, was the first to qualify for this status.

Marshall Moss remained as the Assistant Chief Hydrologist for Research and External Coordination with Roger Wolff managing the National Research Program. Moss maintained his deep interest in surface-water programs, personally conducting analyses of the network of surface-water stations with an eye to improving efficiency. These analyses were particularly important because we always were constrained financially and in search of efficiencies in the operation of the surface-water network.

David Moody, working on Cohen's personal staff, had primary responsibility for the annual production of the National Water Summary, an annual series initiated in 1984. He was fortunate to be supported by Edith Chase and Dick Paulson. Each volume of the series included both a national overview of water issues in the past year and a State-by-State analysis of a specific aspect of the water resource, such as ground water, surface water, water quality, and so forth. Unfortunately, we were never able to provide full funding for the substantial effort required by the Districts to support the series. This led to a certain lack of District enthusiasm for the program. Nevertheless, District writers always came through, and the publications were uniformly well received by the Congress and State governments and over time provided a form of water encyclopedia for each State.

In 1987, the Division created the position of Assistant Chief Hydrologist for Water Assessment and Data Coordination with responsibilities for the annual National Water Summary series and the Office of Water Data Coordination (OWDC). Moody was the natural selection for the new position. Nancy Lopez was the day-to-day manager of OWDC for much of the period. Lopez worked tirelessly to coordinate a multitude of Federal agencies collecting water data. Although we had many successes, most of the Federal agencies involved were much larger than the USGS and some never really signed on to being "coordinated." We had more success in the non-Federal community.

In 1986, Ivan James stepped down as Chief of the Branch of Systems Analysis (BSA) to become the Massachusetts District Chief. Robert Hirsch was appointed to replace him. We consciously staffed BSA with men and women with particularly innovative minds. The Branch served, essentially, as a WRD think tank. During this time, the Branch made key inputs to the design of NAWQA, NASQAN, and the National Water Summary. It also provided leading-edge science in the development of methods to determine trends in floods, water quality, load estimation and other hydrologic parameters. In 1988, when Hirsch was detailed to serve as the USGS liaison to the Department, Dennis Helsel became Branch Chief. He was replaced by Debra Knopman in 1992.

Knopman had come to the USGS only several years before as a Johns Hopkins University graduate student in hydrology. Prior to that time she had been a staff member for Senator Daniel Moynihan of New York. With the change of administrations in January 1993, her background and competence led to her being named Deputy Assistant Secretary of the Interior for Water and Science. From that position, she had significant input into the affairs of the USGS.

In the early 1980's, most of our District Chiefs were GS–14's. For all intents and purposes, this meant that District scientists who did not aspire to management positions could not reach grades above GS–13. Assuming that they wished to continue to advance in the organization, this situation forced them either to petition to enter the NRP or leave the day-to-day practice of science and enter the management path. Either way, this was not a healthy situation for District science.

To remedy this situation, we extended the opportunity to District scientists to volunteer to be evaluated under the Research Grade Evaluation Guide (RGEG). The RGEG, an evaluation system used by the NRP, evaluates candidates for promotion through a series of colleague panels that thoroughly review their publication record. Its application in the Districts allowed for promotion of outstanding scientists to GS–15 and beyond. By the end of the Cohen years, the change had proved successful in every respect. Over 50 top District scientists had opted for the new evaluation system and, by creating a place for senior scientists in the Districts, our field science was markedly enhanced.

In the early 1980's, we began to adapt our data-retrieval systems to take advantage of satellite communications to produce "real-time data." Our first system utilized downloading equipment at the Goddard Space Flight Center to receive our field data. Later we installed our own download stations at five District offices. The South Carolina District under the leadership of Rod Cherry was one of the earliest and most aggressive users of the new technology. But by the end of the Cohen years, much of the surface-water network of all Districts was producing real-time data for our State partners and a variety of other users.

Also at this time, we made the decision to move from a centralized data-storage system (on a mainframe computer in Reston) to a distributed-information system (DIS) housed in District offices. The driving force was to create a less cumbersome, more accessible, and less expensive system. Joe Rosenshein, the Kansas District Chief, was one of the strong promoters of the concept. We initially provided five Districts with minicomputers as a test. That trial was

successful, and we installed a second generation of more sophisticated computers in almost every District (a few Districts shared a system). The next generation, installed in the early 1990's, were workstations. In bringing the skills of District personnel to bear on the fast-evolving data-management scene, we tapped a new source of initiative and imagination that served the Division well.

Anna Lenox replaced Della Laura as Chief of the Office of International Hydrology in 1986. The long-standing USGS program in Saudi Arabia was winding down about this time. As this was happening, we were invited by the government of Abu Dhabi, a member of the United Arab Emirates, to develop a program to assess their ground-water resources. This invitation developed into a substantial and successful program involving many USGS scientists, some living in-country and some contributing by detail. The USGS in-country Chief initially was Joel Kimrey. He was followed by Don Jorgensen and then Joe Moreland. These men lead a multinational team composed of, in addition to the USGS scientists, professionals from throughout the Middle East. The project provided our men with a challenging assignment in a fascinating environment. The resulting reports and data base provided the emirate with a comprehensive understanding of their limited ground-water resources.

Women having entered the scientific workforce in greater numbers, many began to rise to senior positions in the Division during the Cohen years. In the early 1990's, Wanda Meeks was Chief of the large Orlando Subdistrict and Kathy Peter, Linda Weiss, Cindy Barton, and Janice Ward were District Chiefs of Oklahoma, Nebraska, Michigan, and New Jersey, respectively. Cathy Hill was the Special Assistant to the Director, Barbara Ryan was the Bureau Liaison to the Department, and Anna Lenox was Chief of the Office of International Hydrology. The diversity served us well.

Throughout the Cohen years, the overall budget of the Division continued to grow faster than inflation. Most of that real growth, however, was due to increases in the State side of the Federal-State Cooperative Program and from growing programs with other Federal agencies. Increases in the Division appropriation were very hard to come by. The directorate managed the Bureau with a determined eye to maintaining budget equity among the three Divisions. Therefore, despite the fact that water-quantity and water-quality issues were growing in number and seriousness throughout the country, and the WRD was uniquely qualified to play a leading role in support of their resolution, the Division had to fight hard for every USGS dollar.

Some believe that the USGS missed a watershed opportunity during these years. In the view of many of us, the quantity and quality of freshwater was the major natural resource issue of the time and of the future. It seemed probable that the Bureau could have ridden the Division into a central role in the Nation's search for solutions to current and future water-resource issues. However, in the difficult battle for Federal dollars, doing this would have meant that programs of the other two Divisions would have had to take a back seat. We were unable to convince the Directorship to take such a major step. By choosing not to lead aggressively with its largest and strongest programs, we believed that the Bureau missed an opportunity that would have markedly increased its value to the Nation.

This is not to say that we did not win our share of the budget and program battles. Cohen was an indefatigable and tenacious fighter in the Bureau, within the Department and, when opportunities arose, in the halls of Congress. Indeed, the belief in the other Divisions at the time was that the Director gave in too frequently to Cohen's entreaties.

The bright side was that, even though Federal dollars for the Federal-State Cooperative program, adjusted for inflation, remained about level, the States' financial contribution to the program increased markedly. The positive side of that story was that we had more resources to work with in the States. The negative side was that, in many cases, the Federal-State partnership was no longer a fifty-fifty arrangement, making it harder for our District Chiefs in program negotiations with the States.

Each year we were greatly aided in the Federal budget process by the determined advocacy of outside organizations, three in particular. The American Society of Civil Engineers could always be counted on to explain to the Department and to the Congress the importance of our surface-water networks and the basic-data program, in general. They were very effective friends. The Interstate Conference on Water Policy also was a loyal advocate, stressing the usefulness of data from the Federal-State Cooperative program in their deliberations. And the Western State Engineers, heavy users of our basic data, could always be counted on for support.

Overall, between the years 1979 and 1994 the Division budget grew from $174 million to over $400 million. This was a remarkable increase even considering the effects of inflation. It was a measure of the growing number of water issues in the country and a nationwide recognition of the extraordinary ability of our District staffs to bring energy and relevant expertise to bear on their resolution.

A measure of the increasing importance of water issues during this time was that our programs with other Federal agencies also increased. Programs with the Department of Energy grew tenfold. Principal among those was our multi-Division scientific study at the prospective high-level radioactive waste repository at Yucca Mountain in Nevada. The scientific aspects of these studies were highly complex, and the studies themselves were complicated by the highly emotional social and political issues surrounding radioactive waste.

The fact that a site such as Yucca Mountain was even considered as a potential repository was due, in large part, to a 1981 article in Science by Ike Winograd entitled "Radioactive waste disposal in thick unsaturated zones." Winograd's report was followed in 1983 by Gene Roseboom's oft-cited USGS Circular 903, explicitly advocating Yucca Mountain as a potential repository for high-level radioactive waste.

Our part of the Yucca Mountain Program, and later the entire USGS effort at the site, was very ably led by William Dudley and later by Larry Hayes. Having held District Chief positions in Wyoming and Tennessee, respectively, neither man was a stranger to pressure. But the politically charged atmosphere of the Yucca Mountain project was another world. The USGS owes them a great debt.

Our work with the Department of Defense also escalated. In 1986, we were invited to give a training program in ground-water hydrology to senior U.S. Air Force environmental officials at Brooks Air Force Base. Jack Fischer, Gordon Bennett, Scott Keys, and Warren Wood made the presentation; and from that beginning, the Department of Defense Environmental Contamination Program took root. The program expanded to include water-quality work at over 30 military bases across the country and included all branches of the military and the U.S. Coast Guard as well. John Powell was the orchestrator of much of this growth.

Although we maintained a steady eye on water quantity issues, much of our focus in the second half of the Cohen years was water quality. The major Federal water-quality program was the National Water-Quality Assessment (NAWQA) Program. The program was conceived during a series of 1983–84 conversations between Cohen, Jake Rubin, and John Bredehoeft. Coincidentally, in 1984, Sidney Yates, the chairman of our House Appropriations Subcommittee, began to probe about just how much we knew about the Nation's water quality. Mr. Yates asked a question along the lines of, "Well, Mr. Cohen, is our water quality getting better or worse?" It seemed like a fair question to ask, but although we had begun to explore how we might put ourselves in a position to answer it, we were not ready at the time. Nonetheless, with that instigation, Cohen asked Rubin, Sam Luoma, Bob Hirsch, Jim Bennett and Ike Winograd to develop the outlines of a program that might produce answers to the question.

The creation, selling, and implementation of the NAWQA Program were the major accomplishments of the Division in the latter Cohen years. We had to overcome strong, sometimes fierce, opposition from entrenched forces at every juncture. First off, there was significant resistance within the Division itself. WRD managers of programs outside the water-quality realm realized correctly that a program of the proposed magnitude of NAWQA would absorb any potential budget increases in the Division for years to come. In fact, that did happen. The budgets of several excellent Division programs, such as the Regional Aquifer-System Analysis and the Nuclear Hydrology Program, fell victim to the directed requirement that the Division absorb some of the increases necessary to build the new program.

Next, the other Divisions were distinctly lukewarm for the same reasons; that is, if the NAWQA proposal succeeded, major budget initiatives within their programs would have to be subjugated. This fact made the selling of the program within the Bureau a long and painful task. We had a more receptive audience for our proposals in the Department and in the Congress.

Outside the Bureau, the U.S. Environmental Protection Agency (USEPA) was a determined opponent of the program. At the time, the USEPA was trying to launch its own national assessment, one that, unlike our concept, was based in large part on statistical sampling. They correctly viewed our plan as being in direct competition with theirs. The USEPA also appeared to fear that national water-quality

information gathered by an agency other than their own would have the potential to develop findings that could surprise them. In any case, they openly and aggressively opposed the program.

In the midst of the battle, both the USEPA and the USGS made multiple presentations of their proposed program to the National Academy of Sciences, seeking the invaluable backing of that prestigious body. Bob Gilliom, Bill Wilber, Dave Rickert, Sam Luoma, Stu McKenzie, Marty Gurtz, Gail Mallard, and Pat Leahy were key members of our presentation team. They did a marvelous job. Their work was fundamental to gaining the endorsement of the Academy, an endorsement that was instrumental in gaining Department and Congressional backing. (USEPA's statistical plan was roundly rejected by the Academy.)

As NAWQA unfolded, we were fortunate in that we were successful in seeking out some of our very best scientists to work on the initial study areas. These and other major contributors to the success of the program are identified in another section of this history. Suffice it to say here that through the imagination, dedication, and hard work of these people, the program has made, and continues to make, an enormous contribution to the USGS and to the Nation.

Beginning in the early 1980's, we were drawn into an interesting issue involving selenium contamination of wildfowl at Kesterson Reservoir in the Central Valley of California. By the late 1980's, this was a program of great importance in the Department. Although not its original purpose, Kesterson Reservoir had become a sink for agricultural drainage water when delays were encountered in building the primary irrigation drain for the valley, the San Luis Drain. As it turned out, the irrigation return flows picked up extremely high concentrations of selenium as they drained through the fields. Fish populations in the reservoir, including largemouth bass, declined precipitously when the flows began to enter. Then deformities began to occur in the local bird population. In seeking resolutions to the problems, the USGS became a prime source of geologic and hydrologic information for the Bureau of Reclamation (BOR), the U.S. Fish and Wildlife Service, and the State of California. We had a bit of a head start on the issue because an NRP scientist, Ivan Barnes, had done some excellent work on the presence of selenium in surface soils and shallow ground water in the valley. Within the department team, the primary WRD scientist on the scene was Bob Gilliom. The overall coordinator in California was Marc Sylvester with Bill Wilber holding the strings in Reston.

As time went on, the studies of water quality in BOR reservoirs expanded to include 20 or more of the Bureau irrigation projects in the West. As the complexity of the program increased, Dick Engberg came in from his position as Iowa District Chief to head it up. He eventually was named overall chief of the department's multiagency task force, which he headed from a position on the staff of the Assistant Secretary for Water and Science.

The Toxic Substances Hydrology program was designed, in part, to provide study sites nationwide within which the fate and transport of different contaminants could be assessed. Early contaminants included creosote (near Pensacola, Fla.), crude oil (near Bemidji, Minn.), and sewage (on Cape Cod, Mass.). The program was conceived and developed in its early stages almost solely by one man, Steve Ragone. He had to overcome significant initial skepticism in the Division, but by the late 1980's, the program began to bear fruit. In addition to providing a significant scientific benefit, the program provided a wonderful opportunity for collaboration among District and NRP scientists.

A second element of the program focused on the fate of agricultural chemicals in the environment. Study sites were selected throughout the country to examine specific crops and specific geographic environments. This element of the program was conducted in cooperation with local State and university scientists, providing a valuable opportunity to share expertise and develop local professional partnerships. When Ragone was named as Assistant Director for Research, Gail Mallard became manager of the Toxic Substances program.

Another major water-quality achievement during this period was Robert Meade's study of the Mississippi River. Meade, a senior member of the NRP, had previously completed highly regarded studies on the Amazon and Orinoco Rivers in Brazil and Venezuela, respectively, and on the Powder River in southeastern Montana. To study the Mississippi, he formed a broad team of NRP, District, university, and local scientists and, over the course of several years, cruised the entire length of the river several times, collecting a wide array of water samples and other

supporting data along the way. The study provided insights into the long-term effects of both point and nonpoint-source discharges on the quality of river water, in the process laying the foundation for more effective management of those discharges. The work is well documented in USGS Circular 1133.

Acid precipitation occupied a prominent place in the national environmental debates of the late 1980's and 1990's. The USGS played a significant role in developing precipitation data from a nationwide network of stations hosted by a variety of Federal and State organizations. In addition, we supported a number of research projects directed toward understanding the impact of the precipitation on the environment. The NRP's Owen Bricker was a central contributor to this latter effort. The overall program was managed for the USGS by Jack Pickering. Paul Kapinos was his senior assistant.

The issue of possible global changes in the environment came to the fore during this period. The Division established an office to coordinate our efforts in that area. Harry Lins was the leader of the program. The NRP's Chris Milley and Eric Sunquist were two prominent USGS scientists working to understand some of the issues surrounding the observable changes. Milley's interest was in modeling global climate, while Sunquist focused on the intricacies of the carbon cycle. Each of the three became a prominent contributor to the national debates.

As our work in water quality expanded, we worked hard to improve our sometimes rocky relationships with the USEPA. Moody was given the lead in this effort, and he did a wonderful job. Together with USEPA's Elizabeth Fellows and over the course of several years, he established a level of trust and confidence between the agencies that we had been unable to achieve in previous decades. Communications between the agencies were improved, allowing the exchange of program plans and, in some cases, joint program planning. Staff scientists were exchanged to facilitate program planning and understanding and, on occasion, USEPA even provided support in our budget debates. Although the unease that naturally exists between Federal agencies with responsibility in the same resource still existed at some level, Moody's efforts were enormously successful to the great benefit of both agencies and the Nation.

In 1990, Stan Sauer commissioned a study to examine the stability of the smaller Districts. The study found that smaller Districts were having problems keeping up with the fast-evolving technology in water science. In general, they were having trouble finding resources to purchase new, more complex instruments and to hire the skilled scientists necessary to operate them.

To encourage and coordinate support for the smaller Districts from neighboring Districts, we experimented with the concept of creating "Area Hydrologists" on the regional staffs, 15 positions in total. Their role was to identify technical shortfalls in the multiple Districts for which they were responsible and bring resources to bear to remedy those shortfalls from others of their Districts. The concept was expensive, however, and popular neither in the field nor in the States, the latter perceiving that their tax dollars might be used to resolve problems in neighboring States. The positions were disestablished after just 3 years, with existing region staff members being tasked to carry out the coordination role of the former Area Hydrologists.

By the early 1990's, Federal programs had markedly increased in number and in importance. The most prominent of those, NAWQA, was beginning to produce the first national pictures of water quality allowing Cohen, for the first time, to be able to reply knowledgeably to the questions of Mr. Yates. That said, the Federal-State Cooperative program continued to be the backbone of everything we did. It was the rock on which our Districts rested, and the Districts remained the heart of the Division. NRP continued to attract and husband wonderful scientists whose national and international achievements kept the Division on the leading edge of our field.

Throughout the 1990's, the international program made significant contributions in providing water-resource advice and assistance to the U.S. State Department during the Middle East peace talks between Israel, Jordan, and the Palestinian people. Over several years, Fischer, Schneider, Jerry Stephens, Bill Shampine, Jeff Miller, and others worked on a team coordinated by Lenox. Miller eventually was assigned to live in the region to provide direct USGS liaison with the hydrologic programs of each of the parties.

With the change of administration in January 1993, Director Peck retired and was replaced by Gordon Eaton. In the early 1980's, Eaton had been Associate Chief of the Geologic Division. In the interim, he had held a number of senior positions in academia. Eaton entered announcing his view of the need for sweeping change in the USGS, specifically

designed to draw the Divisions closer together. As the Cohen years ended, he was going busily about implementing his particular vision.

Stan Sauer, the Northeastern Regional Hydrologist, retired in 1993. He was replaced by Bill Carswell, the Nevada District Chief. In the same year, Bill Alley was named Chief of the Office of Ground Water upon Gene Patten's retirement.

In 1994, senior staff members under Cohen included Fischer as the Associate Chief with Conomos, Carswell, Blakey, and Cook leading the Western, Northeastern, Central, and Southeastern Regions, respectively. The assistant chiefs were Hirsch (R&EC), Mann (Operations), Daniel (SIM), Moody (WA&DC), and Schneider (PC&TS). Wolff was heading the Office of Hydrologic Research and Leahy headed NAWQA. The three discipline Office Chiefs were Alley in ground water, Boning in surface water, and Rickert in water quality.

The Cohen years resulted in unprecedented growth in the Division both in the size of the budget and in numbers of personnel. This was important in itself, but more important, the growth created a foundation for a growing confidence and strengthened a feeling of individual self worth throughout the Division. We believed in what we were doing and believed that we were doing it well. For the vast majority of Division employees, it was fun to come to work.

This sense of well-being across the Division was due in large part to Cohen himself. That Cohen would be the driving force behind such buoyancy was somewhat incongruous because he is a shy man. He does not like large gatherings nor is he particularly comfortable meeting one-on-one with persons with whom he is not familiar. He could be brusque. But his outward demeanor masked a deep and fundamental concern for the welfare of every person in the Division, especially that of those in any kind of personal or professional difficulty.

Although this core aspect of his personality was seldom apparent, it somehow permeated the Division from top to bottom. There was a feeling from Headquarters, through the Regions, and into the Districts that every individual was important. Decision by decision, small gesture by small gesture, personnel selection by personnel selection, a sense emerged throughout the Division that people cared about one another. A sense of family and mutual support, initiated and encouraged by the former Chief Hydrologist, Joe Cragwall, was carefully nurtured and enhanced. The end result was a national team of hard-working men and women who were proud to be a part of the USGS and of WRD. It was a very good time.

CHAPTER II – THE WRD ORGANIZATION AND PROGRAMS

WRD ORGANIZATIONAL STRUCTURE, 1979–94

By James F. Blakey

Unlike the 1966 to 1979 period of Volume VII when the major reorganization was completed from GW, SW, and QW Branches to Water Resources Division at District level and District laboratories were closed and the central Laboratory system was created, organizational changes were minor during the 1979–94 period. At Headquarters, two Assistant Chief Hydrologists and a Deputy Assistant Chief Hydrologist were established: Assistant Chief Hydrologist for Research and External Coordination, and the Assistant Chief Hydrologist for Water Assessment and Data Coordination, and Deputy Assistant Chief Hydrologist for NAWQA. In the early 1990's, Area Offices were established and staffed by Area Hydrologists. These positions were to be an organizational layer between the Regional Hydrologist and the District Chief with each Area Hydrologist having supervision over three to five District Chiefs. These positions were short-lived and gone by the mid-1990's.

Figure 1 shows the Organizational Chart for WRD for 1980, and figure 2 the Organizational Chart for 1994.

OFFICE OF THE CHIEF HYDROLOGIST

By James F. Blakey

When Philip Cohen became Chief Hydrologist in the fall of 1979, Hal Langford was the Associate Chief Hydrologist and Francis Sessums was Program Officer. Division Staff Scientists on the Chief Hydrologist's staff were as follows:

Hackett, O. Milton	Durum, Walton H.
Hastings, Warren W.	Langbein, Walter B.
Hendricks, Ernest	Stringfield, Victor T.
Schneider, Willliam J.	Kindsvater, Carl E.
Taylor, George C., Jr.	Moody, David W.

All were retirees available for special assignments except for Schneider and Moody. Cohen selected Linda Meadows as his secretary. She had been Secretary for the Associate Chief. Bill Schaefer, Assistant Regional Hydrologist of the Northeastern Region, also served as the Delaware River Master, and this position reported to the Chief Hydrologist.

In 1979, the Office of International Hydrology (OIH) reported directly to the Chief Hydrologist. Scientists in OIH were as follows:

Jones, James R.	Price, Lynne M.
Laura, Della	Tibbitts, Gordon C., Jr.
Giusti, Ennio V.	Moore, Donald O.
Beall, Robert M.	Shampine, William J.
Bradford, Gary M.	Williams, James F. III

In 1981 David Rickert and Bill Wilber joined the staff, and Jerry Meyer joined the retirees as a Staff Scientist. Francis Sessums retired in 1983 and was replaced by Paul Beauchemin.

Hal Langford retired in 1985 and was replaced in 1986 by Bob Averett. After less than 2 years as the Associate Chief, Averett requested to return to research and returned to the National Research Program in Denver, and later Boulder. In 1988, Jack Fischer became the Associate Chief Hydrologist and served through the end of this period.

Linda Meadows moved "upstairs" to the Director's Office, and Gayle Cross became Secretary to the Chief Hydrologist in 1986. Joanne Taylor replaced Cross in 1991 and served through the end of this period.

Phil Cohen retired in December 1994.

OPERATIONS

By William B. Mann

The important issues during this period were to (1) continue a strong and relevant Federal-State Cooperative (Coop) program, (2) continue stressing the importance of having a strong Federal Data program, (3) develop and test state-of-the-art hydrologic instrumentation, (4) redesign the computerized financial management and project management systems, and (5) assist the Division in providing a corps of highly qualified personnel to fill senior vacancies in the Division.

ORGANIZATION OF THE WATER RESOURCES DIVISION, 1980

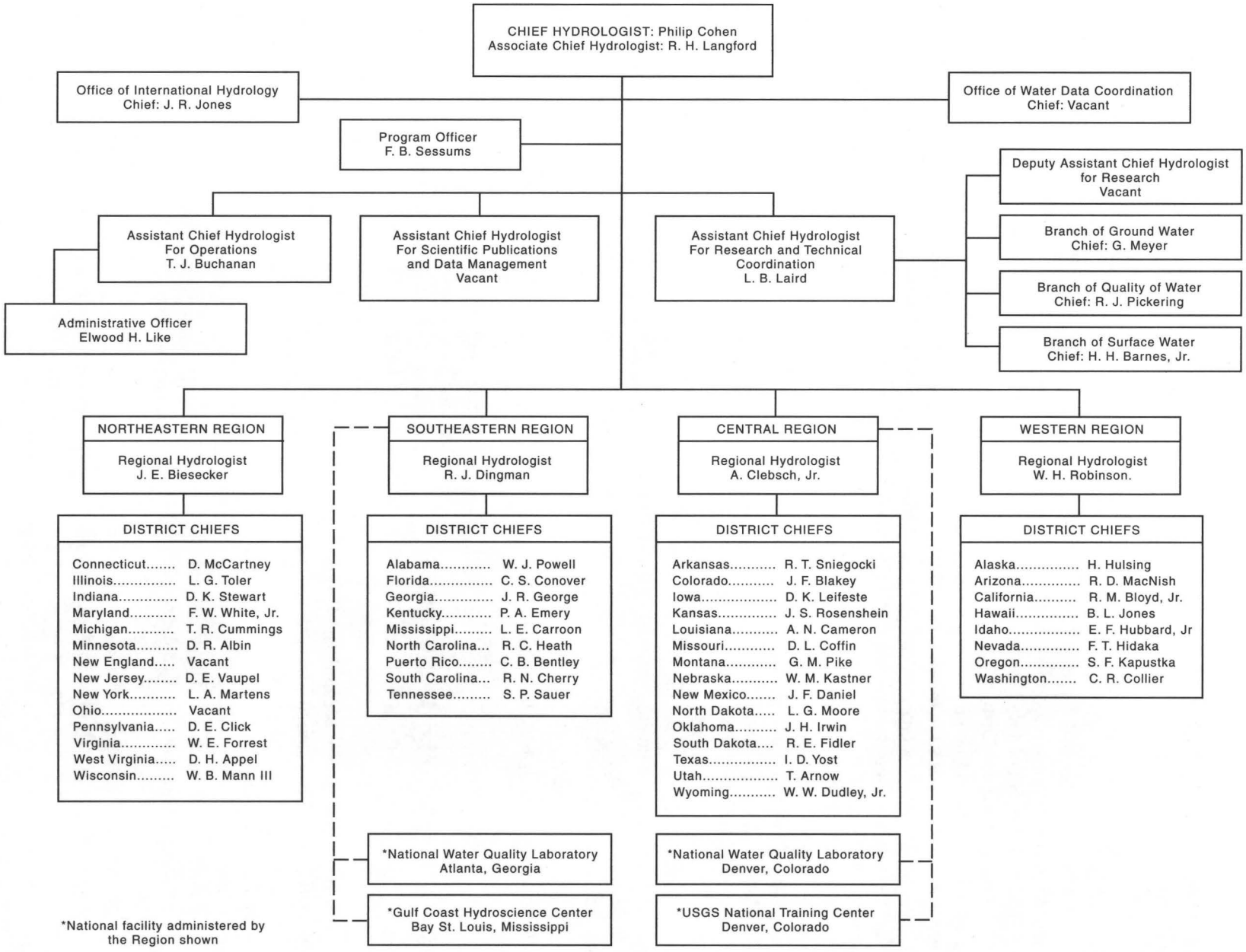
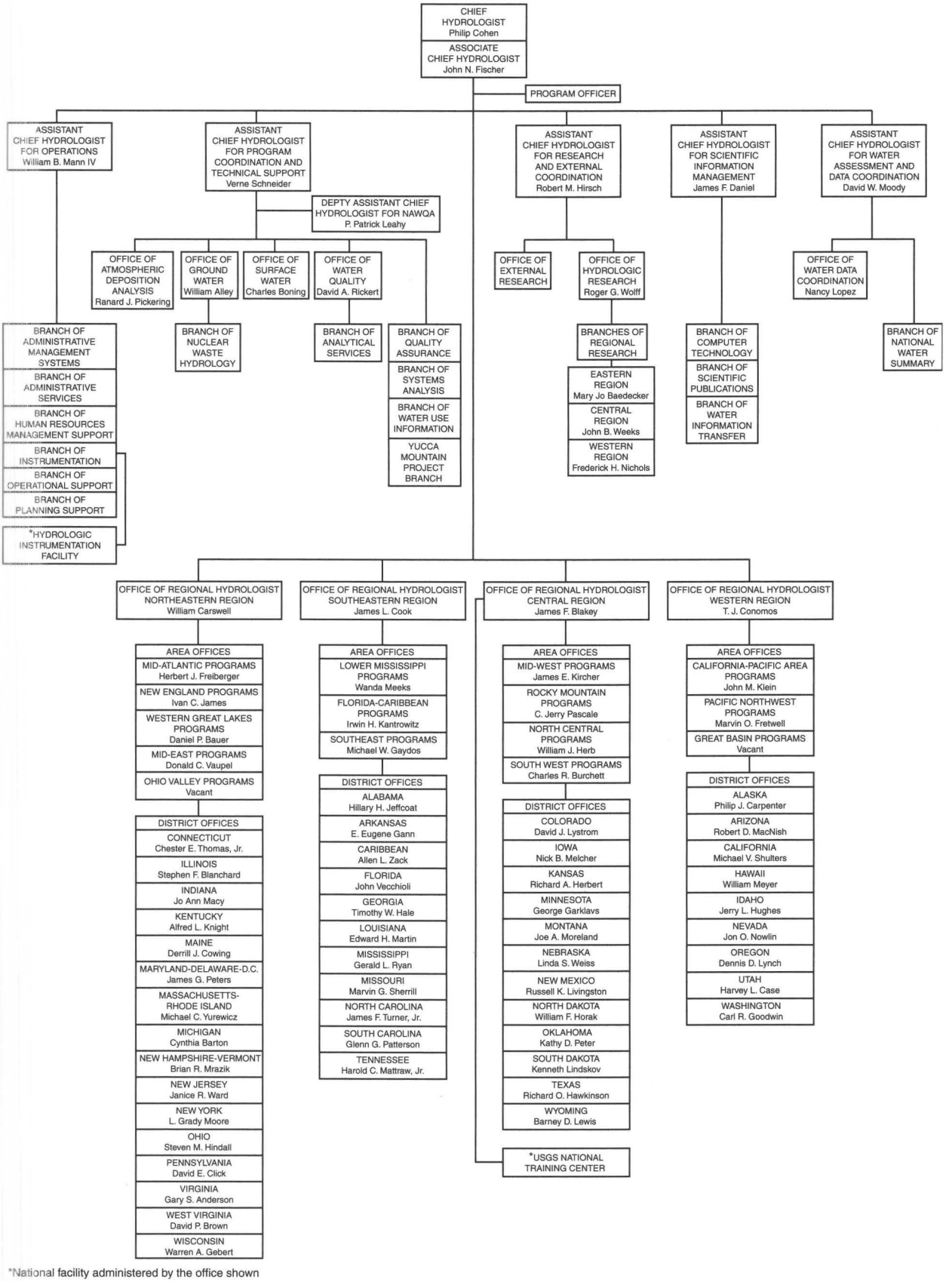


Figure 1. Organizational chart for 1980.

ORGANIZATION OF THE WATER RESOURCES DIVISION, 1994



*National facility administered by the office shown

Figure 2. Organizational chart for 1994.

The Federal-State Coop program was constantly the target for program cuts during this period. Through the diligent efforts of leadership in the Division and Bureau, the funding increased slightly. Quality of water programs increased in numbers during the late 1980's and early 1990's in response to the beginning of the National Water-Quality Assessment (NAWQA) Program, a nationwide program.

The Federal Data program was not as successful as the Federal-State Coop program in maintaining a budget that kept pace with inflation, much less experienced any increases. During most of this period, especially during the later years, it was necessary to decrease the number of Federal Data program stations in the data-collection network. Each of the Regional Hydrologists, at the request of Headquarters, found it necessary to prioritize the Federal Data program stations in their Regions. The available funds then were distributed on the basis of the priorities.

The procurement of new computers for the Division in the 1984–86 period put the Division into a new technology age. This change in the application of computers to financial and project management necessitated the redesign of the financial management system and the project management system. The redesign was successfully completed, but refinements are ongoing. The system was completed with major input from several District Offices. This reduced the need for additional personnel in Headquarters. The integrated system, called the Administrative Information System, included financial management, project planning and management, and preparation of financial reports, including retrieval of historical financial and project information.

Division personnel during this period increased from about 2,800 to almost 5,000. This placed an increased workload on the Regional Personnel Offices and the Division Manpower Office. The two offices handled the increased workload without hiring additional personnel.

Individuals that filled the major positions in Operation are listed:

WRD FUNDING, BY FISCAL YEAR

[FY, fiscal year; OFA, other Federal agencies]

FY	Federal	OFA	State	Federal matching	Total
1979	$61,030,329	$37,620,790	$39,803,844	$38,139,387	$176,594,349
1980	70,440,880	38,797,042	42,285,464	40,069,056	191,592,442
1981	72,528,762	39,806,851	44,822,889	42,033,860	199,192,362
1982	64,978,069	36,836,279	45,586,590	44,142,820	191,543,758
1983	70,520,352	38,365,404	45,504,361	43,373,174	197,763,291
1984	77,033,931	39,708,912	52,106,023	47,760,198	216,609.064
1985	81,247,725	43,543,508	70,153,260	47,935,331	242,879,824
1986	61,464,590	51,510,510	55,515,097	48,132,205	216,622,402
1987	85,207,558	50,663,127	59,963,168	55,142,000	250,975,853
1988	89,320,040	64,189,010	65,949,864	59,614,000	279,072,914
1989	868,332,944	72,623,744	67,081,154	58,865,007	284,902,849
1990	92,385,100	69,191,941	69,958,044	58,893,705	290,428,790
1991	109,352,371	73,650,035	82,342,612	65,707,000	331,052,018
1992	118,175,638	95,666,646	83,644,041	62,813,500	360,299,825
1993	137,575,462	109,995,443	85,986,611	62,995,360	396,554,876
1994	131,304,951	125,487,448	88,949,265	63,488,059	409,229,723

Full-time permanent WRD employees

[Source: WRD data book; *, not available]

Date	Number of employees
1979	*
June 1980	2,817
June 1981	2,762
October 1982	2,794
October 1983	2,819
September 1984	3,266
October 1985	3,536
September 1986	3,561
October 1987	3,621
October 1988	3,815
September 1989	3,853
1991 through 1993	*
1994	≤5,000

Assistant Chief Hydrologist for Operations

Thomas J. Buchanan, 1979–86
William B. Mann, IV, 1986–94

Deputy Assistant Chief Hydrologist

Bruce K. Gilbert, 1979–94

Administrative Officer

Charles S. Herbert, 1979–80
Elwood H. Like, 1980–82
Henry T. Davis, 1982–88
Molly C. Schoenauer, 1988–90
JoAnn Schnepf, 1990–94

Operations Section[1]

Alberto Condes de la Torre, 1979–94

Manpower Section [2,3]

Raymond O. Abrams, 1979–824
Jerry C. Stephens, 1982–86

Norman E. Schmidt, Jr., 1986–94

Instrumentation Group[4]

Richard Paulson, 1979–86
William G. Shope, Jr., 1986–94

Administrative Data Systems Group[5]

Isabelle Halley des Fontaines, 1985–94

Planning Section[6]

George E. Williams, 1979–83
Catherine L. Hill, 1993–94

Water Resources Research Institute Group [7]

Frank T. Carlson, 1984–

[1]Renamed Branch of Operational Support, 1988
[2]Renamed Branch of Manpower, 1988
[3]Renamed Branch of Human Resources Management, 1993
[4]Renamed Branch of Instrumentation, 1988
[5]Renamed Branch of Administrative Management Systems, 1988
[6]Renamed Branch of Planning Support, 1988
[7]Transferred unit to Assistant Chief Hydrologist, Research and External Coordination, 1986

Office of the Assistant Chief Hydrologist for Operations, 1994

Mann IV, William B.
Gilbert, Bruce K.
DiLandro, Alice C.

Branch of Instrumentation

Shope, William G., Jr.
Dreyer, S. Ernest, Jr.
Field, Michael L.

Branch of Planning Support

Hill, Catherine L.
Meadows, Linda E.
West, Carlyn V.

General Services Section

Roen, C. Jeanne
Brenner, Toni
Bower, William K.
Cornwell, Amy C.

Financial Operations/Reporting Section

Sabatini, Alice A.
Young, Elizabeth A.
Biggar, Janice M.
McDonald, Connie F.
Cecchetti, Richard W.

Branch of Water-Use Information

By Wayne Solley

The U.S. Geological Survey began compiling estimates of water use in 1950. These estimates were derived from many sources and had a wide range of accuracy. Therefore, they fell short of providing a national data base that was both current and reliable. In 1977 the Congress recognized the need for uniform information on water use and directed the U.S. Geological Survey to establish a National Water-Use Information Program to complement the Survey's data on the availability and quality of the Nation's water resources.

The National Water-Use Information Program was designed as a cooperative program between the States and the Federal Government. The goals of the program were to collect and compile water-use data, to develop and refine computerized water-use data systems at both the State and national levels, to devise new methods and techniques to improve the collection and analysis of water-use information, and to disseminate this information to those involved in establishing water-resources policy and to those managing the resources. The first manager of the Water-Use Program was Frederick Ruggles (1978).

After Ruggles retired, Bill Mann transferred to Headquarters (1981) to manage the program. Efforts continued to establish a cooperative water-use program in every District Office. The goal was to have water-use information available on an annual basis. Every 5 years the data were compiled and a summary water-use report published for the United States. The Districts and States were encouraged to publish companion reports for their State. An effort was undertaken early in the period to design a computerized water-use data system for use as a site-specific State data base as well as provide for an aggregated national data base. The design was completed and the data base made available for storing State water-use data and aggregating the data in the national data base. This helped provide more consistent water-use data at the State and national levels. Efforts continued to improve the accuracy of the data by using similar definitions, sources of data, and data-collection techniques throughout the Nation. Under the leadership of Solley and a team of regional Water-Use Program coordinators, the program matured during the mid-1980's and 1990's to the point where the USGS is now recognized as the Federal water-use agency.

Branch of Instrumentation

By William G. Shope

Hydrologic field instrumentation development, deployment, and support during the years Philip Cohen was Chief Hydrologist were characterized by the management reviews, restructuring, and redirection of the Instrumentation Program; the strengthening of Field Office representation and influence in determining Water Resources Division (WRD) field instrumentation and equipment priorities; the evaluation and transition to the use of electronic-based instrumentation for the collection of hydrologic data; increased cooperation with Water Survey of Canada; and the improvement and expansion of real-time data collection.

Management reviews, reorganization, and redirection of the Instrumentation Program

- The Director's Office Review of the Hydrologic Instrumentation Facility (HIF) conducted in fiscal year 1987 by an interdivisional team led by Grady Moore resulted in several significant changes involving management and operations.
- Budget, personnel, and technical oversight for the HIF were consolidated under the Office of the Assistant Chief Hydrologist for Operations.
- The focus for instrumentation development was placed on use of private industry.
- The instrument and equipment testing and evaluation mission of the HIF was expanded and given the highest priority.
- Following an agreement between the Assistant Chief Hydrologist for Operations, Bill Mann, and the Chief of the Office of Surface Water (OSW), Bill Boning, management responsibility for the Federal Interagency Sediment Project (FISP) was transferred to OSW in 1993. The FISP was later moved from the University of Minnesota facilities at St. Anthony Falls, Minn., to the U.S. Army Corps of Engineers Waterways Experiment Station at Vicksburg, Miss.
- The use and support of the new electronic instrumentation was closely scrutinized by a 1989–90 Inspector General audit, a fiscal and functional review of the HIF conducted by an ad hoc committee chaired by David Click, and a 1991

survey conducted by a District Chiefs' work group.

The strengthening of Field Office representation and influence in determining WRD field instrumentation and equipment priorities

- The Chief Hydrologist formed a senior management advisory committee for instrumentation (Instrumentation Management Advisory Committee).
- The Instrumentation Committee (ICOM) was re organized and given a new charge to include satellite data relay. The Data Relay Committees completed their work and were dissolved.
- The Instrumentation Technical Advisory Subcommittee was formed to provide senior District data staff the opportunity to provide recommendations to the ICOM on field instrument and equipment priorities and needs.

The evaluation and transition to the use of electronic-based instrumentation for the collection of hydrologic data

- The Branch of Instrumentation and the HIF began work with industry to identify WRD data-collection requirements and to encourage commercial vendors to submit new instruments for testing.
- The first Electronic Data Recorders (EDL) with solid-state computer controls and memories were developed under contract and were termed Basic Data Recorders. These new recorders were deployed as replacements for the Analog-to-Digital Recorders (ADR) that stored data on paper tapes.
- The replacement of mercury manometers with new electronic transducer-based pressure sensors was initiated.
- Advanced Data Collection Platforms (DCP) were purchased for recording and transmitting hydrologic data in near real time.
- Standards were developed and implemented for batteries (12-volt) and for control and communication between electronic data sensors and DCP's and EDL's.

Increased cooperation with Water Survey of Canada (WSC)

- Periodic management and technical meetings were initiated to exchange information on programs, organization, and technical advancements.
- Members of WSC were invited to serve on WRD committees.
- Instrumentation test, evaluation, and performance data were exchanged by the two agencies.

Improvement and expansion of real-time data collection

- Computer software was developed by Ernest Dreyer, Branch of Instrumentation, to convert data output from EDL's and DCP's to standard format acceptable to the National Water Information System (NWIS).
- A contract was awarded for the purchase of Local (District-based) satellite Ground Receive Stations (LRGS) for data relay. Fourteen LRGS's were in operation by 1994.
- Computer software was developed by Ernest Dreyer to continuously (under computer control) route near-real-time data from District LRGS's to the NWIS.
- The use of DCP's at U.S. Geological Survey gaging stations grew from several hundred in 1979 to more than 3,000 in 1994.

Responsibility for instrumentation was delegated to the Assistant Chief Hydrologist and then to the Branch of Instrumentation.

- The Branch was responsible for:
  - –Coordination of hydrologic field instrumentation needs identification, development, evaluation, testing, repair, and supply;
  - –HIF oversight;
  - –Data Relay Project management; and the
  - –FISP (transferred to OSW in 1993).

- The Instrumentation Coordinator/Branch Chiefs during the period were:

  –Richard Paulson, who served as the Coordinator/Branch Chief until 1986, and
  –William Shope as Acting Branch Chief from September 1986 through May 1991, when he was permanently assigned to the position.
- The Facility and Project Chiefs were:

  –Russell Wagner, who served as the Chief of the HIF until 1987, when he was replaced by Vito Latkovich; and
  –John Skinner, who served as the Chief of the FISP.

Scientists and engineers at the HIF were:

Francis Koopman, Sam Rickly, Richard Billings, Alex Sturrock, Edwin Cordes, James Ficken, James Rorabaugh, Donald Rapp, Sam Wilbourn, Gary Loman, James Futrell, James Jelinski, Edward Ford, Doreen Tai, Russell Brown, and Alex Sturrock.

Branch of Human Resources

By Norman E. "Skip" Schmidt, Jr.

INTRODUCTION

The Branch of Human Resources Management Support (BOHRMS), originally named the Manpower Section and later the Branch of Manpower, was established in the 1960's under the administration of Chief Hydrologist Luna Leopold. The original focus was on employee utilization, recruitment, and technical training; however, soon the Section developed into a full-service human-resource "think tank" for the Water Resources Division and liaison for technical management throughout the Division to leadership and staff in the servicing personnel offices of the Bureau. The first Chief of the Section, Raymond O. Abrams, served the Division and the Bureau in that capacity into the early Cohen years.

MISSION

The mission of the Branch included the evaluation of staffing patterns and the need for redistribution of manpower and the recruitment of personnel, the analysis of organizational structure and the recommendation of changes to meet mission requirements of the Division more efficiently, the identification of existing skills and training needs based on present and future programs, and the development of specialized training. Branch staff provided advice to supervisors on personnel-management responsibilities and regulations and developed and interpreted policy on recruiting, staffing, position classification, incentive awards, pay management, disciplinary actions, troubled employee counseling, performance management, labor/management relations, and equal opportunity. Staff also managed the Division's automated Manpower Career Documentation System and its Graduate School Training Program and served as focal point in the Division for issues related to national security.

ORGANIZATION AND STAFF

The Branch was located organizationally in the Office of the Assistant Chief Hydrologist for Operations who reported directly to the Chief Hydrologist. Staff consisted of the chief, one hydrologist on a 3-year rotational management-development assignment, from one to three human-resource management specialists, a computer professional, and either one or two clerical/technical assistants. Though there was no direct organizational link, the Branch maintained and fostered professional and collegial relationships with the Staff Hydrologist for Manpower in each of the four Regions and later with the four Regional Human Resource Management Specialists, as well as with the staff of the National Training Center in Denver, Colo.

Section/Branch Management 1978–94: "The Cohen Years"

Chiefs

1. Raymond O. Abrams (1965)
2. Jerry C. Stephens (1982)
3. Norman E. "Skip" Schmidt, Jr. (1985)

Assistant Chiefs

1. Frank W. Giessner (1979)
2. Norman E. "Skip" Schmidt, Jr. (1980)
3. C. Larry Togans (1985)
4. David C. Voelker (1989)
5. C. Larry Togans (1991

Summary of Program

The Branch had six major service functions that constituted its full range of programmatic activities. These services are described below.

Personnel Service to Headquarters Staff – Activities similar to those provided by administrative staff at the District level, including record keeping; basic classification, staffing, and training support; orientation for new employees; required reports; and liaison to servicing personnel office staff. Service was provided to approximately 200 employees.

Personnel Service to Headquarters Satellite Offices —Activities similar to those provided by the Regional human-resource management staffs to District offices. Headquarters Satellite Offices were Yucca Mountain Projects Branch (about 110 employees); National Water Quality Laboratory (about 170 employees); Branch of Technical Development and Quality Systems (included the National Training Center) (about 27 employees); Hydrologic Instrumentation Facility and Office of Surface Water – South (about 50 employees); and some limited support to the three Branches of Regional Research (about 320 employees).

Advice and Consultation—Activities included consultation to District, Regional, and satellite-office management on potential candidates for vacant positions, staffing plans, reorganizations, award documentation, and promotion potential of subordinate staff.

Management of Division-Level Programs—Programs/activities managed included the agenda of the Human Resources Management Committee (HRMC); the National Association of Geology Teachers (NAGT) summer field training program; the Graduate School Training Program; management/supervisory/leadership training; executive-level and complex position classifications; national-security clearances; and the Manpower Career Documentation System (later called the Career Documentation Profile, or "CDP").

Highest Level Advice and Advocacy—These activities involved significant subject-matter expertise and were some of the more important services provided to the Division's Senior Staff and field managers. Activities included studies of organizational dynamics and the development and modification of personnel policy.

Guardian of the Division's Personnel Policies, Programs, and Actions—Several important aspects of this service were critical to the success of the Division's human-resource management program: an "overview" function that afforded institutional memory to proposed actions, an "analyst" function that provided predictive contingency planning relating to the utilization of human resources, and a "legal conformance" function.

Selected Projects and Activities

The Career Development Plan (CDP), or Career Documentation Profile as it was later called, was proposed by the Division's Manpower Committee (Human Resources Management Committee) in the late 1970's as a tool to capture information on unused or underutilized skills in the organization. Its focus originally was on female employees since few women in the Division at that time held positions in the sciences, professional administrative job series, or supervision and management. The potential value of the CDP as a critical tool in the overall management of the Division's human resources became evident to senior leadership very quickly, and funds were made available to expand its content beyond a paper-copy biographical sketch to a comprehensive automated profile of employees that included a history of positions held, an autobiography and bibliography, education, awards received, preferred career direction, an individual development plan, and a supervisory assessment of a standard set of skills unique to the type of work performed by identified groups of employees. The automated CDP system was managed and administered in the Manpower Section initially by Annette T. Fisher, and later, throughout the Cohen years, by C. Larry Togans. Togans orchestrated many enhancements to the system over the years, often driven by changing Federal personnel policy, most notably the Civil Service Reform Act of 1978.

Individual performance management, linking pay to the performance of supervisors and managers, a Senior Executive Service (SES) that replaced the GS–16, 17, and 18 grade levels, and the recruitment process were among the issues addressed by Civil Service reform. It was during this time under the leadership of Jerry Stephens that the Section's organizational title was changed to the Branch of Manpower. (The title was changed again several years later to the Branch of Human Resources Management Support.) Branch staff members were involved in the design of

policy and process at the Bureau level, and in the implementation of these reforms throughout the Division. Much of the Bureau-level training on performance management and awards and recognition was developed and presented by Branch staff led by Schmidt in cooperation with Janis Nash and other colleagues in the Headquarters personnel office. Over the years, Awards Program management passed from Schmidt to Voelker and ultimately to Charleen Simpson. Responsibility for training in the Awards Program was shared by Schmidt and Simpson with a great deal of support in the later years from Connie Smith, the Human Resources Management Specialist in the Southeastern Region. The conversion of the GS–16 and above "supergrade" positions to the SES fell to Schmidt and Matt Sliwiak, the Division's senior servicing classifier in the Headquarters personnel office. Schmidt and Sliwiak provided classification and position management support to executive leadership on many occasions during the Cohen years as changing program emphases called for major redesign of the Division's organizational structure. A similar classification partnership developed between Sliwiak and Togans, and later between Sliwiak's replacement, Ray Gendron, and Barbara Gunderson. The impact of Civil Service reform on the recruitment process was significant as well. Branch staff developed the first "standard" KASOC's (**K**nowledge, **A**bilities, **S**kills, and **O**ther **C**haracteristics) and Crediting Plans in the Bureau, which were used to evaluate candidates for vacant positions under the revised staffing regulations.

Branch staff members were involved in a number of other significant classification and position management activities during this period. Bill Scott, a hydrologist on rotational assignment to the Branch from 1982 to 1983, worked closely with Roger Wolff, Deputy Assistant Chief Hydrologist for Research, to document revisions to the Division's research peer panel process as it was expanded to include research conducted by District personnel. Schmidt developed a new pay setting and rate increase process for supergrade scientists (ST) and the new senior leader (SL) pay category that was adopted by the Department of the Interior. Togans and Connie Smith designed and tested a template for automated staffing plan development that became a model for future Bureau workforce planning efforts. Staff spent considerable time supporting the professionalization of the administrative officer career field in the Division, and rewrote the Administrative Officer Blue Book that provided guidance on the appropriate grading of administrative officer positions. Gunderson played a major role in promoting the Volunteer for Science Program in the Division, exposing citizens to the work of the Division and providing management with low-cost or no-cost science support.

A critical, ongoing function of the Branch was support to the Division's Human Resources Management Committee (HRMC). HRMC membership included the Assistant Chief Hydrologists, the Regional Hydrologists, and later, a representative of the Technical Discipline Office Chiefs. The Assistant Chief Hydrologist for Operations chaired the Committee. The Chief, Branch of Human Resources Management Support, served as Executive Secretary. The HRMC provided advice and guidance to the Chief Hydrologist on all matters related to the management and career development of Division employees and developed and recommended policy, guidelines, and procedures for human-resource management by Division line officials. It brought "people" issues to the attention of senior executives in the Division. These issues included training needs, recruitment and staffing strategies, and appropriate recognition such as promotion potential and awards for Division staff. The HRMC was a forum to help executive leadership focus on the development of the talent pool that would become the next generation of leaders in the Division. It was also essential to the resolution of management problems such as the need to move personnel and work between cost centers when funding crises arose. Logistics for the six yearly meetings and agenda setting were the responsibility of the Branch Chief until the later Cohen years when those functions were delegated to Gunderson and later to Michelle Frederick, the Division's senior Human Resources Management Assistant.

Liaison to the Equal Employment Opportunity Office was another critical function of the Branch. During the period, the Branch conducted the Division's first barrier analysis and developed its first Affirmative Employment Plan. Stephens, Scott, and Schmidt were much involved in the development of the Bureau's Historically Black Colleges and Universities Program and the Hispanic Serving Institutions Program. Giessner, as women's issues liaison, promoted the development of the Federal Women's Program in the Division. Branch staff with support

from the Regional Human Resources Management Specialists, Lolly Rann (NR), Connie Smith (SR), Carol Coburn (CR), and Sharon Doung (WR), developed the first Targeted Recruitment Plans in the Bureau. Schmidt and Togans worked closely with Dennis Sulam, Staff Hydrologist in the Northeastern Region, to redesign and roll out a revised Upward Mobility Program that provided selected employees with opportunities for employee development that would lead to reassignment to other job categories with greater potential for promotion. During the Cohen years, the Division was recognized for the success it had in the development of opportunities for women and in the increase in the number of women in the sciences and in supervisory and management positions.

The Branch remained very much involved in employee development activities during the Cohen years including technical training, leadership and management development, supervisory training, support to the National Training Center, and development of the K–12 Education Initiative. The Graduate School Program was a major benefit to selected employees and a critical retention tool that helped the Division remain an employer of choice in the hydrologic sciences. The program, which was managed for many years by Beverly Pittarelli and later by Barbara Gunderson, trained many individuals who would become some of the most visible and respected scientists and science managers in the Division. The K–12 Education Initiative was developed cooperatively with Richard Herbert and Stephen Vandas, staff hydrologists in the Central Region, and addressed a major outreach commitment of the White House at the time.

In Conclusion

From a human-resources management perspective, at the end of the Cohen years, the Division was recognized as a leader in the Bureau in innovative and employee-centered human resource programs. Thanks to the interest and support of Phil Cohen and his executive leadership staff, the Division was positioned well to retain that stature as the torch of leadership was passed to Chief Hydrologist Bob Hirsch.

RESEARCH AND TECHNICAL COORDINATION, 1979–85/ PROGRAM COORDINATION AND TECHNICAL SUPPORT, 1986–94

By John N. "Jack" Fischer

In 1979, the Assistant Chief Hydrologist for Research and Technical Coordination (R&TC) was responsible for the National Research Program (NRP), the discipline offices (ground water, surface water, and quality of water), the Branch of Systems Analysis, and the Nuclear Hydrology Program. The Ground Water Branch managed the Regional Aquifer-System Analysis program. The National Stream Quality and Benchmark Networks were overseen by the Branch of Water Quality. The volcano hazards program was managed with the Branch of Surface Water. That program was stimulated greatly by the eruption of Mount St. Helens in 1980. The R&TC organization facilitated technical cooperation between researchers and the discipline offices. Researchers frequently assisted the discipline offices in reviews of District program, and it was not uncommon for scientists to move from NRP into the discipline offices, and vice versa.

In 1984, this comfortable arrangement was complicated when Secretary of the Interior James Watt disestablished the Water Resources Council and transferred the Water Resources Research Institutes and the accompanying Water Resource Grant program to the USGS. Housed within R&TC, the increased program made the existing organization large and unwieldy. Therefore, it was decided to create a new organizational unit titled Research and External Coordination (R&EC) to house the research programs. We referred to NRP as the "internal research" program and to the institutes and the grants as the "external research" program. Marshall Moss was named the first Assistant Chief Hydrologist of R&EC. Roger Wolff remained in charge of the NRP. Frank Carson, who had been associated with the institutes and grants programs in the Department, headed the program in the USGS. When Wolff retired in 1988, John Schefter was named as his replacement.

In 1986, the position of Assistant Chief Hydrologist for Program Coordination and Technical Support (PC&TS) was established. Its purpose was to manage the discipline offices and a growing array of national programs funded wholly by our congressional

appropriation. We called these programs "Federal programs." Gordon Bennett having retired in the interim, Jack Fischer was named as the first Assistant Chief Hydrologist for PC&TS. He had been working for Gene Patten in the Office of Ground Water with responsibility for developing the ground-water element of the nascent NAWQA Program. In the same period, the titles of the discipline offices were changed from "Branch" to "Office," in part, at least, to fend off Bureau and Department raids on our Senior Executive Service positions.

Senior researchers in the Division were uneasy about the new organizational arrangement because it separated the NRP from the Federal programs. Their disquiet stemmed in part from the concern that, from a separate organization, researchers would be less able to provide technical support to those programs. But it also was based on the fact that, over time, NRP had come to rely on receiving a substantial and growing part of its funds from those Federal programs and, with the two programs housed separately, funds would be harder to come by.

The funding issue existed because we never fully succeeded in convincing the Department, OMB, and the Congress of the importance of hydrologic research to the successful completion of our mission. As a result, we always struggled to find adequate funding for the NRP. Nevertheless, in the early 1980's we established an unwritten objective of providing 10 percent of total WRD funding for the NRP.

This objective had unintended consequences down the road. As the years went by, we were able to obtain increases in the Federal side of the Federal-State Cooperative program, and States contributed substantial amounts of money in addition to their traditional fifty-fifty match. Funding for our Federal programs increased and funding from other Federal Departments such as Energy and Defense also was on the rise. But we were seldom able to convince the Congress to provide funds sufficient for our research program even to keep pace with inflation.

With the overall growth in the Division budget and with an essentially static research budget, maintaining the 10-percent objective became a real challenge. Funds from the Federal-State Cooperative program were legislatively inaccessible, and other Federal agencies watched their funds very carefully to make sure they were used as agreed. Despite our efforts, those agreements seldom included research objectives.

As a result, the only funds available to maintain the 10-percent objective were in the Federal programs. But with the other areas of the budget growing fast, the requirement to extract funds from the Federal programs to maintain the overall 10 percent of Division funding for NRP increased rapidly and soon began to drain those programs of funds to accomplish the work for which they were legally appropriated. By 1986, over 20 percent of the RASA and over 30 percent of the Nuclear Hydrology Program were being spent in NRP. Even though the research was relevant to the programs and excellent in quality, it was not the use for which the Congress had appropriated the money. The practice was misleading and dangerous.

By 1986, 30 percent of the funds in the Federal programs was going to NRP, and the percentage was growing every year. It was clear that trying to fund research from the Federal programs was debilitating the field aspects of those programs and, if continued to its logical end, would bankrupt them. Ultimately, we made the decision to relate future transfers of funds from the Federal programs to NRP to changes in funding in the Federal program itself. In effect, we removed the fast-growing budgets of the Federal-State Cooperative program and of programs funded by other Federal agencies from the 10-percent calculation.

This decision stabilized funding for the Federal programs but left funding for NRP in doubt. Fortunately, the National Water-Quality Assessment Program (NAWQA) came along about that time. From the outset of that large program, we identified 10 percent of the funds with research objectives. Also, the Toxic Substances Hydrology Program, conceived and directed by Steve Ragone and later managed by Gail Mallard, was emerging as a major Federal program. That program had a central research component that allowed us to identify 50 percent of its funds for research. The growth in these two programs provided an important shot in the arm for NRP, to some extent making up for closing the valve a bit on the funding pipeline from the other Federal programs.

The Branch of Systems Analysis, organizationally located within the PC&TS, provided a kind of think tank for the Division. During this period, the Branch made important contributions to the design of NAWQA, to the redesign of NASQAN, and to the development of analytical techniques for the analysis of surface-water data. It was headed initially by Nick Matalas and then by Ivan James, followed by

Bob Hirsch, Dennis Helsel, Debra Knopman, and Jim Slack.

Changes and growth in the number of Federal programs during the 1980's had a great impact on the discipline offices and the Division in general. During that period, the Urban Hydrology, Coal Hydrology, and Oil Shale programs were diminished and ended. But NASQAN, Nuclear Hydrology, and RASA continued strong in the 1990's, and new programs such as Acid Precipitation and Global Change seemed to develop every year. During this period the Nuclear Hydrology Program was led by George DeBuchananne and later by Jack Robertson, George Dinwiddie, and Newell Trask. RASA was managed by Ren Jen Sun, followed by Tom Reilly.

NAWQA, of course, was our largest Federal program and required a prodigious effort to design, build, sell, and manage. That program is discussed at length in another section of this history, but suffice it to say that its visibility, importance, and magnitude had a major impact on the management of the Division. To fund the program, we were forced to come up with a substantial part of funds ourselves. This requirement led to long debates and painful decisions to reduce funding in both the RASA and Nuclear Hydrology programs and to forgo opportunities for growth in other programs. Moreover, much of our time and energy was spent in briefings on the program to internal USGS audiences, to Department officials, to National Academy of Sciences committee members, and to congressional staff. Some real heroes emerged in this process—Bill Wilber from PC&TS and Bob Gilliom from the California District, just to name two.

Other Federal programs managed from within PC&TS included the Acid Precipitation program headed by Jack Pickering and Paul Kapinos; the Department of Energy-directed studies to assess the feasibility of siting a nuclear-waste repository at Yucca Mountain in Nevada; the Department's Irrigation Drainage program led for the USGS by Bill Wilber; Steve Ragone's and later Gail Mallard's Toxic Substances Hydrology program; Global Climate Change managed by Harry Lins; and the Volcano Hazards program stimulated by the eruption of Mount St. Helens in 1980, headed by Ernie Cobb in the Office of Surface Water. Responsibility for management of most of these programs fell to the Office of Water Quality. In addition, that office had the challenging and time-consuming job of overseeing the operation of the National Water Quality Laboratory in Arvada, Colo.

The emergence of these federally funded programs had a major impact on the management of PC&TS and the Division. It is not too much an oversimplification to say that, prior to this time, the Division focused on two programs—the Federal-State Cooperative program and the NRP. Beginning in the early 1980's, federally funded programs became a third and very visible element of our mission. It complicated the jobs of our District Chiefs who, always driven to satisfy the needs of their State cooperators, now had to manage, sometimes, several other Federal studies, each with an anxious Headquarters-based manager—and he or she with a ready telephone.

Even with the imposition of managing the multiplying Federal programs, the primary mission of the discipline offices remained to assure the quality of Division science. They accomplished this through technical consultations with District scientists, assisted greatly by members of NRP, reviews of technical reports, and through discipline reviews of District programs.

The focus of the reviews differed historically by office. The Office of Surface Water dwelt mainly on maintaining a complete and accurate data base; the Office of Ground Water focused on the conduct of field projects; and the Office of Water Quality, the fastest growing of the three, maintained something of a balance. We were uncomfortable with the almost single focus of the surface- and ground-water reviews. To address the issue, in the early 1990's, we initiated joint discipline reviews, partly with an eye to bringing the philosophies of the two groups closer together. The idea bore some fruit, although the preference for effective data management on the one hand and project management on the other turned out to be rather endemic to scientists in the respective disciplines.

The Cohen years produced substantial change in the management of Division programs. The addition of the institute and grants programs brought us into closer contact with the university research community and required a substantial change in the organization of the Headquarters staff. Then the growth in the number and size of Federal programs demanded a large Headquarters role in the management of our field programs. This change, in turn, required the Regions and Districts to divert some of their management focus from the Federal-State Cooperative program to the new arena. In the end, the Federal programs enriched

our mix of technical programs, markedly increased our usefulness to the Nation, and improved the visibility of the USGS on the national water scene.

Listed below are the names and approximate tenures of the people who filled major positions with R&TC, R&EC, and PC&TS from 1979 to 1994.

Assistant Chief Hydrologist—Research and Technical Coordination

Les Laird, 1978–80
Gordon Bennett, 1981–85

Deputy Assistant Chief Hydrologist—Research and Technical Coordination

John Bredehoeft, 1979–81
Roger Wolff, 1981–86

Chief, Office of Hydrologic Research

Roger Wolff, 1986–94

Assistant Chief Hydrologist—Research and External Coordination

Marshall Moss, 1986–88
Bob Hirsch, 1989–94

Assistant Chief Hydrologist—Program Coordination and Technical Support

Jack Fischer, 1986–88
Verne Schneider, 1988–94

Chief, Branch (Office) of Ground Water

Gerald Meyer, 1973–80
Gordon Bennett, 1981
Gene Patten, 1982–89
Bill Alley, 1990–94

Chief, Branch (Office) of Surface Water

Harry Barnes, 1979–80
Don Thomas (Acting), 1981
Marshall Moss, 1982–85
Verne Schneider, 1986–87
Ernie Hubbard (Acting), 1988
Bill Boning, 1989–94

Chief, Branch (Office) of Water Quality

Jack Pickering, 1972–84
David Rickert, 1985–94

Chief, Systems Analysis Group

Ivan James, 1976–84
Bob Hirsch, 1984–87
Dennis Helsel, 1988–90
Deborah Knopman, 1991–92
James Slack, 1993–94

Chief, Office of Radiohydrology

George DeBuchananne, 1971–81
Jack Robertson, 1982–85
George Dinwiddie, 1986–88
Newell Trask, 1989–94

Chief, Office of National Water Summary and Long-Range Planning

David Moody, 1986–94

Office of Atmospheric Deposition Analysis

Jack Pickering, 1985–94

Branch of Water Use Information

Bill Mann, 1979–85
Wayne Solley, 1986–94

Chief, National Water-Quality Assessment Program

Pat Leahy, 1990–94

Branch of Water Institutes Program/Office of External Research

Frank Carlson, 1986–88
John Schefter, 1989–94

Office of Water Data Coordination

Porter Ward, 1979–85
Ed Imhoff, 1986–87
Nancy Lopez, 1988–94

OFFICE OF GROUND WATER

By John S. McLean

The principal theme affecting the activities of the Ground-Water Branch (later, the office of Ground Water) through the 1980's and early 1990's was the growing public awareness of ground water as an important and fragile resource. This increased attention resulted in increases in funding for the USGS for ground-water studies and the "discovery" of ground water by many interest groups and government agencies. It also required the Branch to devote more resources to interagency coordination, multidisciplinary studies, and the documentation and support of ground-water models. During this period the Regional Aquifer-System Analysis (RASA) program was started, reached its maximum level of funding and effort, and was largely completed.

Personnel

In 1979, Gerald Meyer was Chief of a Ground-Water Branch staffed with experienced, nationally recognized experts in ground-water hydrology. These included John Ferris, Leonard Wood, Eugene Patten, Gordon Bennett, Leonard Konikow, and Charles Appel. The Branch staff included:

Meyer, Gerald (–82)
Ferris, John G. (–87)
Wood, Leonard A. (–80)
Patten, Eugene P., Jr. (–90)
Bennett, Gordon D. (–82, 1986)
Konikow, Leonard F. (–80)
Appel, Charles A. (–80)
Brown, Charles E. (1980–82)
Sun, Ren Jen (1981–90)
McDonald, Michael G. (1981–84)
Torak, Lynn J. (1981–86)
Davidson, Edward S. (1982–84)
Laney, Robert L. (1981–92)
Reilly, Thomas E. (1982–91)
Ragone, Stephen E. (1985?)
Fischer, John N. (1986?)
Sprinkle, Craig I. (1985–86)
Franke, O. Lehn (1985)
Knopman, Debra S. (1985)
Pollock, David W. (1987–)
Leahy, Phillip P. (1989–91)
Harbaugh, Arlen W. (1990–)
Alley, William M. (1992–)
Hollett, Kenneth J. (1993–)
Brunett, Jillann O. (1993–)

Although a total of 25 hydrologists were assigned to the Office of Ground Water (OGW) during this 16-year period, the number on the staff beginning with 7 in 1979 increased to a maximum of 11 in 1985. Reductions in the full-time equivalent (FTE) ceiling caused the number to decrease through the late 1980's and early 1990's to a minimum of three (with two additional unfilled vacancies) in 1992, increasing again to seven in 1995. Only Charles Appel was present throughout the entire period. Individuals on rotational assignments filled many positions. These assignments provided valuable training for the incumbents, though they failed to provide the long-term "institutional memory" needed.

Activities

Much of the activity of this group was focused on classic ground-water hydrology, with the addition of intense review and training in the maturing discipline of ground-water modeling.

The emergence of ground-water modeling during the 1970's as one of the most "saleable" activities in the Districts' programs placed increased demands on the Branch to provide the necessary training and oversight. To accomplish this, Michael McDonald and Lynn Torak were added to the staff in 1981 to supplement the efforts of Patten, Bennett, Konikow, and Appel.

Programs

The largest and most important program during this period was the RASA program. Begun in 1978, this study of the most significant aquifers encompassed the source of most of the ground water used in the Nation. The widespread use of ground-water models accentuated the existing uncertainties about the extent and boundaries of aquifer systems. It was becoming obvious that it was not possible to apply modern study techniques to extensive aquifer systems, many of which span several States, within State cooperative programs. This deficiency led Gordon Bennett in 1977 to study the feasibility of a federally funded program using new modeling and geochemical techniques to study the hydrology the Nation's aquifers.

This study led directly to the establishment of the RASA program to evaluate the hydrology of the Nation's most important aquifers, with Gordon Bennett as the program's first Chief. The Chiefs of the RASA program during this period of WRD history were:

Bennett, Gordon (1977–82)
Sun, Ren Jen (1982–90)
Reilly, Tom (1990–91)
Rosenshein, Joe (acting) (1991–92)
Alley, Bill (1992–93)
Grubb, Hayes (1993–)

The RASA program created more than 1,000 reports and provided a comprehensive analysis of 25 principal aquifers in the United States.

The success of the RASA program called attention to the deficiencies in our understanding of other important components of these ground-water systems and laid the groundwork for more intensive studies of hydrologic processes in the subsequent Ground Water Resources Program.

The need to make the results of the RASA program readily available to a larger, nontechnical audience gave rise in 1987 to the Ground Water Atlas of the United States. This document summarized, at a common scale, the most important information available for the major aquifers throughout the 50 States, Puerto Rico, and the U.S. Virgin Islands.

A rising interest in ground water by other agencies during this period caused the OGW to spend more time in liaison with other Federal and State agencies who were getting into the game or greatly expanding their activities. These activities included assisting and funding (in part) the American Society for Testing and Materials (ASTM) in developing standards for drilling, sampling, and testing of wells to assist the U.S. Environmental Protection Agency (USEPA) in directing the evaluation of ground-water remediation. The Office also coordinated with the USEPA in procedures for mapping aquifers and worked closely with the Bureau of Reclamation in the evaluation of the High Plains Recharge Demonstration Program.

The USEPA's wellhead protection program sparked a burst of activity in the District programs to apply hydrologic principles when designating wellhead protection areas. The diversity of approaches (some of doubtful validity) sparked the production of technical memoranda defining acceptable approaches to the problem. The application of David Pollock's recently developed MODPATH flow-line analysis program to the problem helped point up the difficulties inherent in identifying source areas. Studies using MODPATH, such as those by Dan Morrissey, of stream/aquifer interaction showed the inadequacy of oversimplified standard approaches.

Ground-water simulation passed a milestone with the development of Michael McDonald and Arlen Harbaugh's modular ground-water flow model (MODFLOW). This well-documented, open source model was to become the national standard for finite-difference models, against which the results of proprietary models were routinely compared, and which brought national recognition to the USGS as the leader in this field. It also served as the framework for a multitude of embellishments, including more efficient matrix solvers, land-surface subsidence, ground-water evapotranspiration, and statistical postprocessors. The modular model was even used to simulate the movement of air through the unsaturated zone. Much of the activity of the OGW through this period involved documenting, training, and technical support for this model and its associated programs. One associated activity was to develop standards for the documentation and archiving of models, their data sets, and the data used in calibrating the model. The application of Geographic Information System (GIS) data bases to the problems of ground-water modeling resulted in enormous bookkeeping problems and the need for standard methods of archiving not only the model data sets, but all the supporting (often much larger) data sets.

Additional models were rapidly being developed to simulate water movement in the unsaturated zone and solute transport with and without chemical reactions, and these also had to be evaluated and supported by the OGW.

The increasing emphasis on detailed studies of contaminated sites, or their analogs, led to frequent use of borehole geophysics to obtain the necessary level of detail; this, in turn, led in 1993 to F. Peter Haeni being named as the Borehole Geophysics Advisor for the OGW.

The traditional field of aquifer-test analysis saw little change during this period; nevertheless, notable studies included the application of pressure-testing techniques to fine-grained materials and widespread use of slug-test methods at contaminated sites. Inappropriate application of aquifer-test methods resulted in the OGW releasing a memorandum that defined

procedures for aquifer-test review and approval by the Regions. Widespread confusion in the naming of aquifers and aquifer systems became obvious during the attempts to describe regional flow systems in the RASA program. This led to the development of a report outlining standards for the naming of aquifers. The development of standards for general-purpose geologic maps likewise fell to the Office of Ground Water.

The addition to the Division of new employees with more diverse specialties brought about a need for more training in ground-water fundamentals and led to the development of a series of publications based on the introductory ground-water training courses given at the National Training Center in Lakewood, Colo.

Branch of Nuclear Waste Hydrology

By Newell Trask

The period from the end of World War II to the 1970's saw a steady growth in U.S. Geological Survey (USGS) programs connected with the testing of nuclear weapons and the disposal of the several types of hazardous waste generated in their production. From about the mid-1970's onward, there was a growing realization of the importance of finding a safe, permanent disposal method for the radioactive waste generated in both the weapons program and the commercial nuclear power industry.

By 1970, a multidiscipline program including research in the Water Resources and Geologic Divisions and totaling some 10 million dollars was ongoing. Site-specific field work and laboratory studies of a general nature were included. George DeBuchananne headed up the Office of Radiohydrology in WRD Headquarters to oversee much of this work. A key component of the hydrologic work was studies of existing low-level waste-disposal sites to determine criteria for the location of new sites that would be needed as more commercial reactors came online. The low-level waste work was coordinated by Jack Robertson.

The year 1979 also saw the publication of USGS Circular 779, "Geologic disposal of high-level radioactive wastes—Earth science perspectives," by John Bredehoeft, Tony England, David Stewart, Newell Trask, and Isaac Winograd. This Circular discussed important gaps in knowledge and needed research efforts at the national level in order to come to grips with radioactive waste disposal. The Circular was widely cited as the Nation sought to implement an integrated and scientifically defensible policy for nuclear waste.

Work at the Nevada Test Site involving the Geologic and Water Resources Divisions expanded in the late 1970's and early 1980's. In 1982, a letter from the USGS to the U.S. Department of Energy (DOE) proposed that a site at Yucca Mountain on the southwest side of the test site, which had been considered as a place to site a repository below the water table, instead be evaluated for a repository in the thick, unsaturated zone present there. The DOE quickly adopted this strategy.

Also in 1982, the Office of Radiohydrology expanded to become the Office of Hazardous Waste Hydrology. Jack Robertson succeeded to the post of Chief of the Office; Jack Fischer managed the Low-Level Waste Program; and Steve Ragone coordinated research on toxic wastes. The toxic waste program was split off in 1985 and subsequently grew rapidly to become a major effort on the science of toxic waste disposal. The remaining programs in the Office of Radiohydrology were placed in the Branch of Nuclear Waste Hydrology in 1986 with George Dinwiddie as Chief and Pete Stevens as Coordinator of low-level waste research.

In 1987, Congress mandated that the Yucca Mountain site would be the only site studied for disposal of high-level nuclear wastes in the United States. This decision resulted in a rapid rise in funding for the work on the site. Larry Hayes became Chief of the Branch of Yucca Mountain Studies, which was established in Denver at that time. Bill Dudley was the Chief Scientist on the program and provided interdisciplinary overviews that integrated the many earth science studies that were undertaken. The extensive and separately funded work at Yucca Mountain continued to expand into the 1990's.

Newell Trask became Chief of the Branch of Nuclear Waste Hydrology in 1989; emphasis was placed primarily on field studies and laboratory work connected with the disposal of low-level waste, both at commercial sites and as part of the growing efforts to clean up the legacy of nuclear weapons production at DOE sites. The USGS work on the unsaturated zone and its capacity for isolating waste continued at a healthy pace and was key to evaluating a potential low-level site in California.

Department of Defense Environmental Conservation Program

By John D. Powell

The USGS–Department of Defense Environmental Conservation (DODEC) Program carries out scientific and technical studies related to environmental contamination issues of concern to Department of Defense (DOD) agencies. The purpose of the program is to provide scientific and technical data and interpretations needed to characterize hazardous waste sites, provide data to support evaluation of plausible remedial alternatives, and search for new technologies to improve cost effectiveness of DOD efforts. These activities support the DOD Restoration Program, designed to address issues of contamination resulting from activities of the past, and the Environmental Compliance Program, designed to address issues of contamination resulting from current operations.

The DODEC Program has included activities at more than 100 military installations in all 50 States, Puerto Rico, and two foreign countries. Facilities involved include those of the Air Force, Army, Navy, Marine Corps, Air National Guard, Army National Guard, and Defense Logistics Agency. Major issues of concern have been the characterization of local geologic frameworks through which ground water moves, the fate and transport of chlorinated hydrocarbon solvents (trichloroethene, dichloroethene, vinyl chloride) in water and soils, the fate and transport of constituents of fuels (benzene, toluene, xylenes) in water and soils, the fate and transport of trace metals (lead) in water and soils, and the documentation of toxicity to local biota of contaminants present in water and soils.

USGS researchers have been leaders in the development of innovative media-sampling techniques to lower costs of environmental projects and in the development of innovative geophysical techniques to refine documentation of local geologic frameworks. The USGS has also been in the forefront of identifying and documenting the processes affecting natural attenuation and phytoremediation of contaminants in ground water and soil.

A need for coordination among the DOD projects was recognized early on among the Project Chiefs. As a result of this identified need, the first DODEC meeting was convened by John Powell in Richmond, Va., in 1987. Attendees were from Hawaii, Arkansas, Colorado, Oklahoma, and Virginia. Subsequent meetings were held at 3-month intervals in Denver, Colo., and Little Rock, Ark. All projects involved in these meetings were with the Air Force through its contracting agency in San Antonio, Tex.

The successes of these projects demonstrated that the USGS could perform in a timely and competent manner. Many new projects followed throughout the country. The number of projects quickly increased from a few to more than 120. The need for continued coordination grew, and annual formal meetings replaced the informal smaller meetings. In 1989, the first national DODEC meeting was held in New Orleans, La. For the first time Regional Hydrologists participated: Jim Blakey from the Central Region and Jim Cook from Southeastern Region. Two years later annual meetings commenced, first being held in Reston, Va., in 1991, the next three in Las Vegas, Nev., in 1992, 1993, and 1994, and the fourth in Albuquerque, N. Mex., in 1995.

The DODEC Hydrology Program was formally instituted in 1989 when Joe Rosenshein was given the responsibility of coordinating the program. Until that time the USGS District Offices were operating separately and issues of consistency among cost calculations and manpower allocations were arising with the DOD partners. Before Rosenshein's appointment the major projects were coordinating among themselves without help from Headquarters. In 1992, Joe Rosenshein tapped John Powell to coordinate the program, and in 1993 John Powell transferred to Reston. At about that time the program changed its name from "Contamination" to "Conservation" at the request of an Air Force partner who advised that the former term conjured up too negative an image for the DOD.

The focus of projects early on was on areas of contamination and meeting the requirements of the DOD's RI/FS (Remedial Investigation/ Feasibility Study) program designed to mimic the USEPA's Superfund Program. Through the years the focus has evolved to one of scientific study, including research, in support of the DOD's cleanup efforts by private contractors. The other divisions/disciplines participated in larger and larger parts throughout the evolution of the DODEC Hydrology Program to the extent that the program is now the DODEC Program, with no particular emphasis toward exclusively hydrologic work.

OFFICE OF SURFACE WATER

By Charles W. Boning and Ernest F. Hubbard

Overview

The Surface Water Branch (SWB) was renamed the Office of Surface Water (OSW) in 1986. Functions of the SWB as stated in the 1979 WRD Directory and of the OSW as stated in the 1993 WRD Directory were essentially the same and essentially were unchanged from functions identified in Volume VII of the WRD History. Functions as stated in 1993 are these:

Provides Division-wide leadership in the development of techniques for the collection, analysis, and interpretation of surface-water data. Provides policy-level advice to the Chief Hydrologist and technical advice to the Regional Hydrologist and District supervisors on matters pertaining to the quantity of the Nation's water resources. Maintains a system of quality control to assure the technical excellence of field programs and personnel with respect to surface water. Responsible for technology transfer from the research program to the Division's surface-water data and investigation activities throughout the Nation. Participates in the establishment of priorities for surface-water research.

During 1979 to 1994, the Branch of Office was under the leadership of:

Harry Barnes, Jr.	1979–80
Marshall E. Moss	1982–85
Verne R. Schneider	1986–88
Charles W. Boning	1989–94

All these Chiefs had engineering backgrounds and were career employees of the Division. Moss rose to Chief from the District ranks through the Research and Systems Analysis programs; Schneider's early years were principally in the Research Program. Barnes and Boning began their careers in District Offices in data-collection and analysis programs and rose through the ranks of District management to SWB and OSW Chief. During periods of vacancy of the SWB or OSW Chief position, management was capably handled by Jacob Davidian, Donald M. Thomas, Stanley Sauer, and Ernest Hubbard.

During these years, the Lead Secretary position was capably filled by Ruth R. "Eileen" Smith, Deborah M. McLean, and Jane Rose.

Personnel

Personnel assigned to the SWB or OSW during 1979 to 1994, including the individuals identified above, those in all subordinate offices, and temporary employees, were:

Harry H. Barnes, Jr. (1979–80), Henry C. Riggs (1979–93), Donald M. Thomas (1979–82), David J. Lystrom (1979–81), Ernest D. Cobb (1979–94), Philip H. Carrigan, Jr. (1979–80, Edward J. Kennedy (1979–82), Alvin F. Pendleton, Jr. (1979–82), Jacob Davidian (1979–84), Wilbert O. Thomas, Jr. (1979–94), Arthur G. Scott (1979–85), George W. Edelen, Jr. (1979–94), William M. Alley (1979–80), Joan A. Hofmann (1979), Ruth R. Smith (1979–85), Toni L. Clark (1979), Betty J. Labin (1979), Marshall E. Moss (1982–85), Sharon K. Baloch (1980–82), Deborah M. McLean (1980–88), Stanley P. Sauer (1980–82), Alan M. Lumb (1981–94), William H. Kirby (1981–94), Sharon Ricketts (1983–84), Arthur L. Putnam (1984–86, 1991), Verne R. Schneider (1984–88), James O. Shearman (1984–92), Patricia Sweeny (1984–86), Mark Fischer (1984), James F. MacDonald, Jr. (1984), Frederick A. Kilpatrick (1985–93), G. Douglas Glysson (1984–89), Kathleen M. Flynn (1984–94), Nancy W. Owens (1985–89, 1993–94), Harvey E. Jobson (1987–94), Lewis L. DeLong (1987–94), Janice M. Fulford (1987–94), Kirk G. Thibodeaux (1990–94), Billie B. Williams (1987–92), Ernest F. Hubbard (1987–94), Marshall E. Jennings (1984–89), W. Harry Doyle (1984), Shyam N. Parsad (1984), Joy A. Lorens (1984–85), Richard D. Ekey (1984), Victor Parish (1984), Colleen L. Baker (1985–86), Walter T. Griffin (1986–87), Dale M. Johnson (1987–88), Carolyn Tuttle (1987–92), Robert A. Baker (1988), William H. Kaehrle (1988–94), Barbara J. Wheat (1987), Thomas D. Ketchum (1987–90), Darrell E. Earwood (1987), C. Russell Wagner (1987–94), David C. Froelich (1987–89), Jane Rose (1989–94), David F. Beaudry (1989–90), David Thompson (1989–92), Barry Wicktom (1980–90), Mary Carpenter (1990–94), Charles W. Boning (1989–94), Mark N. Landers (1990–94), Annette Ledford (1991–94), Merritt Blalock (1992–93), Robert S. Regan (1992–94), Michelle Y. Goze (1992–94), Shara Krieger (1993–94), Gary T. Ulrich (1993), William R. Gilley (1993), Victoria D. Israel (1993), C. Wayne O'Neal (1994), Broderick E. Davis (1994), Bernadette L.

Ward (1994), Tamara Togans (1993), and James C. Schornick, Jr. (1993–94).

Surface Water Branch/Office of Surface Water Organization

In 1979 the SWB organizationally consisted of a single office. Beginning in 1984, however, the SWB was assigned oversight of the Deterministic Models of Surface Water Systems project located at the Gulf Coast Hydroscience Center (GCHC) in Mississippi. This project terminated in 1988 but was reestablished as a Deterministic Models Unit in 1992. In 1987, the Hydraulics Laboratory Facilities Program was assigned to OSW, in 1988 a Surface Water Technical Standards program was established, and in 1989 a Modeling Flow and Transport project was added. These four programs were still in place at GCHC in 1994.

In 1992, USGS activities in the Federal Interagency Sedimentation Project (FISP) were placed under the direction of the OSW. Accordingly, the St. Anthony Falls, Minn., Hydraulic Laboratory, which operated this project, was assigned to OSW. With termination of support by the Minnesota Corps of Engineers, the project was relocated to the U.S. Army Waterways Experiment Station at Vicksburg, Miss.

Recognizing the need for maintenance and advisory support of the numerous surface-water-related modeling and analytical software programs in use in the WRD, the OSW established a Hydrologic Analysis Support Section in 1991. This Section was still in place in 1994.

Projects and Program Oversight

During 1979 to 1994, the SWB or OSW had primary leadership or Division oversight of numerous projects and programs related to technical studies in Division offices, training, model development, technical standardization, and equipment development.

Technical Program Reviews

The SWB/OSW has conducted technical reviews of surface-water programs in District offices since the 1960's. The objective of these reviews is to ensure that appropriate technical procedures are being followed in the collection and analysis of surface-water data and in the surface-water components of investigative programs. Sediment data have been included in the surface-water reviews since 1985. Each District is subjected to a surface-water technical review every 3 years. Some multidiscipline reviews in the late 1980's and early 1990's were conducted jointly by two or all three of the discipline offices. Typically, the review teams were composed of three or more members, with staff of OSW or a Regional Surface Water Specialist outside the subject District's Region serving as leader of the surface-water review team. Other members of the team were District experts, including those from the technician ranks, and the Regional Surface Water Specialist for the District being reviewed. Results of the reviews were documented and reports provided to the Districts.

Review of Technical Reports

The SWB/OSW reviewed each technical report sent to Headquarters for Director's approval for publication that contained significant interpretation of surface-water physical data. Most of the technical staff took part in these reviews, which could be from 10 to 15 papers a year each. Often the reviewer was able to identify and correct technical errors or otherwise improve a report with only a telephone call to the author. Reviewers with the reputation for making substantial contributions to reports are too numerous to mention but included Henry C. Riggs, Donald M. Thomas, Ernest D. Cobb, Wilbert O. Thomas, William H. Kirby, James O. Shearman, and Harvey E. Jobson.

Training

Training to assist in development of surface-water-related expertise in the Division continued to be a significant responsibility in SWB/OSW during 1979–94. Personnel of the office coordinated an average of about 10 classes per year. They held most classes at the National Training Center in Lakewood, Colo., although a significant number of classes were conducted at District Offices in response to specific need. Most classes targeted Division hydrologists, although a Senior Technician training class was established by OSW in 1992. Courses offered on an annual basis during much of the 1979–94 period included Field and Records Techniques, Surface-Water Principles, Surface-Water Hydraulics – Basic and Advanced,

Surface-Water Statistical Analysis, Surface-Water Hydrologic Analysis, Watershed Modeling, Flow and Transport Modeling, Sediment Data Collection Techniques, and Sediment Records Analysis.

Technical Standards

The OSW participated in development of national standards for hydrologic data collection. C. Russell Wagner was active in the American Society for Testing Materials (ASTM). He was instrumental in developing a number of ASTM-published standards.

The SWB/OSW also developed standards for data collection, processing, and interpretation for internal use within WRD. Many standards were published in Techniques of Water-Resources Investigations Reports (TWRI) or other manuals. Others were issued in numbered Technical Memorandums. The popularity of the TWRI series suggested that many outside the agency either used or considered USGS standards in their hydrologic work.

Flood-Frequency and Low-Flow Studies

SWB/OSW continued to play a major role in coordinating flood-frequency and low-flow studies and promoting the application of uniform techniques within WRD. SWB/OSW provided the leadership in developing and documenting improved methods for regional regression analysis of flood- and low-flow characteristics at ungaged watersheds.

Coordination of Floods

Coordination of major floods has long been a responsibility of SWB/OSW, although direct involvement in field activity has been minimal. During 1979–94, the main activity was allocation of funds to Districts for study and documentation of floods. OSW involvement, however, in the Mississippi River floods of 1993 included coordination and oversight of flow measurements, channel scour evaluations, and documentation of the effects of these floods.

Urban Stormwater Runoff and Management Studies

Urban studies have been conducted by the WRD since the early 1970's, with substantial coordination and technical assistance provided by the SWB/OSW. Beginning in 1978, the SWB provided coordination for the National Urban Studies Programs conducted by District Offices in cooperation with State and local agencies and WRD activities in the National Urban Runoff Program (NURP) sponsored by the U.S. Environmental Protection Agency (USEPA). Initial program coordinator was David Lystrom, in 1978. The objectives of these programs were to collect and analyze stormwater-runoff data to provide needed information for city planning, zoning, and design of stormwater-runoff areas. Information collected included data on rainfall, discharge, chemical quality of runoff and atmospheric fallout, basin and storm characteristics, and environmental management techniques.

By the late 1980's, the USGS had collected data at 98 urban stations in 21 metropolitan areas of the United States. A report by Nancy Driver and David Lystrom published in 1987 provided summary results of these studies. Regional-regression models were developed relating stormwater-runoff and volumes to basin and climatic characteristics. In these analyses, the United States was divided into three regions representing areas with specific ranges of mean annual rainfall. Nine regression models with relevant statistics for chemical oxygen demand and total nitrogen stormwater-runoff loads and stormwater-runoff volumes for each of the three regions were developed.

Cascades Volcanoes Observatory (CVO)

CVO, located in Vancouver, Wash., was placed under the general coordination of OSW in the early 1980's. Principal coordination was provided by Ernest D. Cobb. The OSW's responsibility for CVO included allocating funding and providing quality assurance of the studies under progress at CVO. The OSW also had technical oversight for the volcanic studies conducted by Western Region Research at Long Valley in California. Annual reviews were performed at CVO as well as at Long Valley.

Sediment Action Committee (SAC)

The Sediment Action Committee was established by OSW in 1989 with the following charge: Serve as a consulting group to WRD on sediment issues, review WRD's sedimentation activities and make recommendations to the Chief of OSW, and serve as a focal point for ad hoc groups to work on

special problems and to implement needed actions in WRD. SAC membership included one member from OSW, as well as various District, Research, and Laboratory personnel with expertise in sediment transport, one of which served as committee chairman. The SAC met approximately three times each year until 1992 when frequency was reduced following completion of many of the original specific objectives.

Accomplishments of the SAC: (1) Established WRD policy and publication of guidelines on bedload sampling and data publication, (2) established policy on certification of sediment laboratories in WRD, (3) specified a standard filter for sediment data collection, (4) created a set of reference samples for quality assuring the sediment laboratories, (5) recommended national guidelines for the analysis of sediment data, (6) recommended policy on sample splitters, (7) established policy and provided guidance on bias correction factors for computed sediment loads, (8) tested and approved the use of the Sedigraph, an automated sediment-size analysis tool, (9) specified allowable transit rates for sediment samplers, (10) guided the development of software for processing sediment-data records, (11) published a WRD Bulletin containing only articles on sediment, (12) guided conversion of sediment laboratory software, and (13) developed and coordinated several training courses on sediment-data collection and analysis.

Instrumentation Committee (ICOM)

The ICOM was formed in 1980 to give guidance and provide oversight to the Hydrologic Instrumentation Facility. In 1992, the ICOM was asked to expand its role to oversight of all WRD field instrumentation, equipment development, and support. The committee began this task by preparing a comprehensive instrumentation plan for the Division.

Membership on the ICOM included a District Chief from each Region and representatives from each Discipline Office. The SWB/OSW representative for most of this period was Ernest D. Cobb. After Cobb's retirement in early 1994, Ernest F. Hubbard became the OSW representative on ICOM.

Hydraulic and Hydrologic Modeling

By 1979, hydraulic and hydrologic modeling was well established in the WRD. The SWB/OSW was involved in development and Division support of a variety of such models throughout 1979–94. From 1979 to 1984 this involvement was primarily in such areas as flood-routing programs, floodway analyses, and stormwater-runoff models. In 1984, with transfer of a number of scientists from the Research Program to SWB, modeling responsibilities became more formalized in the office. The Deterministic Modeling activities and Modeling Flow and Transport project at GCHC, included models of constituent transport and dispersion as well as additional watershed, runoff, and routing models. Individuals who transferred from GCHC to the OSW Headquarters office in the 1980's and continued work in model development and in the provision of support to District projects included Harvey Jobson, Lewis DeLong, James O. Shearman, and David C. Froelich. Those who continued with modeling efforts at GCHC or who transferred back to GCHC included David Thompson, Janice Fulford, and Lewis DeLong.

Hydrologic Analysis Support Section (HASS)

The HASS began as an internal working group in 1990 and was established as an individual Section of OSW in 1991. The original objectives of HASS were to document and maintain analytical software and to provide support to Division scientists in the use and application of surface-water-related hydrologic models on computers. These objectives were expanded to include a variety of surface-water, ground-water, geochemical, and water-quality applications widely used by Division scientists. In July 1992, the HASS distributed a tape to the Districts containing 14 surface-water applications and 2 ground-water applications for use on agency computers. In June of 1994 a second tape was distributed; this tape included the original 16 applications and an additional 24 surface-water, ground-water, geochemical, and water-quality applications. Principal activities in the HASS were carried out by Alan Lumb, Chief of the Unit, and Kathleen Flynn, Nancy Owens (1993–94), Merritt Blalock (1991–92), R. Steven Regan (1992–94), and Michele (Goze) Crouse (1992–94). Tamara Togans (1993) and Jim Schornick (1993–94) also worked in the HASS.

The HASS contributed to a number of WRD activities, including establishing guidelines for programming in Fortran and C, the software documentation process action team (DocPat), establishing the Computer Policy Advisory Committee (successor

to the Software Issues Team), and instructing at the Training Center in Denver. During the listed time period, HASS developed hspexp, an expert system for calibration of HSPF. HASS also started the work on GenScn, for the GENeration and analysis of model simulation Scenarios.

Hydraulic Laboratory Facility

The Hydraulic Laboratory, located at the Mississippi facility that was named John C. Stennis Space Center in 1988, was designed by the Survey to test and calibrate instruments used in water-resources investigations and to obtain experimental data used in research. The major facilities at the laboratory were a tow tank and jet tank for the testing and calibration of instruments that measure water velocity, primarily Price and other current meters; a tilting flume for obtaining experimental data on water flow; and an outdoor flood plain for large-scale simulation of flows. Personnel at the laboratory tested instruments developed for or at the Hydrologic Instrumentation Facility. Calibration of standard hydrologic instruments was a service to Survey Field Offices and to other Federal and State agencies.

The SWB had technical input to the Hydraulic Laboratory from its inception in 1972. The SWB's actual management of the laboratory began in 1987, when Gulf Coast Hydroscience Center's direct involvement ended. William J. (Bill) Kaehrle managed the laboratory for SWB/OSW through 1994. Beginning in late 1990, Bill was assisted by Kirk G. Thibodeaux, who had previous laboratory experience as a contractor. Kaehrle and Thibodeaux oversaw research on the hydraulics of highway structures, drop inlets, unsteady flow and dam breaks, bridge constrictions on wide flood plains, temporary ditch liners for erosion control, and rough mountainous streams. They participated in the development and testing of devices for measurement of flow in storm sewers and of polymer rotors for current meters. Projects to evaluate noncontact water-level sensors, many kinds of current meters, modified Columbus sounding weights, and pancake weights used for ice measurements in Canada were conducted. Standard rating tables for Price pygmy meters and Price AA meters with optical heads were developed and approved, as were standard ratings for AA and pygmy meters with polymer rotors.

In 1988 the Meter-Exchange Program began. In this program, OSW technical reviewers visiting a District selected one AA meter and one pygmy meter to be calibrated in the laboratory. The purpose was to learn if meters used in the field were in good condition and if the standard rating tables accurately represented the water velocity.

Cableways

Although the OSW was not responsible for cableway safety, it did assume responsibility for the technical side of cableway design and construction. The weight of equipment taken on cableways was thought to have increased over the years with more routine use of power reels, sediment samplers and bottles, and bedload samplers. Thus, in 1991 C. Russell Wagner published an Open-File Report, "Streamgaging Cableways," which supplanted USGS Circular 17, "Structures for Cableways," written by Charles H. Pierce in 1947. Minor computational errors in the Open-File Report and plans to republish it as a TWRI caused the OSW to form a national committee chaired by Ernest F. Hubbard to complete an engineering analysis of cableway structures. The committee—Ernest D. Cobb from OSW, George C. Gravlee from New York, Paul C. Floyd from Mississippi, J. Curtis Weaver from North Carolina, and Jeffrey C. Vigil from Wyoming—evaluated all phases of cableway design prior to publication of the TWRI by the same name in 1995.

Highway drainage studies were carried out in 10 Districts with coordination provided by Frederick A. Kilpatrick. These studies, funded by the Federal Highway Administration, were to document the extent of water that infiltrates beneath highway pavements and to evaluate different roadway sub-bases and edge drains in alleviating the problems caused by such water.

Bridge Scour

In 1988 the Federal Highway Administration (FHWA) required the State departments of transportation to begin identifying scour-critical bridges in their transportation networks. Many departments of transportation, which had a long history of cooperation with the USGS, asked their local WRD District Offices to help with the evaluation necessary to identify these bridges. In these projects, bridges were evaluated at one of three levels. Level I consisted of a field reconnaissance and a qualitative evaluation based on

observed conditions. Level II involved hydraulic computations to estimate the velocity that might be present at bridge piers and abutments. Level III was the calibration of a numerical model to simulate the effects of scour at a bridge site. The FHWA and State departments of transportation also initiated studies to collect scour data during floods to improve the understanding and prediction of scour processes for bridge foundation design. During the 1990's the USGS participated in bridge-scour investigations in most Districts.

Since 1987 the OSW had been involved in a project with the FHWA to evaluate scour at bridges during floods. Principal investigators included David C. Froelich, William R. Kaehrle, Frederick A. Kilpatrick, and James O. Shearman. Thus, it was natural for the OSW to assume responsibility for technical coordination of the District bridge-scour projects. OSW named Mark N. Landers as National Coordinator of the WRD Bridge Scour Program. When Mark left OSW in 1994 to participate in the WRD Graduate Training Program, David S. Mueller assumed the coordination of bridge-scour projects.

Acoustic Doppler Current Profiler (ADCP)

Beginning about 1990, the OSW collaborated with a private company to test and refine a Broad Band Acoustic Doppler Current Profiler for use in measuring flow in large streams. Because the instrument was capable of measuring velocity at incremental depths, it was well suited to measuring flow in backwater situations or where the depth-velocity profile deviated significantly from the theoretical. Principal coordination of the testing and refinement of this promising instrument was provided by Mark Landers and later by Kevin Oberg and David Mueller, District personnel who reported to OSW on this program. By 1994 ADCP's were in use in more than 15 Districts, and numerous other Districts were recognizing the utility of this instrument.

Interagency Programs and Program Coordination

Federal Interagency Subcommittees

Personnel of the SWB/OSW were actively involved in the Federal Interagency Subcommittee on Hydrology under the auspices of the U.S. Water Resources Council and later the Interagency Advisory Committee on Water Data. Working through the Hydrology Subcommittee and its work groups, SWB/OSW staff, and particularly Will Thomas, were the principal scientists who prepared Bulletins 17, 17A, and 17B, all entitled "Guidelines for Determining Flood Flow Frequency." Bulletin 17B, published in 1982, is still the current guideline for Federal agencies in performing flood-frequency analyses for gaged watersheds in the United States.

SWB staff were also key members of another Hydrology Subcommittee work group on Ungaged Watersheds. Nine methods for estimating flood discharges for ungaged, unregulated watersheds were applied to gaged watersheds, assuming these watersheds to be ungaged. Flood estimates from these nine ungaged methods were then compared to gaging station estimates to define the bias, reproducibility, and time to apply these methods. The USGS regression equations were shown to be more unbiased and reproducible and required less time to apply than commonly used rainfall-runoff models. The Hydrology Subcommittee of the U.S. Water Resources Council published these results in 1981 in a report entitled "Estimating Peak Flow Frequencies for Natural Ungaged Watersheds—A Proposed Nationwide Test."

SWB/OSW involvement in the Federal Interagency Subcommittee on Sedimentation included coordination of sediment-data collection and analysis activities among Federal agencies, the annual publication of sediment activities in the United States, and active involvement and sponsorship of a Sedimentation Conference held every 5 years.

National Oceanographic and Atmospheric Administration (NOAA)

The OSW/SWB was actively involved with NOAA, and principally the National Weather Service, in coordination efforts relative to watershed modeling, flood forecasting, the USGS stream-gaging network, telemetry at gages, and in conduct of training for mutual activities.

World Meteorological Organization (WMO)

The SWB/OSW participated in various activities of WMO, particularly in the provision of manuals

for distribution to underdeveloped countries. The USGS, through SWB/OSW, provided numerous materials including technical manuals concerning network design, hydrologic data collection and analysis, including those related to sediment and precipitation, and analytical tools such as flow-routing models and sediment transport and dispersion. The SWB/OSW was involved in various WMO-sponsored research studies, in training, and in establishing technical standards in WMO participating countries.

Canadian Coordination

The SWB/OSW had several avenues of cooperation with Canadian counterparts during the period, including periodic meetings with the National Research Council Associate Committee on Hydrology, St. John River Basin Hydrology Committee, and Water Resources Branch (which included the Water Survey of Canada). Meetings with the first two organizations were generally annual, with the Chief of SWB/OSW or his representative attending as a representative of WRD Headquarters. During most of the period Derrill J. Cowing, District Chief of the Maine District, was very active in the St. John River Basin Hydrology Committee, coordinating OSW participation.

In 1979, at an Eastern Snow Conference meeting, C. Russell Wagner, Chief of the Hydrologic Instrumentation Facility (HIF), and Richard Terzi of the Water Survey of Canada (WSC) decided that the Survey and WSC should stay in contact on equipment issues. A series of informal contacts and finally a formal meeting ensued in 1987. The formal meetings convened every year or two in Burlington, Ontario; Reston; Stennis Space Center; Ottawa, Ontario; Denver; Lake Louise, Alberta; San Antonio; and Quebec City, Quebec. The OSW, HIF, and other Survey personnel participated in these meetings with counterparts from the WSC.

From July 1984 to August 1985, Wilbert O. (Will) Thomas from OSW worked in Ottawa as Chief of the Hydrology Division, Water Resources Branch of Environment Canada, in what was planned to be an exchange program between the two organizations. Unfortunately, the Canadian slated for a Survey position was unable to accept the assignment, effectively ending the program. Other OSW cooperation with Canada during the period included participation in International Joint Commission meetings and workgroups and technical meetings on the development and testing of equipment used for the measurement of flow under ice.

International Standards Organization (ISO)

The United States became involved in ISO Technical Committee (TC) 113, Measurement of liquid flow in open channels (later Hydrometric Determinations) in the late 1960's or early 1970's. George F. Smoot, followed shortly thereafter by Harry H. Barnes, was the first Survey person to participate in TC 113, although Rolland W. Carter, along with fellow researcher, Professor Carl E. Kindsvater, had been appointed as United States representatives to ISO technical committees as early as 1955. Until about 1980, the American Society of Civil Engineering sponsored United States activity in TC 113. When they discontinued sponsorship, the Survey took on this responsibility under the oversight of the American National Standards Institute (ANSI).

Chairmanship of the U.S. Technical Advisory Group (leader of the U.S. delegation to TC 113) has traditionally been the Chief of the SWB/OSW and included Harry H. Barnes, Marshall E. Moss, Verne R. Schneider, Charles W. Boning, and Ernest F. Hubbard. Ernest D. Cobb was Secretary of the U.S. Technical Advisory Group during much of the period 1979–94.

TC 113 was composed of up to eight subcommittees, each dealing with an aspect of hydrometric measurements. The Secretariats of TC 113 and all of its subcommittees were held by India until 1989, when it was decided that India would retain the Secretariats for only TC 113 and Subcommittees (SC) 1 and 6. In 1990 the Survey petitioned ANSI to request the Secretariat of SC 5, "Flow measuring instruments and equipment," be given to the United States. This transfer was accomplished, and Ernest D. Cobb, who had been Secretary of SC 5 since the early 1980's, also became Chairman of that subcommittee. In 1994 Ernest F. Hubbard assumed Chairmanship of SC 5.

Technical Committee 113 met in Ottawa, Canada, in 1979, The Hague, Netherlands, in 1983; Berne, Switzerland, in 1984; Beijing, China, in 1986; London, United Kingdom, in 1987; Reston in 1989; Paris, France, in 1992; and New Delhi, India, in 1994. From 1979 through 1994 TC 113 published 38 international standards and technical reports on hydrologic

data collection, including tracer methods, discharge measurement by various direct and indirect methods, and measurement of sediment and bedload. Virtually all these standards are practically the same as those in USGS manuals, ensuring that the data and methods of USGS have international acceptance.

Federal Interagency Sedimentation Project (FISP)

The FISP was originally based at the Iowa Institute of Hydraulic Research and later moved to St. Anthony Falls Hydraulic Laboratory, St. Paul, Minn. In 1992 the FISP relocated to the Hydraulics Laboratory at the Corps of Engineers Waterways Experiment Station (WES), Vicksburg, Miss., and was placed under the direction of the OSW.

Research conducted by FISP originally focused on hydraulic and mechanical aspects of sediment sampling but expanded to include development of sample-analysis methods, automatic in-situ analyzers, and sampling techniques and equipment for sampling sediment for water quality in streams and rivers. The equipment and techniques of FISP are used by most Federal, State, and local governments and by private organizations collecting sediment samples in the United States. The World Meteorological Organization has used FISP-developed samplers as controls for comparison with suspended-sediment samplers developed in several foreign countries. In its 50-year-plus history, FISP has produced more than 80 reports and papers.

By 1994, or shortly afterwards, the OSW staff at WES consisted of C. Wayne O'Neal, Chief; Broderick E. Davis; and Bernadette L. Ward. Corps of Engineers staff members were Johnny L. McGregor and Joseph A. Farrar. Their major developmental projects included what were to become the US RBP–95 battery pack; the US WBH–96 weighted bottle sampler; caps and nozzles for the US D–77 sampler; and the integrating samplers US D–95, US DH–95, and US D–96.

Transportation Research Board (TRB)

The SWB/OSW has been cooperating for many years with the Transportation Research Board, assisting in TRB research to develop improved design of highway facilities. Cooperative research projects supported by the TRB include those related to development of flow-routing models, roughness characteristics for heavily vegetated flood plains and for high-gradient streams, scour at bridges, highway drainage, quality of runoff from highways, instrumentation (particularly as related to scour), and channel morphology. The SWB/OSW involvement included participation in publication of research reports, sponsorship of technical conferences, and training for Federal and State highway officials.

Federal Highway Administration

For many years WRD offices across the country have developed regional regression equations for estimating flood discharges for ungaged watersheds, principally in cooperation with the Federal Highway Administration and various State Departments of Transportation (DOT's). In 1993 these regression equations were compiled and documented in USGS Water-Resources Investigations Report (WRIR) 94–4002, "Nationwide Summary of U.S. Geological Survey Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Sites" (1993). A computer program entitled the National Flood Frequency (NFF) program for applying the regional regression equations was provided in USGS WRIR 94–4002. The NFF program is widely used by DOT's in designing bridges and culverts and by Federal Emergency Management Agency consultants in estimating flood discharges for flood-plain management.

OFFICE OF WATER QUALITY

By Herman Feltz, Robert Schoen, Bernard Malo, Robert Middelburg, John Briggs, and Richard Engberg, *with reviews by* Robert Schoen, Bernard Malo, and Richard Engberg

Personnel

At the beginning of this reporting period, the Office of Water Quality (OWQ), known as the Branch of Quality of Water until 1986, was headed by R.J. "Jack" Pickering. Pickering transferred in late 1984 to head the Office of Atmospheric Deposition Analysis. He was succeeded as Chief, OWQ, by David A. Rickert in early 1985.

James Culbertson was the Assistant Branch Chief from the beginning of the period until his retirement in 1982. He was succeeded by Wesley Bradford (Acting) who was succeeded by Robert Schoen in 1985. Schoen held the position until 1990, and was succeeded briefly by Hal Mattraw and then by Timothy Miller in 1991. W. Arthur Beetem was the Central Laboratories Coordinator until his retirement in late 1981. He was succeeded by Herman Feltz in April 1982. Other OWQ professional staff members with long or reasonably long tenure included William Alley, Richard Alexander, John Briggs, William Cogger, Kathleen Fitzgerald, Sarah Gerould, Douglas Glysson, Philip Greeson, Sidney Johnson, Gail Mallard, Bernard Malo, Robert Middelburg, David Morganwalp, Art Ott, Stephen Ragone, James Schornick, Earl Skinner, Richard Smith, William Wilber, Francesca Wilde, Michael Yurewicz, and John Zogorski.

The professional staff was supported by many dedicated and efficient editorial, secretarial, and clerical personnel. Among those with long tenure were Mary Amos, Rebecca Beaver, Janice Biggar, Nana Frye, Barbara Guthrie, Carol Harrison, Sandra Loving, Beverly McCoy, Pat McCusker, Mary McDonald, and Iris Oos.

Major Activities And Programs

District Water Quality Reviews

Each of the three technical discipline offices (Water Quality, Ground Water, and Surface Water) had the responsibility to conduct periodic reviews of activities in the Districts that involved the discipline of the respective office. For OWQ, this meant evaluating the collection and field analysis of water samples at National Stream Quality Accounting Network (NASQAN) sites. It also included examination of the District and Subdistrict laboratory operations, and the review of each project that had a major water-quality component. Project reviews tended to be unique as the water-quality issues in each State often were unique. Reviews often lasted a week but sometimes were longer in large Districts.

Reviews were scheduled to include all Districts every 3 to 4 years. In the late 1980's, it became common to schedule OWQ reviews to coincide with a ground-water or surface-water review if there was a notable number of projects that incorporated two disciplines. This helped the Districts save time in the review process as well as it helped members of the review teams to acquire broader scientific insights. In fact, personnel involved in performing District reviews probably gained as much new knowledge from the reviews as did the project chiefs and the field personnel reviewed.

The Assistant Office Chief made the review assignments. The review teams consisted of one or two members of the OWQ staff, one of whom was designated team leader. The teams usually included a member of another District office and sometimes included representatives from the Central Laboratory system or the National Research Program. The Regional Water Quality Specialist always took part in all reviews. The Assistant Office Chief attempted to match the water-quality skills and interests of the reviewers with ongoing projects in the Districts.

Each review team met with the District Chief and staff at the conclusion of a District review to convey their major findings. A written report containing details of the review including comments by each team member was sent to the District Chief and the Regional Hydrologist in a timely fashion following the review.

Standing Committees

The OWQ maintained several standing committees to study specific water-quality areas and to make recommendations to the Office Chief. Among these were committees on training, radiochemistry, and sediment chemistry.

Training: The Training Committee coordinated the offerings of water-quality-related training courses at the Water Resources Division (WRD) National Training Center in Lakewood, Colo. The committee also provided advice and assistance to regional training activities. The committee chairperson scheduled training courses and arranged for suitable instructors for the courses. Committee chairpersons through the period were Wesley Bradford, Robert Schoen, and John Zogorski.

Radiochemistry: The Radiochemistry Committee coordinated research activities with the Geologic Division (GD). A major publication, "Field Studies of Radon in Rocks, Soils, and Water," (1991) included approximately equal numbers of WRD and GD authors.

Sediment Chemistry: The Sediment Chemistry Committee (also known as Task Group) was formed in the mid-1980's to study the chemicals preferentially sorbed to sediments in water, especially heavy metals and halogenated hydrocarbons like DDT and chlordane. While the physical presence of sediment in water had experienced declining interest from most cooperators, the toxic substances sorbed on and transported by sediment began to engender interest and concern. Bottom-dwelling scavenging organisms ingest these sediment particles, which makes the sorbed materials available to the food web. Commonly used water analyses of filtered samples did not provide a measure of the chemicals associated with the sediments, and new and sometimes controversial techniques to accurately measure these constituents had to be devised. This was the principal reason for the formation of the Sediment Chemistry Task Group.

Sampling Techniques

A major effort during the period was training to ensure that truly representative samples of water, suspended sediment, and bottom material samples were collected for chemical and biological analyses. Although the WRD began using Equal Width Increment (EWI) and Equal Discharge Increment (EDI) sampling before the reporting period with the adoption of NASQAN guidelines in 1972, diligent study and refinement of sampling techniques was continuous during the reporting period. Particular attention was directed to transit rates (the speed with which a sampler was lowered from the surface of a stream to the streambed and returned). Isokinetic samples could be collected to a depth of 17 feet, but equalized pressure chambers were required in a sampler used below that depth. Bottom material normally was collected with impact samplers that enclosed a sample inside a spring-loaded chamber/bucket upon contact with streambeds and lakebeds.

There was no question that the OWQ was a strong leader in acceptable sampling techniques. Jim Culbertson and Herman Feltz of OWQ along with Wayne Webb and Arthur Horowitz were prominent investigators in this work.

Field Equipment

It sometimes seems that the OWQ has studied and made minor changes in sampling equipment forever, but in reality few new samplers have ever hit the water. There are many D–77 brass samplers still in use. However, there are also a large number of epoxy-coated samplers in use. These samplers are made of polyethylene and fitted with replaceable nose cones and nozzles to avoid some of the problems associated with freezing conditions.

The need to supply the Central Laboratories with multiple samples treated with different chemical fixatives or preservatives led to the development and testing of churn or cone splitters that could divide composite water samples into several subsamples. The splitter made it possible to obtain 10 equal subsamples which could, if desired, be split further to any percentage of the main sample. Design, refinement and testing of the churn splitter was successfully completed during the reporting period. It became and continues to be standard WRD equipment.

Leadership in sampler and splitter development was provided by WRD staff members from within and outside the OWQ, including Jim Culbertson, David Lystrom, Robert Middelburg, Steven Larson, Paul Capel, Kathy Fitzgerald, and Doug Glysson, with ideas and assistance from many others.

Field Manual

The first truly comprehensive OWQ Field Manual was prepared during this period and releases of completed parts began in 1991. All field procedures in current usage are fully documented, and updates are easily made by using the looseleaf design of the manual. Francesca Wilde and Iris Oos spent more than 2 years preparing the manual with assistance and contributions from Regional and District Water-Quality Specialists.

Sediment

Identification and quantification of numerous constituents sorbed on sediment, including toxic heavy metals and hydrophobic organic compounds, was a major effort for the OWQ and the Central Laboratories beginning in the early part of the reporting period. As the need for analytical precision and sensitivity increased with the advent of newer and short-lived pesticides, multiple separation techniques of organic compounds coupled with positive identification by use of mass spectrometry became common. Automated inorganic analyzers were updated and additional capabilities were added.

The Office of Surface Water (OSW) had long felt that the analysis of physical characteristics of sediment should properly fall within its purview, and such a transfer was accomplished during the period. A discussion of sampling collection for physical characteristics of sediment can be found in the section concerning the OSW. The OWQ continued to be responsible for the collection and analysis of samples for sediment-sorbed chemical constituents.

Central Laboratories

The Central Laboratory System, a very prominent and complex part of OWQ operations, underwent numerous changes in leadership and direction during this period of WRD history. From the beginning of the period to 1986, the system consisted of laboratories in Denver, Colo., and Atlanta, Ga. The system was headed by a coordinator assigned to the OWQ and each laboratory was headed by a laboratory chief. The chronology of leadership is shown below:

Central Laboratories Coordinator

W.A. Beetem
1979–September 1981
B.A. Malo - Interim Resource Person
October 1981–April 1982
H.R. Feltz
April 1982–May 1986

Chief, Atlanta Laboratory
D.E. Erdmann
1979–Spring 1985
W.J. Shampine (Acting)
Spring 1985–April 1986

Chief, Denver Laboratory
R.L. McAvoy
1979–82
H.E. Taylor (Acting)
1982–83
S.S. Duncan
1983–87

The organizational and technical personnel in the National Water Quality Laboratory are given in the following list.

National Water Quality Laboratory 1994

Office of Chief

Rogerson, Peter F., Chief
Williams, Robert F., Supv Hydr
Fishman, Marvin J., Supv Hydr
Kashuba, A. Thomas, Chemist

Administrative Services

Treseder, Deborah M., Admin Officer

Methods Research and Development Program

Sandstrom, Mark W., Supv Chemist
Burkhardt, Mark R., Chemist
Hoffman, Gerald L., Chemist
Patton, Charles J., Chemist
Furlong, Edward T., Rsrch Chemist
Foreman, William T., Rsrch Chemist
Garbarino, John R., Rsrch Chemist
Leiker, Thomas J., Chemist
Truitt, Earl, Chemist
Gates, Paul M., Chemist
Werner, Stephen L., Chemist
Darnel, Bruce R., Chemist
Roberts, Curtis W., Phy Sci Tech
Vaught, Debbie G., Phy Sci Tech
Kemp, Barbara L., Secretary

Safety Office

Arozarena, Carlos E., Chemist
Galloway, Kathleen L., Chemist
Santillanes, Joseph A., Materials Examiner
Smith, Roger A., Chemist
Nichols, Clarence D., Phy Sci

Laboratory Data Systems

Development Team:
Turner, Sandra R., Comp Syst Anal
Feist, Oliver J., Comp Prog
Lewis, James A., Chemist
Gerlitz, Carol N., Comp Spec
Husband, Richard A., Comp Spec
Price, Ken C., Comp Spec
DeNuzzi, Christine, Comp Asst

Quality Management Group

Driver, Nancy E., Supv Hydr
Pritt, Jeffrey W., Chemist
Watterson, Carol-Ann, Chemist
Raese, Jon W., Tech Editor
Allen, Bruce M., Comp Eng
Reed, Carmen G., Chemist
Pirkey, Kimberly D., Chemist
Terry, Kailin K., Phy Sci Tech
Pilon, James L., Chemist
Bryant, Kathleen M., Phy Sci Tech
Kellogg, Elizabeth K., Phy Sci Tech
Mullin, Ann H., Chemist
Hatcher, Jeanne L., Phy Sci Tech
Cree, Mark, Phy Sci Tech

Contracts/IRP

Walker, Dorothy, Chemist
Brock, Robert D., Chemist

Technical Support Unit

Pratt, Linda K., Supv Chemist

Inorganic Program

Shockey, Merle W., Supv Chemist
Coup, Jeffrey D., Chemist
Bushly, Thomas J., Comp Eng

Metals Unit

Driscoll, Alfred J., Chemist
Brown, Glenda E., Chemist
McLain, Betty J., Chemist
Struzeski, Tedmund M., Chemist
Litwin, Michael S., Phy Sci Tech
Dobbs, James R., Phy Sci Tech
Jones, Sandra R., Phy Sci Tech
Hobbs, Debbie S., Phy Sci Tech
Gupta, Colleen A., Phy Sci Tech

Low Ionic Strength Unit

Vasquez, Juan, Supv Chemist
Milne, Donna L., Chemist
Cast, Mary E., Chemist
White, Angie, Chemist
Harris, Carl M., Phy Sci Tech
Litteral, C. Jeff, Phy Sci Tech
Rustin, Benjamin R., Phy Sci Tech
Bottinelli, Dan A., Phy Sci Tech
McElhinney, Leland L., Phy Sci Tech
Werito, Michael J., Phy Sci Tech

Plasma Unit

Zayhowski, Edward J., Supv Phy Sci Tech
DeGiacomo, Wallace G., Chemist
Hill, Mark R., Phy Sci Tech
Amon, Frederick B., Phy Sci Tech
Austin, Gary M., Phy Sci Tech
Millhollin, Charles C., Phy Sci Tech
Markin, Al R., Phy Sci Tech
Schwab, Eric A., Phy Sci Tech
White, Thomas R., Phy Sci Tech

Automated Wet Methods Unit

Ardourel, Harold D., Supv Chemist
Cottrell, Gary L., Chemist
Niebuhr, Ellen E., Chemist
Klimper, Christopher, Phy Sci Tech
Naughton, Elizabeth K., Phy Sci Tech
Pavelich, Mary P., Phy Sci Tech
Alex, Patricia A., Phy Sci Tech
Losche, Scott A., Phy Sci Tech
Milne, Betty C., Chemist

Automatic Data Processing Unit

Glodt, Stephen R., Supv Comp Spec
Nitta, Wayne, Comp Prog Anal
Bartels, Mary-Frances R., Comp Anal
Crisci, John P., Comp Anal
Moffett, Diane L., Comp Anal
Ford, Hazel L., Lead Comp Oper
Rohr, Joanne G., Data Transcriber

Organic Chemistry Program

Manigold, Douglas B., Supv Hydr
White, William R., Chemist

Organics in Water

Brenton, Ronald W., Chemist
Adamson, Cyrissa G., Chemist

Merten, Leslie M., Chemist
Franz, Richard, Phy Sci Tech
Farrar, Jacqueline V., Phy Sci Tech
Woodworth, Mark T., Phy Sci Tech
Burbank, Terresa L., Phy Sci Tech
Cinotto, Peter J., Phy Sci Tech
McGinley, Myron D., Phy Sci Tech
Stroppel, Max E., Phy Sci Tech
Frahm, Galen W., Phy Sci Tech
Harper, Mars L., Phy Sci Tech
Stewart, Jeffrey T., Phy Sci Tech
Sofia, Anthony M., Phy Sci Aid

Organic Carbon

Kammer, James A., Phy Sci Tech

Organics in Sediment

Connor, Brooke F., Supv Chemist
Iverson, Jana L., Chemist
Murtagh, Lucinda, Chemist
Werner, Marilyn G., Chemist
Wiebe, Frank W., Chemist
Abney, Sonja R., Chemist
Horodyski, Suranne S., Chemist
Thompson, Tamara S., Chemist
Markovchick, Dennis J., Phy Sci Tech
Alexander, Jamie F., Phy Sci Tech
Burt, Larry S., Phy Sci Tech

Semivolatiles

Zaugg, Steven D., Chemist
Anderson, Forrest S., Chemist
Olson, Mary C., Chemist
Oppenheimer, Scott D., Phy Sci Tech

Liquid Chromatography Unit

Johnson, Sharon M., Chemist
Lindley, Chris E. Chemist
Bumgartner, Allan D., Chemist
Soliven, Paul P., Chemist
Coffey, Laura J., Phy Sci Tech

Prep Unit

Deacon, Jeff R., Hyd Tech
Oasheim, Linda M., Chemist
Madsen, James E., Chemist
Aitken, Pam J., Chemist
Trumbo, James F., Phy Sci

FC/Volatiles

Schroeder, Michael P., Chemist
Noriega, Mary C., Chemist
Rose, Donna L., Chemist
Wydoski, Duane S., Chemist
Martin, Robert G., Chemist
Smith, Steven G., Chemist

With the closing of the Atlanta laboratory in April 1986 and the transfer of equipment to the Denver laboratory, the Central Laboratory System was no longer a system and there was no need for a coordinator. The unit was renamed the Branch of Analytical Services. The chronology of leadership of the branch is shown below:

Chief, Branch of Analytical Services

J.L. Seeley
June 1986–Fall 1987
S.S. Duncan (Acting)
Fall 1987–October 1988
R.O. Hawkinson
October 1988–Fall 1991
P.F. Rogerson
Fall 1991–94

Following its creation, the Branch of Analytical Services continued to upgrade its equipment, shorten turnaround times and control costs. A renovation of part of the Denver laboratory allotted a dedicated space for preparation and analysis of toxic samples in a clean air system with 100 percent fresh air makeup. Late in the period, considerable effort was devoted to the design of a new facility to be built on the Denver Federal Center subsequent to the reporting period.

During the entire period, a small WRD laboratory in Ocala, Fla., furnished blind samples for the Quality Assurance/Quality Control programs of the Central Laboratories. The Central Laboratory system also participated in the U.S. Environmental Protection Agency quality-assurance program. The Ocala Laboratory, headed during the entire period by Robert Kirkland, provided bacteriological growth media to all WRD District Offices.

National Water-Quality Assessment

Initial planning and implementation of the National Water-Quality Assessment (NAWQA) Program began in the OWQ in the mid-1980's with the assistance of the Office of Ground Water (OGW). Dave Rickert and Bill Wilber of the OWQ spearheaded this early work. As the assessment grew, it became apparent that it needed to be a separate entity, and NAWQA became an office of its own. The organization, operation, and results of their assessments are presented in detail in another section of this report.

National Stream Quality Accounting Network (NASQAN)

The NASQAN was initiated before the reporting period (in 1973) to address national and regional needs for comprehensive water-quality monitoring that were prompted by the enactment of water-pollution control legislation in the 1960's and 1970's. Stations were located near the outlets of major watersheds to describe spatial variability in water quality and to quantify long-term changes in chemical concentrations and flux. Stations were operated uniformly, and therefore, results obtained could be compared directly because the same methods were used to collect and analyze the samples from all stations in the network.

During the reporting period, the NASQAN program was under the direction of the OWQ. Managers of the program during the period, chronologically, were Art Ott, Jim Schornick, Mike Yurewicz, Tim Miller, and Kathy Fitzgerald. The number of stations reached a peak of 513 in 1980 and remained steady until 1986. In 1986, as part as an extensive review of the program, all Districts were visited by review teams that evaluated each station operated by the District. Based on this review, during the period 1987–92, the number of stations was reduced to 400, and budget cuts resulted in decreased sampling frequency at the remaining stations. Further budget cuts meant that by 1993, fewer than 300 stations were still in operation and by 1994, the program could no longer be operated as originally designed. By the end of the reporting period, the number of stations was 140.

The data generated by the NASQAN program were extensively used by many authors in the late 1980's and early 1990's for the analysis of water-quality trends and the estimation of rates of flux from major watersheds. Data also were used in the investigation of relations of water quality to streamflow, climate, physiography, and geology, to anthropogenic pollution sources such as agricultural fertilizers and livestock wastes, to atmospheric deposition, and to water discharges from sewage-treatment plants. The data also served as baseline information for developing and illustrating many statistical methods for analyzing water-resources data. Richard Smith and Richard Alexander of OWQ along with Robert Hirsch were authors of papers that were based on NASQAN data.

Toxic Substances Hydrology

The early 1980's saw the addition of a new frontier in OWQ activities—the initiation of intense studies of toxic substances in the hydrologic environment. The toxics program was managed in its early days by Stephen Ragone (ground water) and Gail Mallard (surface water). Following the transfer of both Ragone and Mallard in the early 1990's, David Morganwalp took over both aspects of the program.

Outstanding research results from toxics program investigators during the reporting period have been widely distributed and well received by the scientific community in national and international meetings and in the literature. Prominent among the projects have been the movement of nitrates in ground water from sewage disposal along the coast of Cape Cod in Massachusetts; migration and fate of an oil spill in Minnesota; chicken waste and munitions wastes in Maryland; and movement and degradation of creosote wastes in California and Florida. In South Carolina, there has been extensive study of bacterial degradation of toxic substances. The program also provided some financial support for the National Irrigation Water Quality Program during the reporting period.

National Irrigation Water Quality Program

The National Irrigation Water Quality Program (NIWQP) of the Department of the Interior (DOI) began in 1985 in response to concerns about contamination of water, bottom sediment, and biota in National Wildlife Refuges or migratory bird use areas, by trace constituents or pesticides carried to these areas in drainwater from DOI constructed or managed irrigation projects. OWQ participation in NIWQP began in March 1985 when a team of scientists from

the USGS and the Bureau of Reclamation (BOR) were tasked by DOI to develop a plan to sample drainwater from departmental irrigation projects in 17 Western States. Bill Wilber and Herman Feltz represented OWQ at the first meeting along with Richard Engberg of the Nebraska District. In September 1985, the DOI Secretary formed an interbureau Task Group within DOI to develop a management strategy, to suggest a sampling protocol, and to generate a list of possible areas for study. David Rickert, OWQ Chief, was chairperson of the Task Group, and the USGS was designated lead agency. By December 1985, a preliminary Task Group report was presented to Congress, a list of study areas was developed, and the position of Program Manager was established in DOI. Jonathan Deason served in the position from March 1986 to August 1989 and was succeeded by Richard Engberg, then Iowa WRD District Chief, who served in the position the rest of the reporting period.

The NIWQP conducted more than 30 reconnaissance investigations from 1986 to 1992 in 14 Western States. Study teams were composed of a scientist from the USGS-WRD, the U.S. Fish and Wildlife Service, and either the BOR or the Bureau of Indian Affairs, depending on which agency constructed or managed the project area under study. The USGS was lead agency for all studies, and the USGS scientist on each team was team leader. USGS activities were coordinated by OWQ. Bill Wilber was the first coordinator; Wilber was followed by Herman Feltz from late 1986 through the end of the reporting period. Each participating agency had a coordinator, and they served together with the Program Manager as the governing body of NIWQP.

Funding for the program was carved from the budgets of the participating agencies. For the 1986–94 period, the USGS contributed less than 30 percent of the total funding of the NIWQP but received over 40 percent of the funds distributed by the Program Managers to conduct investigations. Investigations in nine of the original reconnaissance study areas turned up problems considered serious enough that detailed process-oriented studies were authorized during 1988–93. Again, the USGS was the lead agency for these studies. Interestingly, in all areas that advanced to detailed studies, selenium was the constituent of greatest concern. Bioaccumulation of selenium occurred, in some cases, to alarming concentrations. Almost invariably, the original sources of the selenium were marine shales that occurred in or near the project areas. Infiltrating irrigation water mobilized the selenium from the soils derived from the shales. Selenium-containing drainwater was delivered by receiving streams to downstream refuges or waterfowl use areas.

Five areas ultimately were advanced to remedial planning. For these planning efforts, the lead agency was BOR, the agency that constructed the project areas. A USGS scientist or manager was a member of each of the five planning teams.

The NIWQP is an outstanding example of a successful interagency program. By the end of the reporting period, over 200 reports had been generated by the program, and USGS scientists were the principal authors of most of them.

NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

By William G. Wilber

The origins of the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program can be traced, in part, to the early 1980's and the persistent questions from Congressman Sidney Yates (D-Illinois) to Dallas Peck and Philip Cohen about the status of the Nation's water quality. During the Appropriation hearings in March 1985, it became clear to Congressman Yates that there was no unified and consistent program for national water-quality assessment being performed by any Federal agency. Accordingly, Yates asked Peck and Cohen for: *"...a memorandum on how you get there and how much money it is going to cost"*.

Following the Appropriations Hearings, Cohen formed an Ad Hoc Committee to develop a set of principles which "could guide the Water Resources Division in designing and operating a national, perennial program of acquiring and interpreting data on surface- and ground-water-quality." This Committee, composed of Jacob Rubin (Chair), James P. Bennett, Robert M. Hirsch, and Samuel N. Luoma, published their report later in 1985, providing the initial vision for a National Perennial Data Acquisition and Analysis Program (NaPDAAP). The principles of the proposed assessment program differed significantly in several respects from those upon which traditional water-quality monitoring networks were based. In addition to traditional national (or regional) statistical measures, the committee envisioned that the program

would (1) attempt to discover and delineate areas, exceeding a specifically defined minimum size, that have severe and persistent water-quality problems, and (2) explain, to the extent possible, the nature of observed problems in terms of known processes and mechanisms. A major operational difference between the proposed program and existing USGS monitoring networks (NASQAN and Benchmark) was to shift the bulk of the analyses and interpretations from the Headquarters to the Districts. The annual budget and personnel requirements for NAWQA were estimated to be about $50 million and about 500 staff at full scale. Because of the size of the proposed request and the concern for where these new resources would originate, the proposed program generated much interest from the Department of the Interior (DOI), Office of Management and Budget (OMB) and others who viewed the budget as a zero-sum game. Other agencies, especially the U.S. Environmental Protection Agency, were equally concerned about the proposal because of the potential implications on their activities as well as those of the States.

Concurrently with the USGS planning efforts, Ann McLaughlin, Under Secretary of the DOI, established the Departmental Working Group on Water Policy to serve as a senior forum for developing the Department's policies on a wide range of water-management issues. One of the issues to be addressed by the Working Group was the plan for the NAWQA Program. The Working Group formed a Task Group (table 1) to examine the legal, conceptual, organizational, and financial basis for a NAWQA Program administered by the DOI through USGS.

Based on its findings, the Task Group identified three major options for consideration by the Departmental Working Group:

Option 1: A 3-to-5-year pilot program based on the USGS proposal that would test and modify as necessary the USGS proposal and would include a formal institutional process to ensure that the water-quality information produced serves water-quality management decision making. It would also make use of existing water-quality data-collection programs.

Option 2: Intensive effort to develop a uniform data base for national assessment by encouraging changes in the data-collection programs conducted by State and other Federal agencies.

Option 3: No action

The Task Group recommended option 1—to support the USGS concept and implement a pilot program with the incorporation of interagency coordination and policy-analysis efforts that would establish the linkage between information and decision making.

Pilot Program 1986–90

In December 1985, $2,378,000 was appropriated for fiscal year 1986 for the USGS to develop detailed plans and take the initial steps in implementing a national water-quality assessment program. The stated goals of the program were to:

Table 1. U.S. Department of the Interior Task Group on National Water-Quality Assessment, 1984–86

Martin L. Smith (Chairman), Office of Policy Analysis	Robert Hirsch, Geological Survey	James Cook, Bureau of Reclamation	Dan Muller, Bureau of Land Management
David Behler, Office of Policy Analysis	Darla Knoblock, Territorial & International Affairs	George Farris, Bureau of Indian Affairs	Frank Osterhoudt, Office of Policy Analysis
Victor Berte, National Park Service	James Kress, Office of Surface Mining Reclamation & Enforcement	Jack Fischer, Geological Survey	Larry Roberts, Bureau of Reclamation
John Blankenship, Fish and Wildlife Service	Michele Leslie, Office of Policy Analysis	William Fitch, Bureau of Mines	Wayne Whitlock, Office of the Solicitor
Barbara Chappell, Geological Survey	Nancy Lopez, Office of the Assistant Secretary for Water & Science	Michalann Harthill, Minerals Management Service	

1. Provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources,
2. Define long-term trends (or lack of trends) in water quality, and
3. Identify, describe, and explain, as possible, the major factors that affect observed water-quality conditions and trends.

Information from the program, obtained on a continuing basis, was to be made available to water managers, policy makers, and the public to provide an improved scientific basis for evaluating the effectiveness of water-quality management programs and for predicting the likely effects of contemplated changes in land- and water-management practices.

Seven pilot projects, representing a diversity of hydrologic environments and water-quality conditions, were selected to test and further develop the assessment concepts; four projects focused primarily on surface water, and three projects focused primarily on ground water. "Concepts for the National Water-Quality Assessment Program" (USGS Circular 1021) was published in 1988 to serve as a forum for sharing and soliciting ideas on USGS concepts and approaches to water-quality assessment. The seven project teams and regional specialists for the pilot NAWQA Program contributed immeasurably to the concepts of the Program through the exchange of ideas on the feasibility of various aspects of the design and through their implementation of the concepts in the pilot projects. The Pilot Project Chiefs were Stephen F. Blanchard, Upper Illinois River Basin in Illinois, Indiana, and Wisconsin; Scott C. Christenson, Central Oklahoma aquifer in Oklahoma; Stuart W. McKenzie, Yakima River Basin in Washington; Robert J. Shedlock, Delmarva Peninsula in Delaware, Maryland, and Virginia; James L. Smoot and Kevin D. White, the Kentucky River Basin in Kentucky; John K. Stamer, the lower Kansas River Basin in Kansas and Nebraska; and Alan H. Welch, Carson Basin in Nevada and California. The Regional Specialists were Robert C. Bubeck, Donald A. Goolsby, John S. McLean, W. David Nichols, Gary L. Pederson, Lindsay A. Swain, and Wayne E. Webb. Coordination of the ground-water and surface-water pilot projects was done within the Office of Water Quality by William A. Alley and William G. Wilber, respectively.

An internal Technical Advisory Committee for the Pilot Program was established to review the pilot project concepts and plans for full-scale implementation. This committee consisted of John D. Bredehoeft, John N. Fischer, Irwin H. Kantrowitz, P. Patrick Leahy, Samuel N. Luoma, David A. Rickert, Jacob Rubin, and Verne Schneider. Timothy A. Cohn, Kenneth J. Lanfear, Eugene P. Patten, and Kenneth L. Wahl assisted in the development and implementation of a process to select a preliminary set of study units for a full-scale program.

During the first 2 years of the pilot program, numerous discussions were held on the role of biology in NAWQA. Formal discussions occurred through the Office of Water Quality's Task Group on Biology and Microbiology; through a workshop chaired by Betty H. Olson, held under the auspices of the Water Science and Technology Board's Committee on Water Resources Research; through presentations at professional meetings of the North American Benthological Society and American Water Resources Association; and through discussions and meetings between the USGS and representatives from the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, Environment Canada, and key universities. The following USGS scientists played a major role in helping to define and shape the role of Biology in NAWQA during the pilot program: Robert C. Averett, J.K. Crawford, Thomas F. Cuffney, John Elder, Martin E. Gurtz, Samuel Luoma, Gail Mallard, M.R. Meador, Diane McKnight, Stephen D. Porter, and Keith Slack.

A local liaison committee was established for each pilot project consisting of representatives from Federal, State, and local agencies and private organizations involved in water and land management within the area of the project. The charge to each liaison committee was to assist the USGS by ensuring that the scientific information collected by the pilot project was relevant to local and regional interests.

Appropriations for the pilot program through 1990 were:

1986	$2,378, 000
1987	$7,139,000
1988	$7,215,000
1989	$7,135,000
1990	$6,962,000

To advise the USGS on the overall pilot project program, a National Coordinating Work Group was established with members representing various Federal agencies and non-Federal organizations having an involvement or interest in water-quality information (table 2).

Table 2. Members, USGS-NAWQA National Coordinating Work Group

Lee Barclay, U.S. Fish and Wildlife Service	Dick Hofman, Interstate Conference on Water Policy	Carl Meyers, U.S. Environmental Protection Agency
Carroll Curtis, Council of Environmental Quality	U. Gale Hutton, Nebraska Division of Water Quality	Robert B. Raschke, National Association of Conservation Districts
Norbert Dee, U.S. Environmental Protection Agency	Leon Hyatt, Bureau of Reclamation	Gray R. Reynolds, U.S. Forest Service
Lewis Dodgion, Nevada Department of Conservation and Natural Resources	Carol Jolly, Washington Department of Ecology	Andrew Robertson, National Oceanic and Atmospheric Administration
Judith A. Duncan, Oklahoma State Department of Health	Gyula Kovach, Kansas Department of Health and Environment	Kenneth D. Schmidt, American Water Resources Association
Earl E. Eiker, U.S. Army Corps of Engineers	James N. Krider, Soil Conservation Service	Russ Susag, Chemical Manufacturers Association
Donald C. Haney, Kentucky Geological Survey	Richard Lanyon, Metropolitan Water Reclamation District of Greater Chicago	Hugo F. Thomas, Association of American State Geologists
Ronald Hoffer, U.S. Environmental Protection Agency	Frederick D. Leutner, U.S. Environmental Protection Agency	Peter Tinsley, Maryland Department of the Environment

As part of a colloquium series focused on Emerging Issues in Water Science and Technology, the National Research Council (NRC) Water Science and Technology Board hosted a meeting of about 50 individuals in Reston, Va., to discuss the need for a national water-quality monitoring and assessment program and the major concerns should such a program be developed and implemented. Seven individuals representing a broad diversity of viewpoints were selected to make presentations. William C. Ackermann, University of Illinois at Urbana-Champaign, presented the keynote address. Presentations followed by Gerald T. Orlob, University of California-Davis, and Keros Cartwright, Illinois State Geological Survey, who discussed selected technical considerations in data collection and interpretation involving, respectively, surface water and ground water. In addition, several presentations covered the development of a national water-quality monitoring and assessment program from the perspectives of the USGS (Jacob Rubin), the U.S. Environmental Protection Agency (Lawrence J. Jensen), State government (Victoria J. Tschinkel), and industry (K.C. Bishop). Each of the colloquium attendees was then assigned to one of four separate workshop sessions focused on surface water, ground water, monitoring implications, and setting priorities under budget constraints. The findings of these workshops were summarized and presented by G. Richard Marzolf, Mary P. Anderson, Walter R. Lynn, and Gary Weatherford. The presentations and findings from the colloquium were published by the Water Science and Technology Board later that year. Although they were far from unanimous, the participants at the colloquium concluded that: *"a national water quality monitoring and assessment program, in some form and at some level of effort, is warranted in order to improve comprehensiveness and reliability of information for decisionmaking."*

In 1987, the Water Science and Technology Board was requested to undertake a 2-year evaluation of the NAWQA Pilot Program. The NRC responded to this request in 1988 by appointing the Committee to Review the USGS National Water-Quality Assessment Pilot Program (table 3). The Committee's task was to consider the program's usefulness to State, local, and private entities for making decisions affecting water resources and its usefulness in advancing the scientific understanding of water quality. The evaluation also considered current expenditures for gathering water-quality information by existing programs as well as through NAWQA. The Committee reviewed the extent to which water quality information programs such as NAWQA can be expected to (1) provide a more comprehensive water-quality assessment than existing or alternative programs and (2) support more effective and efficient management of our Nation's water resources.

Prior to the scheduled completion of the pilot projects and the Committee's final report in 1990, the administration was preparing a proposal to the Congress for a water-quality initiative in FY 1991—mostly focused on agricultural nonpoint-source water-quality concerns. As part of this initiative, the OMB was willing to include implementation of the NAWQA

Table 3. Members of the National Research Council Committee to Review the USGS National Water-Quality Assessment Pilot Program (1988–90)

Richard S. Engelbrecht, University of Illinois at Urbana-Champaign, *Chairman*	Robert C. Cooper, University of California, Berkeley	Susan Stafford, Oregon State University, Corvallis, Oregon
Keith C. Bishop, III, Chevron U.S.A., San Francisco, California	David L. Freyberg, Stanford University, California	James Heaney, University of Florida, Gainesville, *Ex-Officio*
Sandra L. Blackstone, University of Denver College of Law, Colorado	James Geraghty, Geraghty & Miller, Inc.	Kenneth Potter, University of Wisconsin-Madison, Ex-Officio
Michael E. Campana, University of Mexico, Albuquerque	Judy L. Meyer, University of Georgia, Athens	Sheila D. David, *Senior Staff Officer, National Research Council Staff*
Margaret Conditt, Procter and Gamble, Cincinnati, Ohio	Donald J. O'Connor, HydroQual, Inc. Mahwah, New Jersey	

Program, provided that it received favorable review from the NRC Committee. Graciously, the NRC Committee agreed to provide an interim report of their findings in September 1989. The interim report concluded that:

". . . a national-scale, long-term water quality assessment is in the best interest of the country. Additionally, we believe that the USGS is well qualified to implement the proposed NAWQA Program because it is a nonregulatory agency and because of its ability to undertake the long-term commitment necessary for such a program to be successful. . . "

The findings of the Committee were published their final report in 1990. The deliberations and discussion with the Committee during the pilot program were extremely helpful to the USGS. Among the many substantive contributions from the Committee were the suggestions to (1) conduct integrated investigations of both surface and ground water in each study unit, (2) use modeling to provide a more quantitative analytical framework for conducting the assessments, and (3) acknowledge the need for issue-based national synthesis.

Two publications from the pilot program— "Are fertilizers and pesticides in the ground water? A case study of the Delmarva Peninsula, Delaware, Maryland, and Virginia" by Pixie Hamilton and Robert Shedlock and "Persistence of the pesticide DDT in the Yakima River Basin, Washington" by Joseph F. Rinella, Pixie A. Hamilton, and Stuart W. McKenzie—deserve special recognition because of their excellence and because they served as models for future publications focused on communicating scientific information on issues of regional and national concern to the general public. Joan M. Rubin was responsible for graphic design and layout for these publications.

Implementation of a Full-Scale NAWQA Program (1991–95)

In fiscal year 1991, the Congress appropriated funds for the USGS to begin full implementation of the NAWQA Program. Management and coordination of the program occurred through the NAWQA Leadership Team which consisted of P. Patrick Leahy, Chief, of the NAWQA Program; William G. Wilber, National Synthesis Coordinator; Jeffrey T. Armbruster, Assistant Regional Hydrologist for NAWQA (ARH/N) Southeastern Region; Mark A. Ayers, ARH/N, Northeastern Region, Barbara J. Ryan, ARH/N Central Region; and Marc A. Sylvester, ARH/N Western Region. In 1994, Ivan C. James and Michael C. Yurewicz replaced Ryan and Ayers, respectively. In 1995, Leahy was selected as Chief Geologist. Timothy L. Miller was selected as Chief of the NAWQA Program.

Appropriations during this timeframe were as follows:

1987	$18,219,000
1988	$28,463,000
1989	$38,260,000
1990	$51,822,000
1991	$58,071,000

Sixty study units (major river basins and aquifers) distributed across the United States were selected for the program. In aggregate, these study units encompassed about 60–70 percent of the Nation's water use and population served by public supplies and represented settings that differ widely in the natural and human factors that affect water quality. One-third of the study units were to be studied intensively at any one time. The first group of study units along with the Project Chiefs of these studies are listed in table 4.

Table 4. National Water-Quality Assessment Program study units started in 1991, and Project Chiefs

Apalachicola–Chattahoochee–Flint River Basins, David J. Wangsness	Potomac River Basin, James M. Gerhart and Joel D. Blomquist
Albemarle-Pamlico Drainages, Timothy B. Spruill	Red River of the North Basin, Jeffrey D. Stoner
Central Columbia Plateau, Alex K. Williamson	Rio Grande Valley, Sherman R. Ellis
Central Nebraska Basin, Thomas L. Huntzinger	San Joaquin-Tulare River Basins, Neil M. Dubrovsky
Connecticut, Housatonic, and Thames River Basins, Stephen P. Garabedian	South Platte River Basin, Kevin F. Dennehy
Georgia-Florida Coastal Plain Drainages, Edward T. Oaksford	Trinity River Basin, Larry F. Land
Hudson River Basin, Patrick J. Phillips	Upper Snake River Basin, Walton H. Low
Lower Susquehanna River Basin, Kevin J. Breen	White River Basin, Charles G. Crawford
Nevada Basin and Range, Hugh E. Bevans	Willamette River Basin, Dennis A. Wentz
Ozark Plateaus, David A. Freiwald	Western Lake Michigan Drainages, Charles A. Peters

Table 5. National Water-Quality Assessment Program study units started in 1994 and Project Chiefs

Allegheny-Monongahela River Basins, Steven D. McAuley	Puget Sound Drainages, James C. Ebbert
Central Arizona Basins, Gail E. Cordy	Sacramento River Basin, Joseph L. Domagalski
Eastern Iowa Basins, Stephen J. Kalkhoff	Santee River Basin and Coastal Drainages, Brian W. Hughes
Kanawha-New River Basin, James H. Eychaner	South Central Texas, Marshall Jennings
Lake Erie-Lake St. Clair Drainages, Donna N. Meyers	Southern Florida Drainages, Benjamin F. McPherson
Long Island-New Jersey Coastal Drainages, Mark A. Ayers	Upper Colorado River Basin, Nancy E. Driver
Lower Illinois River Basin, George E. Groschen	Upper Mississippi River Basin, James R. Stark
Mississippi Embayment, Barbara A. Kleiss	Upper Tennessee River Basin, Paul S. Hampson

The first cycle of assessment for each group of study units was focused on characterization of the broad-scale geographic and seasonal distribution of water-quality conditions in relation to major point and nonpoint sources and natural and background conditions. A key objective was to fill gaps in existing data for each study unit. To the extent possible, design features, such as chemical constituents measured, media sampled, and spatial and temporal resolutions were consistent among the study units. This "occurrence and distribution" assessment was the largest and most important component of the first 3-year intensive study phase in each study unit and served as the basis for the design of assessments of long-term trends and changes and of more detailed case studies of specific water-quality issues.

The first cycle of assessment for each group of study units consisted of 2 years of initial planning and retrospective analysis of existing data, 3 years of intensive data collection and analysis, and 6 years of report preparation and low-level assessment activity before the second cycle of intensive data collection and analysis would begin. The first complete cycle of intensive investigations of all study units was scheduled for completion by 2002. "Design of the National Water-Quality Assessment Program: Occurrence and distribution of water-quality conditions" by Robert J. Gilliom, William M. Alley, and Martin E. Gurtz described the goals, environmental framework, and major design components of the program to be implemented.

In addition to the study unit investigations, two National Synthesis Projects were started in 1991 focused on Pesticides and Nutrients. The National Synthesis teams provided technical support to the study units on key assessment design and protocol issues. In addition, they were responsible for interpreting the results from multiple study units as well as information from other studies to produce regional and national assessments for priority water-quality issues. The Pesticides and Nutrient National Synthesis Teams were led by Robert J. Gilliom and Dennis R. Helsel, respectively. In 1994, the National Synthesis Component of the Program was expanded to include a team of scientists focused on Volatile Organic Contaminants. This team was led by John S. Zogorski.

In addition to the National Synthesis teams, technical support for the NAWQA Program was provided by key Region and Headquarters staffs. Each Regional Office was staffed with two biologists—one from the Water Resources Division and one from the newly formed National Biological Survey (NBS). WRD and NBS Regional Biologists were Stephen K. Sorenson and Stephen B. Smith, Northeastern Region; Cliff R. Hupp and Wade L. Bryant, Southeastern Region; Stephen D. Porter and Lawrence R. Deweese, Central Region; and Terry M. Short and Steven L. Goodbred, Western Region. Thomas A. Muir was the Headquarters coordinator for NBS. The North Carolina Ecology Group consisted of Martin E. Gurtz, Thomas F. Cuffney, and Michael R. Meador. Groundwater technical support was provided by O. Lehn Franke, Michael T. Koterba, and Wayne W. Lapham.

BRANCH OF SYSTEMS ANALYSIS

By Robert M. Hirsch

This was a highly productive period for the Systems Analysis Group (later called the Branch of Systems Analysis) within Headquarters of WRD. The group was situated within Research and Technical Coordination (R&TC) and later within Program Coordination and Technical Support (PC&TS). The mission included development of methods of data analysis, publishing those methods and training District staff in the use of those methods, research and special projects in support of the major programs of the WRD including analysis of the data collected and developing plans for new programs, conducting applied research in hydrology and economics, and serving as a center of excellence for the USGS in statistical hydrology.

Water Quality Analysis Methods and Networks:

A dominant theme of Branch work during this period was the design of water-quality networks and the uses of the data from these networks. NASQAN had been initiated in 1972, and by the late 1970's considerable data had been collected. It was apparent within the USGS and outside that, although a major goal of the network was to detect trends, there was no agreement on how to proceed with meaningful and statistically powerful trend analysis. The Systems Analysis group took on this task by exploring the common features of the data: they were often highly skewed, strongly related to streamflow, showed seasonal cycles, and sometimes included "censored" values (reported as less than the limit of detection). Within the group, Robert Hirsch, Dick Smith, and Jim Slack developed a set of techniques for dealing with these conditions. The key ingredients of the techniques were the use of flow adjustment and a robust statistical procedure invented by the group and called "the seasonal Kendall test." These ideas, and some national analyses, were published in a series of papers starting in 1982 (by Hirsch, Smith, and Slack) and culminating with a review paper in 1991 (by Hirsch, Alexander, and Smith).

Related techniques were developed and applied to a variety of data sets by others in the group. Harry Lins, Dick Smith, and Rich Alexander applied them to stream sulfate data from the Hydrologic Benchmark Network and made contributions to the study of the acid rain problem. Smith and Alexander, in an article in the journal *Nature*, and as coauthors of a National Research Council Report on long-term trends in acid rain, were the first to show that headwater stream sulfate (like industrial sulfur emissions) had been declining in the Northeast since the early 1970's while increasing elsewhere. Similarly, Hirsch, working with Terry Schertz of the Texas District, took the first look at the National Trends Network atmospheric deposition data, developing and applying statistical techniques appropriate to exploring trends in these data. Robert Gilliom, Rich Alexander, and Dick Smith applied related techniques to analysis of the first national data set of pesticides in streams. These data were particularly difficult to work with, and these studies led to important guidance as to what would be needed in the future to run a meaningful pesticides network.

All of this work on trends culminated in some important papers on the state of knowledge of trends in surface-water quality. These included papers by Smith and M. Gordon Wolman (of Johns Hopkins University) in *Science* magazine, and a paper by Smith and Debra Knopman in *Environment* magazine. Also, a chapter of the 1990–91 National Water Summary by Smith, Alexander, and Kenneth Lanfear presented the most comprehensive study of national water-quality conditions and trends up to that time.

Another major goal of USGS water-quality networks was the estimation of load or transport of various constituents. In general, such data consisted of

perhaps a dozen instantaneous samples per year (for several years) and a continuous record of discharge. A method was needed that exploited the relation between flow and concentration, the regular seasonal variations in this relation, long-term trend (if it existed), and the vast amount of flow information available. Particularly important was the need to develop estimates that were unbiased. This was not a simple matter because of the use of log-log regressions. The problem was tackled by a team of Tim Cohn, Ed Gilroy, and Hirsch. They also added an important result that quantified the error of these estimates. Cohn collaborated closely for several years with the Maryland District on the application of these methods to the nutrient issues of Chesapeake Bay. Like the trend-analysis techniques mentioned above, these methods have now become widely accepted inside and outside the USGS.

The problem of "less than" values is a particularly vexing problem in the analysis of water-quality data. The problem includes the difficulty of estimating mean values, standard deviations, trends, and loads. A team of Gilliom, Dennis Helsel, and Cohn developed some robust methods for dealing with censored data. This culminated in a paper by Helsel that was featured as a "cover story" in 1990 in the journal *Environmental Science and Technology.* The paper was entitled "Less than obvious: Statistical treatment of data below the detection limit."

These approaches to describing water quality at individual stations, while important, begged the question: what was the condition of water quality throughout the entire network of streams of a river basin, State, or Nation. It was this question that was addressed by the team of Dick Smith, Rich Alexander, and Greg Schwarz in their development of the SPARROW model (Spatially Referenced Regressions on Watershed Attributes). The first applications of this technique came in 1993 and continue to be a very active direction of water-quality studies in the next decade.

Statistical Methods Related to Other Topics:

Hirsch continued a line of research begun in a local drought in 1977 to find ways to estimate risks of water-supply shortages. These stochastic techniques involving simulation of streamflow, reservoir storage, and water delivery to users can provide water-system managers with up-to-date estimates of the probability that they will fail to deliver water to their customers over some finite time horizon (typically several months). These techniques, called "Position Analysis," have been applied to a number of systems including the Potomac and Delaware River Basins. A related issue in water-supply analysis is the need to "extend" hydrologic records. Traditional methods of estimating flow at a stream gage with a short record, based on flows from a nearby stream gage with a much longer record, is that the estimates will have too little variability and hence understate the chances of shortage. Hirsch developed a method, closely related to regression, called Maintenance of Variance Extension (MOVE), which is in common use by hydrologists within and outside the USGS.

Hirsch and Cohn (together with Professor Jery Stedinger of Cornell University, who spent a sabbatical year with the group in 1982–83), worked on methods for estimating flood frequency in light of historical or paleo data. The issue is how best to use information about the very large floods from years before the start of the stream-gage record along with the stream-gage records themselves.

Helsel worked with District Staffs conducting the first regional assessments of ground-water quality under the Toxic Substances Hydrology Program. Methods were implemented for both the design of representative regional networks and the analysis of subsequent data. These studies later became prototypes for regional ground-water quality studies within the NAWQA Program.

Finally, John Schefter and Greg Schwarz at various times carried out econometric research on water use, water-use forecasting, and demand estimation. They wrote several papers on the science and economics of water use and provided training and guidance to the USGS Water Use Information Program.

A culmination of much of these efforts on statistical methods was the development of a USGS training course called "Statistical Methods for Environmental Data Analysis." It started as a series of informal workshops and then was formally initiated as a National Training Center course in 1986 taught by Hirsch and Helsel. This course has been the single most widely attended course in the history of the Training Center. Through 2001 it has been taught 38 times to a total of 730 students. Instructors have included most of the members of the Systems Analysis group from this era. Course coordinators have been Helsel, Gilroy, and Alexander. The course begins with a correspondence

course to make sure all students are up to speed on basic statistical techniques.Then, during the week of classroom work, the emphasis is on how to determine which of the many available statistical methods is most appropriate for the hydrologic data set at hand. This is done through extensive use of sample problems with real USGS data sets. The course text and problem sets were published by Elsevier Publishers as "Statistical Methods in Water Resources" by Helsel and Hirsch in 1992. These techniques are also presented in a chapter on "Statistical treatment of hydrologic data" by Hirsch, Helsel, Cohn, and Gilroy in the "Handbook of Hydrology" published in 1992.

National Water Summary and the Genesis of the NAWQA Program:

In the years leading up to 1983 the Systems Analysis group had done extensive work on the plans for a potential National Water Resources Assessment (a function previously carried out by the Water Resources Council). In 1983, Secretary of the Interior James Watt, in conjunction with abolishing the WRC, asked the USGS to prepare a scientific summary of national water conditions. This volume was prepared rapidly, with a team of three lead authors and various supporting editors. The authors, assigned full time for about 2 months were Hirsch and Gordon Bennett (Assistant Chief Hydrologist for R&TC) and Robert Averett (Regional Research Hydrologist in Denver). Hirsch's primary responsibility was to prepare the section of the report on water availability in terms of surface water. This was closely coupled with Bennett's work on ground water. The report was produced rapidly, and its products are still in use.

During the review of National Water Summary, Jacob Rubin (NRP, Menlo Park) noted that while the water-quantity information in the report had a sound structure and was able to convey a good general picture of the national situation (thanks to the long-standing existence of the stream-gaging program and the recent efforts of the RASA program) the same could not be said for water quality. Although there was interesting and important information presented, there was no coherent national picture that could be conveyed. This convinced Rubin that the USGS needed to address itself to creating some kind of perennial program of water-quality assessment. He persuaded Philip Cohen of this, and a committee was asked to lay out a conceptual design. Rubin chaired the committee. Hirsch (along with Bennett and Sam Luoma) was on the committee. After the completion of the committee work, Hirsch continued to carry the major responsibility in Headquarters for defining the program and explaining it to officials within the USGS, Department of the Interior, USEPA, OMB, the National Academy of Sciences, and then the Congress. Hirsch moved on to serve as Staff Assistant to the Assistant Secretary of the Interior James W. Ziglar in 1987 but carried this responsibility with him. The Systems Analysis group continued to be very involved in the NAWQA Program in subsequent years, including reports by Knopman and many other special assignments of staff. William Alley left the Systems Analysis group to accept the assignment as ground-water coordinator of the pilot NAWQA Program.

Hydrology and Climate:

Harry Lins came from the USGS geography program in 1982 and brought a focus on climate issues to the Systems Analysis group, and indeed to all of WRD. Lins authored a section on "Hydrologic conditions and water-related events" that appeared in four successive issues of the National Water Summary. This was an important chronicle of the major droughts and floods of each year that related them to the synoptic weather patterns of the Nation. Lins authored several reports that examined the spatial and temporal patterns of streamflow in the Nation and their connection to atmospheric circulation. He was a leader in applying principal components analysis to these large data sets and went on to teach these techniques in an advanced WRD multivariate statistics course. In the early 1980's Alley did research on the subject of drought indices and their relation to ground water. His work showed that drought indices, which have been designed for agricultural applications, are of rather limited use in understanding the variations in hydrologic conditions.

Hydrologic researchers need a carefully chosen set of hydrologic records for doing long-term national analyses of streamflow conditions (trends and correlations with atmospheric variables). To this end, Jim Slack, working with Jurate Landwehr (NRP, Reston), assembled the Hydroclimatic Data Network (HCDN), a set of streamflow records from stream gages that are not significantly affected by regulation or diversion. This data set was first published on CD–ROM in 1992. It has been updated since then and has formed the

basis of important research within and outside the USGS.

In 1988, the midcontinent region was in the grip of a major drought and heat wave. Lins was called on to explain the situation to the political leadership at the Department of the Interior and relate it to the "greenhouse effect." He went on to work with Marshall Moss to describe a conceptual plan for USGS research that related hydrology to climate variability and change. This formed the basis of the USGS Global Change Hydrology Program, and Lins became the first coordinator of that program in 1989.

Ground-Water Issues:

Among the three major technical areas of WRD work, ground water is the one that received the least attention by the Systems Analysis group, but there was some work of note. Debra Knopman, working with Cliff Voss in the NRP in Reston, developed and applied new techniques for the design of optimal sampling strategies in contaminated ground-water systems. They were able to show that sampling methods that utilize some level of knowledge about the underlying physical system can be vastly more cost effective and informative than systematic sampling techniques alone. Their methods have been applied by the Swedish nuclear waste repository program and elsewhere. Knopman also worked with the Regional Aquifer-System Analysis (RASA) program to apply common statistical analyses to well data and thus infer some general associations between well yields and hydrogeologic formations in central and eastern Pennsylvania. This statistical work led to the recognition of the need for the Office of Ground Water to establish a full-time position of Data Coordinator to gain control of the Survey's vast data holdings produced from the 10-year-long RASA program. Also, Alley and Schefter published an economic perspective on individual farmers' pumping decisions for the High Plains Aquifer, exploring the extent that individual decisions affect neighboring farms and in what timeframes.

Systems Analysis Group Members: Where did they end up?

The members of the Systems Analysis group have collectively and individually had considerable effect on the WRD and on water science in the Nation. This list provides some indication of the types of positions that they have held (through 2001).

Robert Hirsch: Chief Systems Analysis Group (1980–87); Staff Assistant to the Assistant Secretary of the Interior; Assistant Chief Hydrologist for Research and External Coordination; Acting Director USGS; Chief Hydrologist.

Harry Lins: Coordinator Global Change Hydrology Program; Coordinator Watershed Modeling Program; USGS Drought Science Coordinator and staff hydrologist in Office of Surface Water. (Served on NRC Committee on Risk-Based Analyses for Flood Damage Reduction.)

William Alley: Coordinator, Ground Water Pilot Program of NAWQA; NRP Project Chief; Coordinator of the RASA Program; Chief Office of Ground Water. (Served on NRC committee on Ground Water Vulnerability Assessment Methods.)

John Schefter: Manager of Water Resources Research Institutes and Grants Program. Also, 1-year assignments to each of the following: DOI Office of Policy Analysis, Congressional Committee Staff, and USGS Congressional Liaison Office.

Debra Knopman: Chief, Systems Analysis Group (1991–93); Deputy Assistant Secretary of the Interior; Director, Center for Innovation and the Environment at the Progressive Policy Institute; Associate Director, RAND Science and Technology; member of the Nuclear Waste Technical Review Board. (Served on NRC Commission on Geosciences, Environment, and Resources.)

Dick Smith: NAWQA National Synthesis Team for nutrients. (Served in NRC Committee on Total Maximum Daily Loads.)

Tim Cohn: Staff hydrologist of Office of Surface Water; AGU Congressional Science Fellow; USGS theme coordinator for hazards. (Served on NRC Committee on American River Flood Frequencies.)

Ed Gilroy: Retired

Jim Slack: Mathematician in NRP, Menlo Park; Chief of the Hydrologic Analysis Support Section; and mathematician in Office of Surface Water.

Robert Gilliom: Manager of California District studies of San Joaquin Valley drainage issues; Project Chief of NAWQA National Synthesis Team for Pesticides.

Rich Alexander: NAWQA National Synthesis Team for nutrients.

Greg Schwarz: NAWQA National Synthesis Team for nutrients.

Dennis Helsel: Chief, Systems Analysis Group (1987–91); Project Chief of NAWQA National Synthesis for Nutrients; Project Chief of NAWQA National Synthesis for Metals; Associate Regional Geologist, Central Region, USGS.

OFFICE OF ATMOSPHERIC DEPOSITION ANALYSIS

By Ranard J. Pickering

Beginning in the late 1950's, the WRD conducted a number of studies of the effects of precipitation chemistry on water quality, both in federally funded research and in the Federal-State cooperative program. In 1982, because of increasing concern about the possible environmental effects of "acid rain," the level of hydrologic research was significantly increased and the program broadened to include the effects of atmospheric deposition on limestone and marble building stones.

In 1984, the WRD established an Office of Atmospheric Deposition Analysis to coordinate the acid-rain research. Ranard J. "Jack" Pickering was reassigned from Chief, Quality of Water Branch, to Chief of the new office. Subsequently, Paul Kapinos became principal assistant to the Chief, and Bernard Malo was signed on as Chief of Quality Assurance. Joel Frisch worked part-time at this activity. Much of the effort of office personnel was put into interagency activities.

The WRD Federal acid-rain program, at a funding level of about $3 million annually, was carried out as part of the National Acid Precipitation Assessment Program (NAPAP) conducted by the Federal interagency Acid Precipitation Task Force. The Task Force and its research program was established by the Acid Precipitation Act of 1980, and later reauthorized in the Clean Air Act Amendments of 1990.

The purposes of the WRD program were to:

- Monitor the chemical composition of precipitation (rain and snow) nationwide and describe its variability geographically and with time;
- determine the susceptibility of lakes and streams to acidification and to monitor susceptible areas for long-term changes that may result from acidic deposition;
- define the chemical and hydrologic processes by which acidic deposition affects the quality of surface and ground waters in the United States; and
- define the chemical and atmospheric processes by which acidic deposition damages carbonate building stones.

The USGS, through the Office of Atmospheric Deposition Analysis:

- Served in NAPAP as lead agency for the Task Group on Deposition Monitoring and was a member of the Working Group on Effects on Materials and Cultural Resources and the Task Group on Aquatic Effects.
- Coordinated the 150-site National Trends Network for monitoring precipitation chemistry nationwide. The WRD operated about 60 sites in the network; other sites were operated by a variety of Federal, State, university, and private organizations. The core from which the National Trends Network was built was the already-existing deposition-monitoring network of the National Atmospheric Deposition Program of the State Agricultural Experiment Stations, in which the USGS was a participant.
- Monitored 13 sites for long-term changes in water quality in areas identified by the Aquatic Effects Task Group as being sensitive to the effects of acid rain.
- Conducted studies in seven watersheds to define geochemical and hydrologic processes by which acidic deposition affects the quality of streams, lakes, and ground water.
- Conducted studies at three test-sample exposure sites and in the laboratory to define geochemical and atmospheric processes by which acidic deposition damages carbonate building stones.

WRD authors, reporting on the results of their studies, contributed to several of the set of 28 State-of-Science/State-of-Technology reports that constituted a large part of the NAPAP final Phase I report to the President and Congress on the results of its program.

USGS personnel in the Acid Rain Program were active in efforts by the United States and Canada to

develop a bilateral agreement on transboundary air pollution. As Chief of the Office of Atmospheric Deposition Analysis, Jack Pickering frequently served as Department of the Interior representative at meetings of technical working groups and attended negotiating committee meetings as an advisor to the Department of the Interior representative—the Assistant Secretary for Water.

NUCLEAR HYDROLOGY PROGRAM—YUCCA MOUNTAIN PROJECT BRANCH

By William W. Dudley and Louis G. Ducret

Nuclear Hydrology Program, 1979–1985

By the beginning of 1979, hydrologic studies of the Nevada Test Site (NTS) by the Nuclear Hydrology Program (NHP) were dominantly in support of the U.S. Department of Energy's (DOE) Nevada Nuclear Waste Storage Investigations (NNWSI). This was in contrast to the previous two decades, during which NHP's primary role related to the siting, safety, and engineering support of underground nuclear explosions at NTS. An intensive regional and site-specific evaluation of NTS in 1977–78 led to the focus of NNWSI interest by 1979 on the Yucca Mountain area, which straddled the southwestern border of NTS. The evaluation was an interdivisional USGS effort, formulated jointly under the leadership of William W. Dudley, Chief of NHP, and William S. Twenhofel, Chief of Geologic Division's (GD) Special Projects Branch. Dudley served as the principal contact and Operations Coordinator for the Bureau. Scientists in several offices of both divisions were actively involved in the planning and eventual execution of the program.

During 1979, Dudley was reassigned to Wyoming as District Chief and was succeeded as NHP Chief by William E. Wilson. Twenhofel assumed leadership of the Survey's NNWSI program, relying heavily on Wilson and Gary L. Dixon to oversee the hydrologic and geologic aspects, respectively. Upon Twenhofel's retirement in 1980, Wilson and Dixon jointly represented the USGS program to DOE, as well as leading their respective disciplines in planning, operations, and scientific reporting. Several branches in GD provided expertise in regional and borehole geophysics, stratigraphy, structure, tectonics, volcanism, and isotope geology. An office of National Mapping Division supported the tectonics study with high-precision surveys of quadrilaterals that straddled several major faults and of a level line along U.S. Highway 95 across the northern Amargosa Desert. NHP had an existing, though small, ground-water staff, and Wilson elicited additional support in paleohydrology (and eventually in unsaturated-zone hydrology) from research scientists in Northeastern, Central and Western Regions, as well as from academia. Nevada District staff expanded their duties to provide flood-discharge studies, crest-stage monitoring, and regional ground-water monitoring.

In order to concentrate the effort of his direct NHP staff on NNWSI studies, Wilson negotiated the transfer of the NTS weapons-program work to the Nevada District. The NHP staff in 1981 included hydrologists F. Eugene Rush (Assistant Chief), Hans C. Claassen, Gene C. Doty (in Nevada), Richard K. Waddell, James E. Weir, Merrick S. Whitfield, and William Thordarson. Instrumental and field support was provided by Technicians Leonard E. Wollitz, Wayne A. Evert, Charles L. Washington, and William J. Oatfield. Although the NHP projects were principally field-oriented, Waddell developed the first two-dimensional ground-water flow model for the NTS region.

The rapidly expanding site-characterization program required a much larger hydrologic staff, which Wilson initially acquired as detailees from other WRD offices while he recruited permanent staff from within and outside of WRD. Permanent staff additions in 1981 and 1982 included Richard K. Blankennagel, a drilling and testing specialist who previously had headed NHP; Larry V. Benson, a specialist in geochemistry and paleohydrology acquired from Lawrence Berkeley Laboratory; and hydrologists Robert W. Craig, John B. Czarnecki, James R. Erickson, David H. Lobmeyer, and James H. Robison, all of whom conducted and reported on testing of the saturated zone. Professor Richard Hay and his doctoral student Robert Pexton studied the origin of clays in the Amargosa Desert whereas Geoffrey Spaulding, University of Washington, contracted to define the paleoclimates of southern Nevada based primarily on packrat middens. Joe S. Downey transferred from the Northern Great Plains RASA in 1983 to support saturated-zone and paleohydrology studies.

About 20 exploratory holes penetrated to depths as much as 6,000 feet beneath the Yucca Mountain area by 1984. Most of these holes targeted rocks

beneath the water table, which lies at depths of about 1,000 to 2,500 feet. Selection of drilling locations was an integrated effort by GD and WRD, as was providing the scientific direction of drilling and testing operations conducted by DOE contractors. The GD personnel had primary responsibility for geophysical logging, description of lithologic and structural features of core and cuttings, and picking stratigraphic contacts. The WRD was responsible for the hydrologic testing, which in most of these holes consisted of pumping and injection tests, interval head measurements and hydraulic tests between packers, additional geophysical logging, borehole flow and temperature surveys, and hydrochemical and isotopic sampling and analyses. The growing store of hydrogeologic and hydraulic information made it possible for Czarnecki and Waddell to prepare a finite-element flow model for the vicinity of Yucca Mountain, though still in two dimensions and lacking solute-transport capability.

Results of the USGS testing program that had been obtained by about the end of 1981 had already shown that the deep saturated zone probably was too permeable to host a nuclear-waste repository. At meetings and in correspondence, Isaac Winograd, of WRD's Northeastern regional research staff, and Wilson encouraged DOE to invest substantially in exploratory testing of the great thickness of unsaturated rocks above the water table. Because of the expected small infiltration flux, the unsaturated environment was predicted to offer major benefits for waste isolation and for excavation and operation of an underground repository. Confirming this prediction, however, required another large expansion of NHP to assemble a team with the talents and creativity to develop an understanding of the hydrologic conditions and processes operating in the thick unsaturated zone. Wilson began building this specialized staff during 1983 while the saturated-zone field program was in full swing and when many years of data compilation, interpretation, and report writing lay ahead. By the end of that year, Parviz Montazer had joined NHP from the Colorado School of Mines, bringing experience in investigating unsaturated flow in fractured hardrock mines in Colorado. Dale P. Hammermeister transferred from California to Las Vegas to help establish and maintain the field experiments. Wilson and Montazer collaborated in developing characterization plans and a conceptual model, specific to Yucca Mountain's hydrogeology, that became a basic reference for NNWSI unsaturated-zone studies.

In 1984, Warren E. Hofstra transferred to NHP as Assistant Chief for Operations. Dwight T. Hoxie, Albert Yang, Jack Kume, Phillip E. Harrold, and Carole Loskot joined the unsaturated-zone staff, along with technicians Ray Vaughns, Charles Warren, and Stanley Breshears. The Saturated-Zone Hydrology and Paleohydrology Section acquired Devin L. Galloway, Patrick W. McKinley, and Alan C. Riggs.

Earlier, the Nuclear Waste Policy Act of 1982 had specified that, as part of site characterization, DOE would obtain in-situ data by means of underground testing, with access to be provided by an exploratory shaft (ES). Los Alamos National Laboratory (LANL) was designated by DOE to be the lead organization for ES design and testing. LANL was given the responsibility for developing an integrated test plan (ESTP) that described and coordinated the experiments to be conducted by all of the NNWSI technical participants. Sandia National Laboratory (SNL) was responsible for geomechanical and thermomechanical tests; LANL was responsible for geochemical and nuclide-transport testing; and Lawrence Livermore National Laboratory (LLNL) was to determine the thermal, chemical, and stress conditions in the near-field waste-package environment. The USGS was responsible for hydrologic testing to characterize the natural unsaturated-zone conditions. In addition, USGS was responsible for geologic mapping of the shaft and lateral excavations that would house all of the NNWSI experiments, but GD staff who were assigned to NNWSI had little experience in underground mapping and were generally reluctant to accept the role of mapping the freshly exposed walls of the ES. However, the Bureau of Reclamation (BOR) was experienced in underground mapping as part of their dam-site investigations and agreed in 1984 to join with USGS in the ES geologic studies. The BOR also was experienced in machining equipment needed for in-situ testing and soon fabricated a sophisticated surveying platform on which their geologists could be lowered while mapping and sampling geologic units, faults, and fractures.

Development of the ESTP began in 1984, and shaft sinking by a drill-and-blast method was scheduled to be initiated in 1986. Early in the planning process, however, it became evident that an inclined ramp offered substantial operational and scientific advantages over a vertical shaft. The redesign was partly responsible for a delay of several years in beginning the excavation, which provided a needed reprieve

for the USGS to acquire and train the staff to perform the complicated, first-of-a-kind experiments far beneath the surface of Yucca Mountain. DOE also decided to mine the main drift of the ESF (Exploratory Studies Facility) by lateral drilling with a rail-mounted tunnel-boring machine (TBM), and BOR promptly changed its down-hole mapping platform to a trailing-car design that was pulled behind the TBM. In order to preserve the unsaturated environment for both characterization tests and eventual repository performance, application of fluids was minimal, creating a dusty but aggressively ventilated underground workplace.

The scientific scope of Gary Dixon's GD program also was growing throughout the early 1980's as analyses of earthquake monitoring, in-situ stress measurements, and patterns and ages of volcanism revealed perplexing questions about the tectonic environment of Yucca Mountain. Faced with managing increasingly broad and complex scientific programs, both Wilson and Dixon were hard-pressed to respond to DOE's expanding programmatic and administrative requirements. To a large extent, these requirements emerged from DOE's recognition that its program to locate, construct, and operate a nuclear-waste repository was a Major System Acquisition (MSA), as defined in Federal Regulations, and must be licensed by the U.S. Nuclear Regulatory Commission. With this designation came very exacting financial accounting standards, detailed and long-range planning requirements, and the dictate that NNWSI develop and comply with rigorous quality-assurance (QA) controls that mimicked those imposed on the construction and operation of nuclear powerplants. In 1981, Wilson and Dixon obtained DOE's assistance in receiving QA support from LANL, which had an existing QA section.

DOE's NNWSI Project Manager, Donald L. Vieth, asked USGS in 1982 to designate a single point of contact and responsibility, that is, a Technical Project Officer (TPO), for its NNWSI efforts in both GD and WRD. In response, WRD (the lead division for waste-disposal programs) established the position of Coordinator for NNWSI under the Assistant Chief Hydrologist for Research and Technical Coordination, who selected William Dudley to fill the new position in late 1982. Wilson's NHP continued to be under the Central Region. During 1983, Dudley acquired a secretary, Phyllis Burnham (now Phyllis Jeffery), who served an administrative role as well, soliciting and compiling monthly activities and financial reports from about a dozen different offices in the two divisions. Craig B. Bentley, who had become interested in the project while on detail to NHP's hydraulic testing effort, also joined the Coordinator's office in 1983 to serve as alternate TPO and help in formulating the Yucca Mountain Site Characterization Plan (SCP). Finally, in 1983, Joe R. Willmon transferred from the Central Region office, where he had gained experience in overseeing the development of quality-control procedures in water-quality laboratories. He quickly applied himself to learning QA as it was evolving in NRC and other NNWSI participant organizations.

Dixon requested a transfer to the Office of Regional Geology's geologic mapping program in Western Region in late 1983, and Elmer H. Baltz was named GD Coordinator. As a Geologist in the Albuquerque Area Office, Baltz had geologic and hydrologic experience at the Nevada Test Site. In addition, he had worked as a USGS advisor to NRC in evaluating sites for nuclear powerplants. He had witnessed the difficulties of forcing earth-science investigations into the ill-fitting mold of a QA program designed for nuclear powerplant construction and operation. He foresaw that difficult times lay ahead for the NNWSI site-characterization program. Baltz retired in early1985, and Robert B. Raup was appointed GD Coordinator for NNWSI. Though himself lacking line authority over the many GD branches, Raup maintained the cooperative joining of the Divisions, persuading frequently reluctant scientists to endure the seemingly excessive planning, reporting, and quality-assurance requirements.

Recognizing that USGS had neither the appropriate staff nor the inclination to develop in-house capabilities to respond to all of DOE's requirements, Dudley sought and obtained in 1984 a management-support contract with the Denver office of Science Applications International Corporation (SAIC). With SAIC's help, the USGS made significant progress in preparing its chapters of the Yucca Mountain Site Characterization Plan and numerous subsidiary, more detailed Scientific Investigation Plans (SIP's), as well as preparing budget requests and expenditure reports on schedule. SAIC support also made it possible in 1985 to terminate the QA assistance from LANL, providing local, responsive, and knowledgeable support to QA Manager Joe Willmon. Later, SAIC established a large records-management section in

order to meet another DOE directive to maintain detailed documentation of all technical information pertaining to the site.

Branch of NNWSI

During 1985, the NNWSI Coordinator's office was converted to the Branch of NNWSI, with Dudley as Branch Chief and incorporating the Nuclear Hydrology Program. For the hydrologic investigations, this established the line of authority that DOE had requested of USGS 3 years earlier, but the geologic investigations were bound to NNWSI only by common scientific interests, commitment to a national priority, and budgetary expediency. WRD assigned Richard V. Watkins from the Director's office into the new position of Associate Branch Chief. While Dudley concentrated on developing and reporting the geologic and hydrologic scientific programs with DOE, maintaining close coordination with Raup and Wilson, Watkins addressed branch staffing needs and the associated space problems.

A DOE quality-assurance audit of USGS in March 1986 identified a large number of procedural QA deficiencies that, if left uncorrected, could have caused many USGS investigative results to be inadmissible in a licensing action. After consulting with QA Manager Joe Willmon, Dudley issued a stop-work order against most of the USGS studies that produced site-characterization information. Exempted were such activities as planning, prototype testing, training (particularly in QA topics), analysis of natural-state samples, and collection of other data that otherwise would be permanently lost, such as earthquake seismic monitoring. Vieth quickly imposed a DOE stop-work order over Dudley's, assuring that DOE would gain control of the eventual lifting of the order. Subsequently, similar deficiencies were found during audits of the National Laboratories, of DOE's engineering, construction, and drilling contractors, as well as of DOE's NNWSI Project Office, bringing the entire site investigation to a halt for about 2 years. (The USGS was released from the DOE-imposed order in December 1987 and was the first of the major NNWSI participants to regain control of its quality program and be authorized to resume scientific work.)

In November 1986, Larry R. Hayes entered on duty as NNWSI Branch Chief in Denver, replacing Dudley, who was reassigned as Special Assistant for NNWSI in the Office of the Assistant Chief Hydrologist for Program Coordination and Technical Support. In that position, Dudley continued in full-time support to the branch, serving as USGS representative on several DOE/NNWSI committees, helping to resolve controversial issues regarding geologic mapping, the origin of calcite-silica veins, in-situ stress measurements, and heat-flow studies, the last leading to a long-term collaboration with John H. Sass of GD's Branch of Tectonophysics in relating subsurface temperatures to ground-water flow patterns.

By the end of 1986, the branch had acquired a Financial Administration Specialist, Joseph P. Piro; an Administrative Services Section composed of Administrative Officer C. Deborah Keen, Budget Analyst Edward D. Villanueva, and four support positions, two of them authorized but still vacant; a Planning and Evaluation Section, headed by Alonzo H. Handy, which oversaw the SAIC contract activities; and a Regulatory Support Section consisting of William H. Langer, Joe E. Reed, Gary N. Ryals, and F. Eugene Rush. Joe Willmon was authorized three professional positions in the new Quality Assurance Section, one of them filled by Joseph W. Reid, and a secretary, Alexandra Anderson. Finally, in order to improve day-to-day communications between DOE and USGS, WRD established an NNWSI Operations Office in Las Vegas, reporting to the Branch Chief in Denver.

The Nuclear Hydrology Program staff also increased strikingly in 1986. Daniel C. Gillies joined in the combined capacities of Associate Chief and Chief of the Saturated-Zone Hydrology and Paleohydrology Section. K. Wilford Causseaux transferred as Assistant Chief for QA and Data Management, and Barney L. Lewis joined the NHP staff in Las Vegas. The Unsaturated-Zone Section added Alan L. Flint, Joseph P. Rousseau, Charles A. Peters, and Ray A. Vaughns, as well as gaining authorization for four professional positions. The Saturated-Zone project recruited Hydrologist Richard R. Luckey and Hydrochemist William C. Steinkampf to help characterize the site hydrology. Kent C. Glover and Arthur L. Geldon were added to conduct tracer tests at the three-well experimental site that had been completed in saturated fractured rocks near the site. Finally, Edwin D. Gutentag joined the Paleohydrology Project.

In 1987, Montazer resigned and Barney Lewis transferred to Denver to become Chief of the Unsaturated-Zone Section, which also added Robert C. Trautz to its staff. Charles L. Washington was converted from

Hydrologic Technician to Computer Program Analyst, foreshadowing the eventual establishment of centralized computer support in NHP and the Branch of NNWSI.

Revision of the USGS Quality Assurance Program Plan following the stop-work order included removing the branch Quality Assurance Section to the Office of the Assistant Director for Engineering Geology in order to ensure its independence from the Branch of NNWSI. In 1987, Thomas H. Chaney was named Deputy QA Manager, and Hydrologists Martha H. Mustard, Joseph W. Reid, and Susan Shipley were added to the Denver staff. John R. Evans of GD's Branch of Tectonophysics was designated to act as Willmon's representative in Menlo Park, California.

The Szymanski Controversy, 1985–

Beginning in 1985, a DOE staff member, Jerry S. Szymanski, developed an elaborate theory on the origin of caliche-like layers and fracture-filling veins that are ubiquitous at and near the surface in the Yucca Mountain area. Indeed such deposits of calcium carbonate and silica have long been recognized as common products of soil development in desert regions. Szymanski, however, purported that they were formed from hot, mineral-laden fluids that were expulsed from great, subcrustal depths by cyclic tectonic processes, happening every few-thousand to several-thousand years. Thus, it was certain, he claimed, that a repository at Yucca Mountain would be forcefully invaded by these corrosive fluids which, upon nearing surface, would flash to steam. Nuclear waste would be mechanically dispersed by the explosion and be dissolved by the corrosive fluids still in the repository. Szymanski developed a small cadre of supporters from several organizations. Because his principal duty had been reviewing NNWSI earth-science reports and processing them for DOE approval, publication of site-characterization findings came to a standstill. Szymanski's supervisor reassigned him to the full-time task of documenting his theory and the evidence to support it in a written report that the project could review.

Szymanski's first report was completed in 1987, and a team of more than 20 scientists was assembled from USGS, LANL, LLNL, and SNL to review parts of the document. Dudley, George Barr of SNL, and Christopher Fridrich of DOE were assigned to compile the comments into a composite NNWSI review document. Earth-science topics that were addressed by Szymanski included regional and local geology and hydrology, tectonics, rock mechanics, hydromechanics, soil science, geomorphology, geochemistry, mineralogy, and isotopic dating. The review was completed in 1988 and identified critical misrepresentations of data and logical flaws in the theory and the supposedly supporting data. Far from accepting the results of this review, Szymanski demanded and received reviews by two additional panels, one that he selected and one that was selected by the NNWSI Project Manager, composed of scientists who were independent of DOE and the NNWSI participants. Both panels reached unanimous but opposite conclusions. In a voluminous document, Szymanski's panel reported that not only was he correct, but that his assertions greatly understated the risk of proceeding with the repository project. The independent panel reached conclusions that were similar to those of the earlier NNWSI review team—that Szymanski's thesis and arguments were not credible. Finally, DOE asked the National Academy of Sciences to form a special review committee, which included several nationally renowned scientists, including former WRD researcher, John D. Bredehoeft. Once again, the NAS panel found no merit in Szymanski's theory.

Yucca Mountain Project Branch, 1988–90

DOE redesignated its NNWSI Project as the Yucca Mountain Project in 1988, and the WRD office became the Yucca Mountain Project Branch (YMPB). Robert Craig transferred to the YMPB Nevada Operations office, and Craig Bentley retired.

In March of 1988, Hayes obtained GD's concurrence for him to name John S. Stuckless, Branch of Isotope Geology, as Project Chief, Paleohydrology and Future Ground Water, in NHP, though Stuckless would remain in GD. This unusual appointment principally reflected the critical scientific and coordination roles that Stuckless was playing in the interagency confrontations with Szymanski and his followers.

Wilson transferred in 1988 to the YMPB staff as Science Advisor, being replaced as NHP Chief by Donald G. Jorgensen. Bruce T. Brady joined NHP in a position dedicated to reports improvement. Hydrologic Technician James Gemmell joined NHP's fractured-rock hydrology project, which was initiating hydraulic and tracer tests. In the UZ section,

Michael P. Chornack, an experienced geologist with Fenix and Scisson, Inc., at NTS joined the USGS to oversee surface-based drilling and testing. The UZ section also acquired Gary D. LeCain, Falah Thamir, Carole L. Loskot, and Edward M. Kwicklis in Denver and William J. Davies in Nevada. Janine S. Ferarese joined the UZ hydrochemistry laboratory.

In 1989, the YMBP acquired Raye E. Ritchey (later Raye Arnold), a Program Analyst who had several years of experience with the demanding program planning and reporting requirements that DOE was increasingly placing on Yucca Mountain Project participants. QA Manager Joe Willmon retired, and the Office of Quality Assurance was administratively transferred back to the Branch under the leadership of David H. Appel. Wayne Rodman and Susan Shipley joined the QA Office. Elisabeth M. Ervin and Gary L. Patterson were recruited by the SZ Section, and Alan L. Flint and Carol J. Boughton joined the UZ Section. The Nevada Operations section acquired Charles S. Savard to monitor ephemeral streamflow losses and resulting recharge to the saturated zone.

Following Donald Jorgensen's reassignment to the Office of International Hydrology, David Appel was named Chief of the former Nuclear Hydrology Program, which was renamed Hydrologic Investigations Program (HIP) in 1990. He was succeeded as QA Manager by Thomas H. Chaney. Al Handy retired, and Daniel J. Gockel and Alice E. Lykins were added to the QA staff. Joseph L. Henderson joined the Branch as Administrative Officer. Under the Management Operations Section, the Computer Operations Unit was established, led by Neil Stuthmann and consisting also of Barbara Kerans, Charles Washington, Marti Vaught, and Charles Freestone. In 1991, William Sockriter, William Oatfield, and Douglas Burkhardt were added to the unit.

Also in 1990, Emily M. Taylor joined the Paleohydrology Section of HIP to study the Quaternary deposits and soils that were the center of the Szymanski controversy, and Claudia C. Faunt was acquired to compile the regional hydrogeologic data. Amjad (MJ) Umari was appointed Project Chief of the fractured-rock SZ tracer tests. Kenneth A. Richards, supporting Alan Flint's UZ Matrix Properties Project, became the first full-time hydrologist dedicated to laboratory measurements of unsaturated-rock properties in Mercury, Nev.

Dudley was reassigned to YMPB in 1990 as Science Advisor, shortly before the retirement of William Wilson. At that time, the State of Nevada had determined that the Yucca Mountain Project was no longer exploratory in nature, having been designated as the only site of interest by the Nuclear Waste Policy Act of 1987. Therefore, DOE would be required to obtain a water-use permit from the State Engineer before site-characterization activities could continue. DOE requested that YMPB accept the role of testifying in support of its application. Dudley, Luckey, Claassen, and Czarnecki testified, respectively, in the areas of regional hydrogeology and ground-water flow, ground-water characteristics of the site, hydrochemical characteristics, and results of modeling the effects of pumping water for repository development. State Engineer Michael Turnipseed granted DOE's application at that time but reversed his decision a decade later, on the basis of a State law prohibiting nuclear-waste disposal in Nevada.

An agreement was reached in 1991 between Ben Morgan, Chief Geologist, GD, and Philip Cohen, Chief Hydrologist, WRD, in which 10 permanent, full-time professional employees were voluntarily reassigned to WRD/YMPB with an option to return to GD when they had completed their YMP work. This group formed the core of the new Geologic Studies Program within YMPB and was quickly supplemented with others who were hired or accepted transfers without the repatriation guarantee. Membership in the group was as follows:

Geologic Studies Program
John S. Stuckless, Chief

Isotope and Geochemistry Section
Zell E. Peterman, Chief
Brian D. Marshall
Kiyoto Futa
James B. Paces
Shannon A. Mahan
Duane Craft

Paleoclimate Section
Richard Forester
Joseph Whelan
Kelly Conrad

Rock Characteristics Section
Richard W. Spengler, Chief
W. Clay Hunter

Tectonics Section
John W. Whitney, Chief
Christopher J. Fridrich
Chris M. Menges
Jeffrey A. Coe
F. William Simonds

Additional expertise in geologic mapping, rock characteristics, and tectonics was obtained by increasing the scopes of the agreement with BOR and the contract with SAIC. In addition, several branches of GD entered into Memoranda of Agreement (MOA) with Hayes that specified funding, reporting and deliverables, and QA matters such as training and audits. These MOA's were principally used for discrete tasks such as geophysical surveys.

Yucca Mountain Project Branch, 1991–94

Louis G. Ducret transferred to YMPB in Denver in mid-1991 as Associate Branch Chief and Chief, Planning and Support Section. Two new positions were established in the Branch office; Robert E. Lewis was named Reports Improvement Officer, and Patrick McKinley was named Data Management Coordinator, overseeing a large staff of contract personnel. Anthony Buono transferred from Las Vegas to California, and Robert Craig took charge of the Nevada Operations Program. Dwight Hoxie transferred to Las Vegas, where he served as the Branch scientific representative on several committees and task forces. Increased field activity in the UZ section led to the appointment in 1992 of Debra Edwards as ESF Coordinator and of Daniel J. Soeder as Field Test Coordinator.

In 1991, the HIP Saturated-Zone Section, headed by Richard Luckey, acquired Patrick Tucci to synthesize the large store of hydrologic information generated during site characterization. He was assisted by Grady M. O'Brien, initially a student who was converted to Hydrologist in 1992. Frank A. D'Agnese joined the Section while completing his Ph.D. thesis at the Colorado School of Mines; this thesis documented the first regional, 3-dimensional model of the Death Valley ground-water system in Nevada and California. Diana Perfect joined the SZ Section in 1992 to compile and evaluate hydrochemical data for the region. Also in 1992, John D. Earle and Jon Darnell were added to Umari's Fractured Rock Hydrology project to aid in conducting tracer studies in cooperation with LANL, which was responsible for solute-transport aspects.

The position of Chief, Unsaturated-Zone Section, was vacated in late 1990 by the reassignment of Barney Lewis to the Wyoming District, and Michael P. Chornack was subsequently selected for the position in 1991. Larry O. Anna was hired in 1991 to characterize and model the fracture systems in the unsaturated zone. Gary R. Severson was acquired to conduct the ESF percolation experiments, and Joseph J. Hevesi joined the surface-based UZ Infiltration project. During 1991–93, while still Western Region, Rufus T. Getzen assisted Rousseau's surface-based percolation studies in installing and operating downhole equipment to measure moisture characteristics in vertical boreholes. Anita L. Sims and Jerry N. Walker assisted in the field instrumentation and data processing in the UZ laboratory and offices in Mercury. In Denver, Murray E. Beasley and Gordon W. Rattray joined Al Yang's UZ hydrochemistry project, recovering and analyzing moisture from borehole and ESF samples.

During 1992–94, Stuckless added Bruce Parks to the Geologic Studies Program as Assistant Chief and Chief of the Paleoclimate Section. Quaternary geologist Scott Lundstrom and PST Richard J. Moscati also joined the staff. David C. Buesch was hired in Las Vegas to assist Spengler in the stratigraphic characterization of Yucca Mountain. Dennis O'Leary transferred into the GSP Tectonics Section to develop the regional tectonic-framework model, assisted by earthquake specialist Silvio Pezzopane.

With the inclusion of the Geologic Studies staff, HIP was renamed Earth Science Investigations Program (ESIP) in 1993. In late 1994, Stuckless transferred to the Branch office as Science Advisor, and Michael Chornack was selected to be GSP Chief.

Funding increased from about 8 million in the early 1980's to about 25 million in 1994.

TOXIC SUBSTANCES HYDROLOGY PROGRAM

By Stephen Ragone

The Toxic Substances Hydrology Program began in 1982 as the Toxic Waste–Ground Water Contamination Program. The program assumed its

current name in 1985 when a surface-water component—Hazardous Substances–Surface Water and Sediment—was added. The program was initiated in response to a growing concern about the hazards resulting from the infiltration of chemical and biological wastes into the Nation's ground water and ultimately into water supplies. Places like Love Canal in New York focused public attention in the late 1970's on the extensive social, political, and economic impact that can result from even a relatively small area of ground-water contamination. Preliminary estimates by the U.S. Environmental Protection Agency (USEPA) during this time indicated that millions of legal and illegal waste dumps, pipeline leaks, industrial plants, and chemical spills discharged billions of gallons of pollutants into the environment every year. Passage of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) marked the beginning of what was to become an estimated $750 billion effort to correct current contamination problems and prevent future ones.

The argument that earth-science information was needed to support regulatory efforts to improve waste-disposal practices and help mitigate existing and future surface- and ground-water contamination problems resonated with Congress. Program funding increased from about $1 million in 1982 to about $4 million in 1983 and to more than $8 million in 1984. Funding peaked at nearly $15 million in 1992. It remained at about $14 million through 1994.

The program had three major components: process-oriented research and methods development, focused interdisciplinary field investigations at contamination sites, and regional water-quality investigations. It was believed that the first component would provide the quick results needed to demonstrate the importance of the program and ensure continued funding. Based on familiarity with the National Research Program (NRP), it was clear that much of NRP's ongoing research was relevant to programmatic goals and could be put to immediate use. Thus, one-half of the program's original funding was given to the NRP in order to expand relevant ongoing research and start new research endeavors. Additional funds also were reserved for NRP scientists to work on focused interdisciplinary field investigations, the second component of the program. The intention of providing funding for both "basic" and "applied" research was to allow researchers, should they wish, to tailor their efforts to meet programmatic needs.

The focused field investigations provided the opportunity for interdisciplinary research. It was envisioned that scientists in District Offices, the NRP, other USGS Divisions, other Federal agencies, and universities, and from a variety of scientific disciplines, would work together on joint projects to determine the fate of ground-water contaminants. An early model for such an endeavor was the Bay Park, New York, Deep-Well Injection project that provided the opportunity for cooperative research between District scientists and NRP researchers. Achieving truly interdisciplinary research required a rather hard-nosed approach: project funding would be contingent on the acceptance of an integrated-research plan that contained hypotheses to account for the entire mass of the contaminant in question. As no project funding target was identified, those proposing the projects were forced to take a risk: propose a comprehensive but costly integrated research project with the risk of being out of the funding ballpark or propose a limited and less expensive project with the risk of not meeting the challenge to account for the entire mass of the contaminant. To the credit of District staff and NRP researchers, a concerted search began to find sites where conditions provided the opportunity for interdisciplinary research. Competition developed among candidate sites as teams of researchers formed to identify the scope of effort and put together research hypotheses and plans.

Three field sites were identified: Cape Cod, Mass.; Bemidji, Minn.; and Pensacola, Fla. Each had a relatively simple hydrogeologic setting and a well-defined contaminant plume. The Cape Cod project involved the study of the infiltration of sewage-treatment effluent and chlorinated hydrocarbons. The Bemidji project provided the opportunity to study crude-oil infiltration that resulted from a pipeline break. The Pensacola project studied the effects of creosote and pentachloro-phenol infiltration from water-disposal ponds on ground water and surface water.

Success of the field studies fell on the shoulders of several key people. Roger Wolff never failed to support the program through the tough early days (years!) as it strove for achievement and acceptance. Mary Jo Baedecker proved to be a strong proponent of the program from its inception. She led projects at the Pensacola and Bemidji sites and was instrumental in bringing university expertise to bear at the sites. Jim McNeal gave fully of himself to involve Geologic

Division researchers. The District Offices were technically very well represented by the likes of Bernie Franks of the Pensacola project, Mark Hult of the Bemidji project, and Denis LeBlanc and Steve Garabedian of the Cape Cod project. These scientists were challenged not only with the responsibility to do their own research and provide all logistical support at the site but also to serve as site spokesmen. They were required to report on the overall research strategy for the site that integrated the individual research endeavors into a comprehensive whole.

A major concern at the outset of the Toxic Substances Hydrology Program was how to ensure that the program maintained its scientific momentum in subsequent years. National meetings were held periodically, usually every 12 to 18 months, to help in this regard. The meetings would prove to be instrumental in building collegial relationships and programmatic visibility. The first meeting was held in Tucson in 1984. As was mentioned earlier, it was expected that early programmatic results would come out of the first component of the program—the component concerned with process-oriented research and methods development. This proved to be the case as there were no formal presentations about the three field sites at the Tucson meetings. However, the meeting served to galvanize the program. The healthy competition that was observed among sites at the outset of the program continued at the meetings.

Also, the meetings served to "sell" the program to the broader scientific, regulatory, and funding community. The open-file publications that contained the papers of the meeting were "fast-tracked," often to the consternation of the report-review specialists, and distributed quickly and widely. Philip Cohen, the Chief Hydrologist during this period, was skeptical when told that the first meeting's report would be completed just months after the meeting. When the approved report was delivered to his desk as promised, Cohen looked at it, then promptly ran it up to the Director. Project funding increased substantially in the first years of the program, not only as a result of good science but also because of good salesmanship.

The second in the series of meetings, at Cape Cod in 1985, proved to be an unqualified success. It was at this meeting that site investigations came to the fore. Reports from speaker after speaker unraveled technical mysteries about the often-unexpected distribution of the contaminant plume and the physical, chemical, and biological processes that affected it. Reports were also given on several new sites and methods-development activities as the program sought opportunities to study different classes of anthropogenic contaminants.

It was our intention not only to have high-quality national meetings but to make them fun. Meetings were held near research sites so the District Offices could arrange field trips and informative demonstrations at the sites. Maxine Dinwiddie, the staff assistant, was the key person who selected the hotels, created wonderful theme dinners, and enlisted free entertainment that was enjoyed at meetings.

Another way to ensure scientific momentum was to fund the projects on a year-to-year basis. This understandably made fiscal planning more difficult for the District Chiefs and Regional Hydrologists who received program funds. There were loud and angry vocal complaints about this and about the unequal distribution of program funds from Region to Region. Cohen also was concerned about the unequal distribution of program funds. However, he never second-guessed the Program Coordinator's approach and deserves much credit for allowing the program to apply new scientific and managerial paradigms.

It was the intention of the program to fund the study of more complex contaminant plumes—having multiple phases, for instance—at sites having more complex hydrogeologic characteristics. It was expected that the new sites would be phased in and eventually replace the original sites as the research endeavors at the original sites were completed. Allan Shapiro and Paul Hsieh spearheaded studies of fractured-flow transport at Mirror Lake in New Hampshire. Art Baehr was a key researcher in the study of hydrocarbon fate and transport in both the saturated and unsaturated zones at the Galloway research site in New Jersey. This work led to the development of practical ways to design vapor-extraction remediation systems.

The program was broadened to include the study of surface-water contamination sites in 1985. Gail Mallard ably coordinated these efforts before and after the merger with the ground-water projects. Sam Luoma played a key role in the research on San Francisco Bay. Briant Kimball contributed to the successful study of acidic mine drainage at Saint Kevin Gulch in Colorado.

The third component of the program—regional water-quality investigations—responded to the concern about the effects on ground water of nonpoint

sources of pollution from agricultural practices, urban sprawl, and industrial operations. In 1989, the program initiated an ambitious effort to study the fate of agricultural chemicals in the 11-State area that constituted the Nation's corn- and soybean-growing region. Designated the Midwest Herbicide Initiative, the objective was to account for the distribution and fate of nutrients and herbicides—particularly nitrates and atrazine—in surface and ground waters, precipitation, soils, and reservoirs. The Initiative, which was cofunded by USEPA and the Department of Agriculture, included regional reconnaissance studies of the temporal and spatial distribution of agricultural chemicals and basic research. Basic research was conducted at "Management System Evaluation Areas" that were representative of the hydrologically, pedalogic, and climatic regions in the Midwest. Mike Burkart took on the responsibilities for the management of field activities out of the Iowa District Office. Don Goolsby, then the Regional Water Quality Specialist in the Central Region, was instrumental in the application of new methods and research.

Progress in determining the presence of anthropogenic chemicals in ground water that originated from nonpoint sources was hampered by the cost and difficulty of measuring low concentrations of chemicals, especially pesticides and other organic chemicals. The methods-development projects that were funded by the Toxic Substances Hydrology Program led to more sensitive and less expensive analytical screening tools. Mike Thurman contributed to the efforts to measure low concentrations of atrazine in ground water and surface water by using enzyme techniques and relating the concentrations to climate and agricultural practices. Jack Gibbs and Tom Imbrigiotta of the New Jersey District contributed to the development of more sensitive and cheaper sampling and analytical methods for organic chemicals. Herman Feltz helped to get the methods adopted for use by the Central Laboratory.

A major achievement of the program came out of the collaboration between Dennis Helsel and District scientists to develop and test nonparametric statistical methods to correlate the occurrence of anthropogenic chemicals in ground water with land uses and other measures of human activity. Doug Cain of the Colorado District and Dave Eckhardt of the New York District played a key part in this regard. The methods would become the statistical method of choice for the subsequent National Water-Quality Assessment Program.

The Toxic Substances Hydrology Program received very high marks over the years from colleagues at other Federal agencies, from the university community with whom we worked, and from the National Research Council. Cohen called the program the "Tool Building" for the Division. The program hit a responsive chord with Federal regulators and the environmental community as the results of the research program were distributed through technical publications and meetings. This writer had innumerable opportunities to speak at technical and professional meetings. Joe Cragwall, a former Chief Hydrologist, and Bob Dingman, a former Regional Hydrologist for the Southeastern Region, were in the audience at one meeting. I was a bit awestruck by their presence as these men were my heroes when I first joined the USGS. Before starting my formal remarks I acknowledged their presence and jokingly wondered out loud why I wasn't at the meeting to listen to them rather than having them listen to me. Bob responded without hesitation, "Because it's your turn." The fact is the 1980–90 period was the USGS' turn as "thrust programs" such as the Toxics Substances Hydrology Program flourished as the Nation sought technically sound answers to a myriad of complex environmental problems.

OFFICE OF HYDROLOGIC RESEARCH

By Roger G. Wolff and John B. Weeks

BACKGROUND

As summarized in Volume VII of the history of WRD, a centralized research activity, ultimately named the National Research Program (NRP), evolved to where it represented about 10 percent of the Federal funding for programs with FTE (staffing) allocations at about the same level. Initially, the NRP was administratively under the Regional Hydrologists. Technical oversight and funding were provided by the Assistant Chief Hydrologist for Research and Technical Coordination (ACHR&TC). The Deputy ACHR&TC had the primary responsibility for managing the NRP. Personnel and programs in NRP were supervised by Regional Research Hydrologists who reported to the Regional Hydrologists on administrative matters and to the Deputy ACHR&TC on technical program.

During his tenure as Chief Hydrologist, Phil Cohen reorganized the NRP, implemented Research

Grade Evaluation (RGE) throughout the Division, and established a Research Committee. These changes were made to provide the best environment possible for the conduct and review of WRD research and to enhance the stature of research not only within the Division and Bureau, but nationally and internationally.

NRP MANAGEMENT AND ORGANIZATIONAL CHANGES

The NRP was administratively supervised by the Regional Hydrologists, but decision making regarding programs, funding, and staffing was the responsibility of the Deputy ACHR&TC. This dual line of authority for the NRP did not function efficiently and, more importantly, it inhibited the development of a nationally coordinated program necessary to foster world-class research, a consideration vital to WRD, the Nation's premier water fact-finding organization. This dilemma was recognized and described by the Chief Hydrologist in WRD Memorandum 81.46:

> Since shortly after becoming Chief Hydrologist in the fall of 1979, I have been increasingly aware of the fact that many research personnel and senior members of the Water Resources Division are deeply concerned about several issues related to the Division's National Research Program—the program of research under the purview of the office of the Deputy Assistant Chief Hydrologist for Research. First and foremost, concern is expressed about the role of the National Research Program in the Water Resources Division. Second, numerous uncertainties and questions exist regarding how the Program is being managed and how it should be managed in the future.

Through WRD Memorandum 81.46, the Chief Hydrologist changed the line of supervision of the Regional Research Hydrologists from under the Regional Hydrologists. The Regional Research Hydrologists were placed directly under the Deputy ACHR&TC, with the strong admonition that they closely coordinate with the Regional Hydrologists and District Chiefs.

The reorganization of the NRP created a clear supervisory line of authority between the Deputy ACHR&TC and the Regional Research Hydrologist (the title was later changed to Chief, Branch of Regional Research). When Phil Cohen became Chief Hydrologist in 1979, Les Laird was the ACHR&TC. Roger Wolff replaced John D. Bredehoeft as Deputy ACHR&TC in the fall of 1979. During the Cohen years (1979–94), the following 14 people served in the position of Regional Research Hydrologist and(or) Chief, Branch of Regional Research:

Northeastern Region (1979–94):

Philip H. Carrigan, Jr. (1979–84)
James P. Bennett (1984–87)
David B. Grove (1987–92)
Mary Jo Baedecker (1992–94)

Southeastern Region (the Branch of Regional Research was discontinued in the Southeastern Region in 1986):

Robert A. Baker (1979–86)

Central Region (1979–94):

Lee C. Dutcher (1979–81)
Robert C. Averett (1982–85)
E. Michael Thurman (1985–87)
John B. Weeks (1988–94)

Western Region (1979–94):

Frank W. Trainer (1979–82)
T. John Conomos (1983–85)
Samuel N. Luoma (1986–87)
James P. Bennett (1987–90)
Frederick H. Nichols (1990–94)

To facilitate research throughout the Division, the Chief Hydrologist, in WRD Memorandum 81.81, adopted the Research Grade Evaluation Guide (RGEG) as the classification guidance document to be used to evaluate all research positions in the Division regardless of their organizational location. Many managers and scientists expressed concern about possible inequities that might result from the application of the research grade evaluation (RGE) system to positions in the operational program. However, RGE significantly enhanced the prospects for advancement of scientists in research positions. This improved the Division's ability to recruit and retain outstanding young scientists and raised the quality of science throughout the Division. With the implementation of RGE throughout WRD, the number of research positions increased considerably. In 1981, when Phil Cohen announced the Divisionwide RGE system, there were fewer than 100 positions classified under

the RGEG. When Phil Cohen retired in 1994, there were over 300 positions classified under the RGEG.

The RGE provided the opportunity for researchers to work and live in areas that suited their research interests and personal preferences. E.M. Thurman provides an excellent example of the benefits of the RGE system. In 1987, after 12 years in the NRP in Denver, Thurman transferred to the Kansas District where he was very successful in developing funding for his widely recognized research on the chemistry and fate of herbicides and their degradation products in hydrologic systems. He pioneered the development of analytical methods for herbicide degradates. His research in the Kansas District earned him Senior Scientist (ST) status, a grade significantly higher than any other scientist in the District, including his supervisor. This ability to advance while continuing to do science has resulted in a very productive, exciting relationship for researchers, WRD, and the USGS.

In WRD Memorandum 81.82, the Chief Hydrologist took an important step in providing management and technical oversight for the NRP. The Chief Hydrologist established a Research Committee that included the ACHR&TC, the Deputy ACHR&TC, the Discipline Office Chiefs, the Research Advisors, the Regional Research Hydrologists, the Regional Hydrologists, and the Regional Discipline Specialists. The Committee, chaired by the Deputy ACHR&TC, met annually to review the activities of the NRP, to coordinate NRP and operational programs, to establish staffing priorities, and to provide technical direction for the NRP.

In 1982, Laird transferred to the Western Region and Gordon Bennett became the ACHR&TC. In 1985, Bennett retired at about the same time Headquarters was reorganized to accommodate the Water Resources Research Institutes, which the Department of the Interior moved to the USGS. This reorganization resulted in the division of the office of the ACHR&TC into two ACH offices, one for Program Coordination and Technical Support (PC&TS) and one for Research and External Coordination (R&EC). The NRP was part of R&EC; the title of the manager of the NRP became Chief, Office of Hydrologic Research (OHR), and the title Regional Research Hydrologist became Chief, Branch of Regional Research. Roger Wolff remained as Chief, OHR, until he retired in 1994 and was replaced by Mary Jo Baedecker. The first ACHR&EC was Marshall Moss. In 1989, Moss transferred to Tucson, Ariz., and Robert Hirsch replaced him.

Hirsch was the ACHR&EC until 1994 when, upon Phil Cohen's retirement, Hirsch became Chief Hydrologist. Hirsch's clarity of thinking with regard to the role of the NRP in WRD can best be exemplified by his memorandum entitled "Research & Leadership Responsibilities," a masterful synthesis of many previous ideas about establishing and defining the role of the NRP in WRD. Hirsch defined the expectations and responsibilities of NRP personnel and the role of NRP within WRD and the science. This memorandum is still referred to when questions arise about the responsibilities of researchers and how beneficial research benefits the WRD.

To promote collaboration and communication among the growing number of researchers, Roger Wolff, the Chief, OHR, initiated a series of interdisciplinary research meetings. Each of these meetings brought together NRP and District researchers from two research disciplines. Wolff chose meeting places that encouraged the technical and informal interactions of the researchers from diverse locations, backgrounds and interests. These meetings were held between 1989 and 1991 and provided a forum for technology transfer and development of contacts for future interaction. These meetings were very successful endeavors that promoted collaboration and interdisciplinary research throughout the WRD. These interdisciplinary research meetings helped to facilitate the scientific collaboration that resulted in some of the Division's most noteworthy research projects. It is not possible in these pages to identify the numerous research projects involving literally hundreds of WRD scientists and support staff whose contributions have made the NRP and WRD a worldwide leader in water science. But, to highlight some of those contributions, five research projects are summarized below.

SELECTED RESEARCH HIGHLIGHTS DURING THE COHEN YEARS

Age Dating of Ground Water

Shallow ground-water supplies are valuable and renewable resources. Because they are generally younger (more recently recharged) than deeper ground-water supplies, they are more susceptible to contamination. USGS scientists, Niel Plummer and Ed Busenberg, developed techniques to use chlorofluorocarbons (CFC's) as tools for determining the age of

ground water up to 50 years. Probably better known to the public as Freon, CFC's enter ground water during the recharge process and thus provide excellent tracers and dating tools of young ground water. Knowledge about the age of ground water can be used to define recharge rates, develop hydrologic models of ground-water systems, predict contamination potential, and estimate remediation times for contaminated ground-water systems. These age-dating techniques are valuable tools for water-resources managers in developing management strategies for shallow ground-water systems.

Paleoclimate Research at Devils Hole

USGS scientists Ike Winograd, Tyler Coplen, Jurate Landwehr, Ken Ludwig, and Alan Riggs developed a 500,000-year global climate change record based on calcite deposits from Devils Hole, a cave in south-central Nevada. This record posed several challenges to the leading theory for the Pleistocene ice ages, the Milankovitch hypothesis, which attributes the ice ages to variations in insolation due to changes in the Earth's orbit. Although the Devils Hole record does not rule out the possibility that variations in insolation have a role in the ice age cycles, it does suggest that other factors are important. Other than Devils Hole, there are only two continuous paleoclimate records of the last half million years—the oxygen-isotope records from deep-sea sediments and the Antarctic ice core; both records are indirectly dated using models. The Devils Hole calcite samples are directly dated by radiometric techniques for which calcite is ideal.

The record from Devils Hole closely resembles the paleoclimate records from deep-sea sediments and the Vostok Antarctic ice core, but there are significant differences in the timing and duration of events. Understanding the differences in these records is a primary key to understanding climate and climate change. As noted in *Discovery Magazine* (May 1989, page 75), "If you wanted to find out what causes ice ages and you had the whole planet to search for clues, you'd probably never even think of heading for Devils Hole, Nevada."

Natural Organics

While scientists in other agencies were concentrating on studies of manmade pesticides, USGS scientists recognized the need to study humic and fulvic acids, naturally occurring organic compounds. Little was known about the chemistry or source of such compounds in water even though more than 90 percent of the organic solutes in water are of natural origin. WRD research by Ron Malcolm, Bob Wershaw, Mike Thurman, Jerry Leenheer, George Aiken, Diane McKnight, and others led to the recognition that dissolved organic compounds complex trace metals, transport pesticides, and form carcinogens upon chlorination, in addition to being a food source for aquatic organisms. WRD researchers became world leaders in this field. They developed many of the techniques used to isolate and characterize natural organic compounds, and they helped create and organize the International Humic Substances Society to promote research on natural organics.

Mississippi River Study

Although the Mississippi River System drains water from 31 States and is the source of 23 percent of the public surface-water supplies for the United States, there had not been a systematic water-quality study of the entire length of the Mississippi River prior to the USGS study. In 1987, the study began by assessing the water quality of the Mississippi River System downstream from St. Louis, including assessing the contributions from the Missouri and Ohio Rivers. In 1991, the study was expanded at the request of Congress to cover the entire Mississippi River System. The study incorporated methods for representative sampling of large rivers that USGS scientists Herb Stevens, Carl Nordin, and Robert Meade, among others, had developed originally in studies of the Columbia, Amazon, and Orinoco Rivers. The USGS coordinated activities with various State agencies along the Mississippi River, as well as with the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers.

The Mississippi River study was conducted under the leadership of Meade, who designed and coordinated the study, Jerry Leenheer, who led a stellar team of organic and inorganic chemists, and John Moody, who organized and scheduled the data-collection elements of the investigation. Dozens of USGS scientists were involved in the data collection and analysis leading to the water-quality assessment of the Mississippi. The study demonstrated that sewage contamination in the river has been decreasing since

the enactment of the Clean Water Act of 1972. Atrazine, a preemergent herbicide used mostly on cornfields, and ethylene diamine tetracedic acid (EDTA), a general indicator of industrial contamination, were found in relatively high concentrations especially near St. Louis. PCB's were found to have persisted in Mississippi River sediments even though their disposal into the river had been banned years before the study began. Results from a cooperative study with the U.S. Fish and Wildlife Service indicated that PCB's found in fish are being remobilized from bottom sediments.

San Francisco Bay

USGS scientists, including John Conomos, Dave Peterson, Fred Nichols, Sam Luoma, Ralph Cheng, Jim Cloern, Jan Thompson, and others, have conducted estuarine research in San Franciso Bay since 1968. The Asian clam, *Potamocorbula amurensis*, was first detected in the bay in October 1986 and probably arrived in ballast water of cargo ships from China. Within months of its first detection, it became the most abundant benthic organism in the northern part of the bay (Suisun Bay) near the mouths of the Sacramento and San Joaquin Rivers. Its great abundance and its efficient filtering of food particles from water changed the ecosystem of the bay, nearly eliminating phytoplankton from the water of Suisun Bay and causing a major change in the food web. Native species that depend on phytoplankton for food were deprived of food, and their abundance declined.

Since the 1970's, the USGS has monitored water quality in sediments and organisms near the outfall of the Palo Alto Wastewater Treatment Plant. In the late 1970's, USGS scientists under the direction of Sam Luoma demonstrated that there was substantial contamination in the aquatic biota. Copper and silver concentrations were affecting the health and survival of resident invertebrates and, thereby, other aquatic organisms in the bay, and mammals and birds in a nearby marsh refuge. Because of these findings, improvements in treatment-plant operations and source-control programs have decreased contamination in sediments and aquatic organisms.

NRP scientists, their discipline, and their duty station in 1994 are given in the following list:

Office of Hydrologic Research, 1994

Office of Hydrologic Research, Reston
Wolff, Roger G.
Friedman, Linda C.

EASTERN REGION BRANCH, RESTON

Office of the Chief
Baedecker, Mary Jo
Shultz, David J.

GROUND-WATER HYDROLOGY

Transport Modeling in Saturated Zone
Konikow, Leonard F.
Granato, Gregory E.

Subsurface Transport Phenomena
Voss, Clifford I.

Reaction Transport Phenomena
Sanford, Ward E.

Transport Phenomena in Fractured Rock
Shapiro, Allen M.

Flow in Tight Media
Neuzil, Christopher E.

Heterogeneous Controls on Ground Water
Reilly, Thomas E.

Multivariate Statistics in Geohydrology
Brown, Charles E.

SURFACE-WATER HYDROLOGY

Regression and Data-Network Design
Tasker, Gary D.

Regional Hydrologic Processes
Landwehr, Jurate M.

Numerical Simulation of Surface-Water Hydrodynamic Processes
Baltzer, Robert A.
Jenter, Harry

Modeling Hydrodynamic Systems
Schaffranek, Raymond W.

Surface-Water Transport
Lee, Jonathan K.

ECOLOGY

Wetland Studies
Carter, Virginia P.
Rybicki, Nancy B.

Vegetation and Hydrogeomorphology
Yanosky, Thomas M.

Microbial Geochemical Models
Lovley, Derek R.
Phillips, Elizabeth J.
Woodward, Joan C.
Widman, Peggy

GROUND-WATER CHEMISTRY

Geochemical Constituents in Ground Water
Back, William
Wicks, Carol M.

Organic Degradation
Cozzarelli, Isabelle M.
Phinney, Curtis S.
Tran, My-Chau T.

Transport and Fate of Organics
Eganhouse, Robert P.
Bryant, Wendy R.

Ground-Water Dispersion
Wood, Warren W.

Paleoclimatology/Aquifer Geochemistry
Winograd, Isaac J.

Water Quality and Health
Feder, Gerald L.

Kinetic Modeling
Plummer, L. Niel
Busenberg, Eurybiades
Glynn, Pierre D.
Van Hoven, Raymond L.
Williams, Rosalynd A.
Wayland, Julian E.

Mineral/Water Interaction
Jones, Blair F.
Webster, Daniel M.
Libby, Brenda

Isotope Fractionation
Coplen, Tyler B.
Revesz, Kinga M.
Hopple, Jessica A.
Michel, Robert L.

Nitrogen Isotope Laboratory
Bohlke, Johnkarl F.P.
Gwinn, Cynthia J.

Radioisotopes in Ground Water
Kraemer, Thomas

SURFACE-WATER CHEMISTRY

Sediment/Water Exchange of Nutrients
Callender, Edward
Deike, Ruth G.

Geochemical Cycling of Trace Elements and Nutrients
Bricker, Owen P.
Kennedy, Margaret M.
Kuebler, Anne
Shackelford, Philip M.
Anderson, Robert T.

Speciation of Metals
Simon, Nancy S.
Dennen, Kristin O.
Landa, Edward R.

NATIONAL RESEARCH PROGRAM, ER, WOODS HOLE, MASSACHUSETTS

SURFACE-WATER CHEMISTRY

Carbon Fluxes
Sundquist, Eric T.
Davis, Holly C.

NATIONAL RESEARCH PROGRAM, ER, PRINCETON, NEW JERSEY

SURFACE-WATER HYDROLOGY

Hydrology in Atmospheric GCM
Milly, Christopher
Dunne, Krista A.

CENTRAL REGION BRANCH, DENVER

Office of the Chief
Weeks, John B.
Peart, Dale B.
Anderson, Barbara J.
Carey, William P.

Geochemical Kinetics Studies
Claassen, Hans C.
Halm, Douglas R.

Simulation of Subsurface-Water Flow
Cooley, Richard L.
Hill, Mary C.

Bedload Transport Research
Emmett, William

Chemistry of Sediment Surfaces
Goldberg, Marvin C.

Ground-Water Transport
Grove, David B.

Paleohydrology and Climate Change
Jarrett, Robert D.

Solute Transport Simulation

Kipp, Kenneth L.
Stollenwerk, Kenneth G.

Hydrological Biogeochemical Interactions
LaBaugh, James Wesley

Precipitation-Runoff Modeling
Leavesley, George H.
Lichty, Robert W.
McCabe, Gregory J.
Fountain, Andrew G.
Stannard, Linda G.
Hay, Lauren E.

Movement and Storage of Sediment in Rivers
Meade, Robert H., Jr.

Sediment-Transported Pollutants in the Mississippi River
Meade, Robert H., Jr.
Moody, John A.

Application of Stochastic Processes in Hydrogeology
Naff, Richard

Sediment Impacts from Disturbed Lands
Osterkamp, Waite R.
Miller, Andrew J.

Borehole Geophysics
Paillet, Frederick L.
Morin, Roger
Taylor, Ticie A.

Coupled Flow and Reactions
Parkhurst, David L.

Environmental Interfaces
Striegl, Robert G., Jr.
McConnaughey, Edward

Chemical Modeling
Thorstenson, Donald C.

Statistical Analysis of Errors in Hyhdrologic MOdels
Troutman, Brent M.
Karlinger, Michael R.
Vecchia, Aldo V.

Unsaturated Zone Field Studies
Weeks, Edwin P.
Healy, Richard W.
Anderson, Dean E.
Stannard, David I.
Tindall, James A.

Channel Morphology
Williams, Garnett P.

Hydrology of Lakes
Winter, Thomas C.
Rosenberry, Donald O.
Parkhurst, Renee S.

Sorption and Partition Phenomena
Chiou, Cary T.
Kile, Dan E.
Rutherford, David W.

Comprehensive Organic Analyses
Leenheer, Jerry A.
Barber, Larry B. II
Noyes, Ted I., Jr.
Brown, Gregory K.

Organic Hydrogeochemistry
Malcolm, Ronald L.
Kennedy, Kay R.

Organic Substances in Streams
Rathbun, Ronald E.
Rostad, Colleen E.

Organic Polyelectrolytes
Wershaw, Robert L.
Thorn, Kevin A.

Organic Carbon Migration - Boulder
Aiken, George R.

River Mechanics - Boulder
Andrews, Edmund D.

Ecological Interaction of Lakes and Streams - Boulder
Averett, Robert C.
Campbell, Wesley L.

Arid Regions Climate - Boulder
Benson, Larry
Hostetler, Steven W.

Clay/Water Reaction - Boulder
Eberl, Dennis D.
May, Howard M.

Bacteria/Contaminant Interactions - Boulder
Harvey, Ronald W.
Metge, David W.

Biology of Lakes and Reservoirs - Boulder
Marzolf, G. Richard

Organic/Trace Metal Interaction - Boulder
McKnight, Diane M.
Harnish, Richard A.

Chemical Modeling and Thermodynamic Data - Boulder
Nordstrom, D. Kirk
Ball, James E.
Cunningham, Kirkwood M.

Corrosion by Wet Precipitation - Boulder
Reddy, Michael M.
Schuster, Paul

Flow and Sediment Mechanics - Boulder
Smith, J. Dungan
Wiele, Stephen M.

Microbial Geochemistry of Organic Matter in Water - Boulder
Smith, Richard L.
Brooks, Myron H.

Sediment/Water Chemistry in Large Rivers - Boulder
Stallard, Robert F.
Axtmann, Ellen V.
Martin, Deborah A.

Inorganic Constituents in Water - Boulder
Taylor, Howard E.
Peart, Dale B.
Antweiler, Ronald C.
Brinton, Terry I.

WESTERN REGION BRANCH, MENLO PARK

Office of the Chief
Nichols, Frederic H.
Alpine, Andrea E.
Dileo-Stevens, Jeanne S.
Jones, David R.

ECOLOGY

Plankton Dynamics
Cloern, James E.
Powell, Thomas M.
Cole, Brian E.
Canuel, Elizabeth A.
Rudek, Joseph
Wienke, Sally M.

Microbial Ecology, Ground Water
Godsy, Edward M.
Warren, Ean M.

Solute Transport Processes Involving Biota
Kuwabara, James S.
Chang, Cecily C.

Trace Elements
Luoma, Samuel N.
Carter, James L.
Cain, Daniel J.
Fend, Steven V.
Van Geen, Alexander
Brown, Cynthia L.
Hornberger, Michelle I.
Kennelly, Susan S.

Estuarine Benthic Community Dynamics
Nichols, Frederic H.
Thompson, Janet K.
Parchaso, Francis

Microbial Ecology, Surface Water
Oremland, Ronald S.
Culbertson, Charles W.
Miller, Laurence G.
Blum, Jodi Switzer

Estuarine Biogeochemistry
Peterson, David H.
Schemel, Laurence E.
Smith, Richard E.
Hager, Stephen W.

Limnology
Slack, Keith V.
Tilley, Larry J.

Biota/Solute Transport Interface
Triska, Frank
Jackman, Alan P.
Avanzino, Ronald J.
Duff, John H.

GROUND-WATER CHEMISTRY

Stable IsotopeTracers
Kendall, Carol
White, Lloyd D.
Huebner, Mark
Silva, Steven R.

Partitioning of Solutes Between Solid and Aqueous Phases
Davis, James A.
Fuller, Christopher C.
Kent, Douglas B.
Anderson, Linda D.
Coston, Jennifer A.
Rea, Brigid A.

Chemistry of Aquatic Organic Matter
Goerlitz, Donald F.

Unsaturated Zone Chemical Processes
James, Ronald V.

Geothermal: Hydrogeochemistry of Fine-Grained Sediments
Kharaka, Yousif K.
Ambats, Gil
Thordsen, James J.

Geothermal: Hydrogeochemistry of Cascade Range
Mariner, Robert H.
Carothers, William W.
Evans, William C.

Kinetics of Water/Rock Interaction
White, Arthur F.
Bullen, Thomas D.
Presser, Theresa S.
Blum, Alex E.
Peterson, Maria L.
Schulz, Marjorie S.

GROUND-WATER HYDROLOGY

Well-Strain Meters
Bredehoeft, John D.
Riley, Francis S.

Getzen, Rufus T.
McPherson, Brian J.
Abrams, Robert H.

Temperature Effects in the Unsaturated Zone
Constantz, James E.
Green, Timothy R.

The Fate and Transport of Immiscible Contaminants in the Subsurface
Essaid, Hedeff I.
Dillard, Lesslie A.

Ground-Water Monitoring Network Design
Wagner, Brian J.
Hyndman, David W.

Nonisothermal Multiphase Flow
Herkelrath, William N.
O'Neal, Clyde F. II
Murphy, Fred

Hydrology of Fractured Rocks
Hsieh, Paul A.
Goode, Daniel J.
Tiedeman, Claire

Geothermal: Heat and Mass Transport
Ingebritsen, Steven E.
Scholl, Martha A.

Unsaturated-Zone Flow
Nimmo, John R.
Shakofsky, Stephanie M.

Analytical Modeling of Aquifers
Moench, Allen F.

Unsaturated Zone Theory
Rubin, Jacob
Curtis, Gary P.

Geothermal: Modeling Geothermal Systems
Sorey, Michael L.
Colvard, Elizabeth M.

Infiltration and Drainage
Stonestrom, David A.
Akstin, Katherine C.

SURFACE-WATER CHEMISTRY

Chemistry of Hydrosolic Metals and Constituents of Natural Water
Hem, John D.
Lind, Carol
Vivit, Davison V.

Solute Transport Processes in Low-Flow Streams
Kennedy, Vance C.

Fate and Transport of Organic Contaminants
Pereira, Wilfred E.
Hostettler, Frances D.

SURFACE-WATER HYDROLOGY

Flow and Geochemical Interactions
Bencala, Kenneth E.
Zellweger, Gary W.

Mathematical Modeling Principles
Bennett, James P.

Fluvial Mechanics
Chen, Cheng-lung
Ling, Chi-Hai

Estuarine Hydrodynamics
Cheng, Ralph T.
Burau, Jon R.
Gartner, Jeffrey W.
McDonald, Ellen T.
Gross, Edward

Research Vessel Polaris Operations
Conomos, T.J.
Richards, Byron J.
Conard, William S.

OFFICE OF EXTERNAL RESEARCH

By John E. Schefter

The Office of External Research was established in 1984 following the transfer of responsibility for administration of the provisions of the Water Resources Research Act to the U.S. Geological Survey. Principal among these provisions was administration of the State Water Resources Research Institutes and a national competitive research grant program first authorized by the Water Resources Research Act of 1964.

The Water Resources Research Act of 1964 established a Water Resources Research Institute in each State and Puerto Rico. Subsequent amendments to the Act authorized Institutes in the District of Columbia, the U.S. Virgin Islands, Guam, the Federated States of Micronesia, the Commonwealth of the Northern Mariana Islands, and American Samoa. By 1983, there were 54 Institutes, one in each State, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and Guam.

Administration of the Institutes and of the other provisions of the Act was initially vested in the Office

of Water Resources Research (OWRR) within the Department of the Interior. In 1974, the OWRR was merged with the Department of the Interior's Office of Saline Water to form the Office of Water Research and Technology (OWRT).

In the late 1970's, the House of Representatives Interior Appropriation Subcommittee recommended that OWRT be placed under the auspices of the USGS. No action was taken to effect this transfer. The OWRT was abolished by Secretarial Order on August 25, 1982, and the responsibility for the administration of the Institutes was vested with the Office of Water Policy within the U.S. Department of the Interior. Administration of the national competitive research grant program was transferred to the Bureau of Reclamation.

The Conference Report accompanying the fiscal year 1984 Interior and Related Agencies Appropriations Act again recommended that the Institute Program be placed under the USGS. The Office of Water Policy was abolished by Secretarial Order on October 19, 1983, and the Institute Program was transferred to the USGS at that time. The Institute Program was temporarily placed within the Water Resources Division under the Assistant Chief Hydrologist for Operations.

On October 18, 1983, the Chief Hydrologist directed Bob Averett to convene a 2-day conference to consider the implications of the transfer of the Water Resources Research Act programs to the USGS. The conference was held at Airlie House in suburban Washington, D.C., on January 10–12, 1984, and involved 43 people representing research, operations, and management personnel from the Districts, Regions, and Headquarters. The conferees produced a range of recommendations constrained by the nature of the reauthorization and continued funding of the Water Resources Research Act.

At the time the conference was held, reauthorization of the Water Resources Research Act was before the Congress and its fate was not certain. Congress passed the Act, the President vetoed it, and Congress overrode the President's veto. The Water Resources Research Act of 1984, which became Public Law 98–242 on March 22, 1984, reauthorized the State Water Resources Research Institute Program. It also reauthorized the national competitive grant program administered by the Bureau of Reclamation.

On August 9, 1984, the Chief Hydrologist established two committees to address the organization of the Water Resources Division given its new responsibilities under the Water Resources Research Act of 1984. A committee consisting of Hal Langford (chair), Gordon Bennett, Bruce Gilbert, and Bill Mann was directed to address the organizational structure and staffing to meet the expanded mission of the Division. A second committee composed of Marshall Moss (chair), Tom Buchanan, Roger Wolff, and Bob Hirsch was directed to consider the planning, documentation, and activities needed to successfully meet the Survey's responsibilities under the Act.

The primary organizational consequence of the deliberations of these committees was the establishment of the Office of the Assistant Chief Hydrologist for Research and External Coordination. This Office was given responsibility for administration of the programs authorized by the Water Resources Research Act and for administration of the National Research Program (NRP), which had previously been under the Assistant Chief Hydrologist for Research and Technical Coordination. Marshall Moss was selected to serve as the Assistant Chief Hydrologist for Research and External Coordination.

On January 24, 1985, the national competitive research grant program was transferred from the Bureau of Reclamation to the U.S. Geological Survey. This action was urged by several in the academic community and by Senators Stafford, Randolf, Abdnor, and Moynihan of the Senate Committee on Environment and Public Works in a joint letter to Secretary Clark on May 16, 1984. The USGS was designated as the administrator of the Water Resources Research Act of 1984 by Secretarial Order on February 28, 1985.

On that same date, the Chief Hydrologist provided a status report on the actions taken to absorb the Water Resources Research Act programs into the Division. He announced that Frank Carlson was to serve as Chief of the State Water Institute Program unit and Robert Madancy as the Chief of the Water Research Grant Program unit within the Office of External Research. Other individuals transferred to the USGS with the Water Resources Research Act programs included Quentin Florey, Madge Ertel, and Georgia Thomas, who were initially assigned to the State Water Institute Program unit, and Frank Coley, Sid Johnson, Bob Robinson, Melvin Lew, Ewel Mohler, Allen Ford, Donna Perry, and Virginia Hogan, who were initially assigned to the Water Research Grant Program unit.

One of the first tasks facing the Office of External Research was an onsite evaluation of all 54 institutes, as required by the Water Resources Research Act. Five-person teams, consisting of a USGS team leader, an Institute Director, a university faculty member or administrator, a State water agency representative, and a private citizen, conducted the evaluations. The composition of the team varied, but all evaluation teams were accompanied by Madge Ertel, who usually served as executive secretary to the team, though she served as team leader on occasion. The designated team leaders were Jeff Armbruster, Jim Blakey, Charles Boning, Philip Emery, Ivan James, Grady Moore, and Garald Parker. All 54 institutes were evaluated between September 1985 and June 1987.

As a result of the evaluations, six institutes were placed on probation and given 1 year to remedy deficiencies in their programs. All were eventually removed from probation.

John Schefter replaced Frank Carlson as Chief of the Office of External Research in November 1989. By that time, the staff of the Office of External Research had been reduced to Quentin Florey and Allen Ford, who were assigned to the Institute Program, and Mel Lew, who was assigned to the Water Research Grant Program. Pamela Murray served as secretary to the Office.

The State Water Institute Program did not fare well in the budget process, especially in the President's budget requests. The President's fiscal year 1986 budget requested $5.2 million for the Institutes, down about $1 million from fiscal year 1985, and Congress appropriated $6.2 million. The President's fiscal year 1987 budget again requested $5.2 million for the Institutes, and Congress appropriated $5.7 million. In fiscal year 1988 the President's budget request for the Institutes was reduced to $4.6 million, and again Congress appropriated $5.7 million. The President's budgets for fiscal years 1989 through 1993 requested about $2.8 million for the Institutes, and the Congress appropriated between $5.5 and $5.7 million for the program in these years. This pattern was temporarily broken in fiscal year 1994, when the Congress appropriated the full $5.5 million requested in the President's budget.

The Water Research Grant Program fared even more poorly in the budget process. The President's fiscal year 1986 budget requested $2.5 million for the program, while Congress appropriated $4.8 million. For fiscal year 1987, the request was reduced to $2.0 million and the appropriation was $4.4 million. The President's budget requests for fiscal years 1988 through 1982 stood at about $1.8 million, and Congress appropriated between $4.3 and $4.4 million each year until fiscal year 1992, when the appropriation dropped to $1.8 million. After fiscal year 1992 the President's budgets did not request funds for the Water Research Grant Program and Congress did not provide an appropriation. The research grant program was therefore terminated at the end of fiscal year 1992, and Mel Lew was reassigned to the Assistant Chief Hydrologist for Operations shortly thereafter.

The Water Resources Research Act of 1984 was reauthorized again in 1990 by Public Law 101–397. The Administration opposed the reauthorization but signed it into law after it was passed by the Congress.

In 1991, the Federated States of Micronesia (FSM) joined the Institute Program. Though another territory was represented in the program, the number of institutes remained at 54 because the FSM joined Guam in forming a regional institute.

As of 1994, the Office of External Research, consisting of John Schefter, Allen Ford, and Pamela Murray, continued to administer the State Water Resources Institute Program.

OFFICE OF INTERNATIONAL HYDROLOGY (1979–85) AND INTERNATIONAL WATER RESOURCES PROGRAM (1985–94)

By Jerry C. Stephens, Anna M. Lenox, and William J. Shampine

INTRODUCTION

The USGS has been involved in water-resources activities in foreign countries for more than a century. A memorandum from Chief Hydrologist Philip Cohen in 1988 summarized WRD's international activities as follows in WRD Memorandum 88.65, dated July 28, 1988:

> Since the 1890's, USGS water scientists have been assigned from time to time to overseas activities under special bilateral agreements with other countries or in support of other U.S. Federal agencies' foreign programs. For many years, USGS scientists have actively participated in water-related international professional and technical organizations and collaborated with counterpart scientists from other countries in research and related activities. As a recognized world leader in water-

resources studies, the USGS also provides formal training courses and on-the-job training opportunities for foreign scientists, engineers, and technicians.

Until 1985, responsibility for oversight of WRD's international activities was assigned to the Office of International Hydrology (OIH) and its predecessors, reporting directly to the Chief Hydrologist. A reorganization of Headquarters functions in 1985 reassigned international activities to the new Assistant Chief Hydrologist for Research and External Coordination (ACH/REC), Marshall Moss. At that time, OIH was abolished, its staff reassigned to the office of the ACH/ REC, and its primary functions assigned to the newly created International Water Resources Program (IWRP).

PERSONNEL

Numerous staff changes, brought on by reorganization, reassignments, retirements, and policy and budget limitations, took place in OIH and IWRP during 1980–94. James R. Jones, Chief of OIH after 1975, retired in 1980 and was replaced by Della Laura, who continued in that position until the 1985 reorganization. Anna Lenox, who joined the OIH staff in 1984, assumed leadership of the new IWRP in 1985 under the direction of Marshall Moss and his deputy, Jerry Stephens. Moss transferred to Arizona in 1987 and was succeeded by Robert Hirsch as ACH/REC. Stephens retired in 1990 but continued to assist IWRP on a part-time basis until 1994. By 1994, IWRP principal staff consisted of Anna Lenox and Daisie Oden, under Hirsch's direction. District and Research program offices were called upon as needed to supply the scientific and technical expertise required to meet the Division's international commitments.

BILATERAL PROGRAMS

Saudi Arabia—The Saudi Arabia water-resources program began in 1976 as a part of the United States–Saudi Arabia Joint Economic Commission of Riyadh (JELOR). It was based in Riyadh in the Ministry of Agriculture and Water. Principal U.S. agencies were the U.S. Departments of Agriculture and the Interior.

In 1980, WRD staff on long-term assignments in Riyadh included Gordon Tibbitts, Jr. (Project Chief), James Williams (Ground-Water Specialist), Willard Mills (Surface-Water Specialist), William Shampine (Water-Quality Specialist), Lester North (Computer Specialist), and Donald Moore (Water Atlas Project Chief).

From 1979 to 1986, the following WRD employees were on long-term assignments with the Saudi Arabia program:

Tibbitts, Gordon C., Jr. 1979–84
Moore, Donald O. 1979–85
Mills, Willard B. 1981–85
Shampine, William J. 1979–82
North, Lester D. 1981–86
Shaw, Robert A. 1982–86
Adorno, William G. 1982–83
Handy, Alonzo H. 1982–86
Tucker, Roger 1982–86
Williams, James F. 1980–84
Adolphson, Donald G. 1982–84
Westmoreland, Edwin O. 1982–84
Doraiswamy, Paul C. 1982–86
Williams, Henry F., Jr. 1982–85

A number of other specialists were involved on short-term assignments.

By 1985, the JECOR was focusing more on agriculture, and funding became inadequate to maintain the WRD work. As a result, the Department of the Interior withdrew from JECOR and the WRD Saudi Arabia program was terminated in 1986. Among specific accomplishments of the 10-year program were these:

1. Establishment of a computer system for the Ministry of Agriculture and Water, which program staff helped to design (including the building housing it) and implement;
2. Importation of the USGS Ground-Water Site Inventory concept and the water-quality portion of WATSTORE;
3. Compilation and entry of all available water-quality data in the Kingdom into the system, and publication of those data;
4. Installation of 200 crest-stage gages in a new monitoring program and institution of well-logging and water-quality sampling programs; and
5. Publication of the "Water Atlas of Saudi Arabia."

China—In the late 1970's, United States–Sino relations experienced a warming trend. President Carter and Vice Premier Deng signed a basic science and technology agreement early in 1979 that signified increased support of the field of science. As a result,

relations between the United States and China increased exponentially. As USGS sister agencies opened their doors to Chinese scientists, the USGS initiated a Protocol for Scientific and Technical Cooperation between the United States and the People's Republic of China (PRC) in the Study of Surface Water Hydrology. In October 1981, the Director of the USGS and the Director of the Department of Hydrology of the PRC Ministry of Water Resources signed the initial protocol. This protocol spanned 5 years and was extended in 1986, 1991, and again in 1996. The agreement supported a vast array of scientific and technical activities including the exchange of hydrologic instrumentation, studies in the fields of sedimentology and water quality, and a wide array of projects on hydrologic extremes. The protocol also supported a flood-forecasting annex between Chinese and National Weather Service scientists. The Surface-Water Protocol fostered long-term collaborative research and the sharing of scientific and technical data, and the agreement proved to be an effective mechanism for technology transfer among hydrologists in the United States and China. Chinese scientists traveled to the United States and USGS scientists traveled to China. The opened door provided a positive opportunity for USGS participants and contributed to bringing Chinese hydrological science into the 20th century.

United Arab Emirates—In 1986, influenced by the success of the WRD program in neighboring Saudi Arabia, the Emirate of Abu Dhabi, United Arab Emirates, requested USGS to undertake a study of the Emirates' ground-water resources. Following a 6-week reconnaissance in 1986 by an interdivisional USGS team led by Joel Kimrey, and with strong support form the U.S. Department of State, an agreement was reached in 1987 by the Chairman of the Abu Dhabi National Drilling Company, the sponsoring agency of the Emirate government, the U.S. Ambassador to the UAE, and Marshall Moss, on behalf of the USGS, to initiate the Abu Dhabi Ground-Water Project.

From 1987 through 1994, WRD staff on long-term assignment to project headquarters in Al Ain, UAE, were the following:

Kimrey, Joel (Project Chief) 1987–94
Jorgensen, Donald (Project Chief 1990–>1994
Nassar, Edmund 1987–90
Smith, Patrick 1987–89
Villanueva, Edward 1989–91
Williams, George 1992–94
Signor, Donald 1987–93
Young, Harley 1987–90
Hutchinson, Craig 1992–>1994
Maddy, David 1987–92
Stuthman, Neil 1992–>1994
Smith, Patricia 1987–89
Hayes, Eugene 1992–93
Imes, Jeffrey L. 1990–93
Bright, Daniel J. 1993–94
Gillespie, Joseph 1991–92

Two geologists were assigned to the project by the Geologic Division from 1987 through 1993, and a number of WRD District and Research Program specialists were detailed to the project at various times for advice and assistance. Oversight of the project by WRD Headquarters on behalf of ACH/REC was largely the responsibility of Jerry Stephens from 1987 through 1993 and of Anna Lenox after 1993.

MULTINATIONAL PROGRAMS

Middle East Water Resources Working Group—At the bilateral Arab-Israeli peace negotiations initiated in Madrid in October 1991, several specific issues critical to Mideast peace were identified. In Moscow in January 1992, the negotiating parties formed multilateral working groups to address each of these issues. Some 40 countries plus the European Union (EU) and the Palestinians agreed to participate in the working groups, one of which was focused on Mideast water resources.

The United States was designated to chair the Water Resources Working Group (WRWG). In March 1992 the Department of State formed an advisory group of representatives of U.S. governmental agencies to support and assist their efforts. Jerry Stephens and Anna Lenox represented the USGS; other agencies represented were NOAA/NWS, U.S. Army Corps of Engineers, USAID, Department of State, and the Bureau of Reclamation. One of the topics addressed at the first WRWG meeting in Vienna in May was water-data enhancement, for which the USGS was requested to provide the principal technical support. Stephens and Kenneth Lanfear were members of the U.S. delegation to Vienna, where Lanfear made a presentation on real-time data acquisition and mapping, based on work done in the South Carolina District of WRD.

At the Washington WRWG meeting in September 1992, Stephens gave a summary briefing

on NAWDEX. Lenox was requested to plan a study tour of the Colorado River Basin for WRWG members to demonstrate water-data requirements for water development and management on a regional basis. That plan was accepted by WRWG at its April 1993 meeting in Geneva, Switzerland, and the tour for 21 WRWG members was conducted July 11–22 under Lenox's leadership, with participation by numerous USGS staff in Denver, Salt Lake City, and Phoenix.

In May 1993, the Department of State selected USGS to head an international mission to develop a viable approach to data sharing and a long-range plan for meeting water-related training needs of Mideast participants. A water-data questionnaire developed by USGS and supported by the EU was distributed to regional participants in August. Jack Fischer and Lenox were delegates to the October 1993 meeting in Beijing, where they presented USGS proposals for workshops on modeling the Jordan River and on standardization of data-collection methods. Both proposals were accepted by the WRWG, as was the concept of a Mideast regional data bank.

The international mission on data sharing visited Israel, the Occupied Territories, Jordan, and Egypt in January 1994, with Verne Schneider and Irwin Kantrowitz representing the USGS. In February, Schneider, Kantrowitz, and Lenox completed a draft plan for implementing a regional data bank as a followup to the Beijing meeting. Also in February, James Blakey served as U.S. representative to a French-hosted water-data study tour.

The USGS-developed workshop on standards for water-data acquisition and processing proposed at the Beijing meeting was held for WRWG participants in March 1994 in Atlanta. In April, Jack Fischer proposed to the WRWG meeting in Muscat, Oman, that the United States work with regional representatives on an approach to achieving the recommendations of the Atlanta workshop, including establishment of a Palestinian data bank. Lenox, Schneider, Blakey, and Shampine prepared a draft implementation plan for the data bank, which was presented and accepted at the WRWG meeting in Athens in November 1994.

The Mideast WRWG activities, with significant WRD involvement and support, are ongoing.

International Hydrological Program—The International Hydrological Program (IHP) was initiated in 1975 by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) as a followup to the International Hydrological Decade. The Department of State chartered a U.S. National Committee on Scientific Hydrology, chaired by the Chief Hydrologist and with membership by U.S. water-related governmental and professional organizations, to oversee U.S. participation in the IHP. Della Laura, as Chief of OIH, served as Executive Secretary to the Committee from 1980 to 1985; Jerry Stephens was Acting Executive Secretary from 1986 to 1993, when he was succeeded by William Shampine.

Lack of significant funding, a reflection of the concerns of the U.S. Congress with UNESCO at that time, severely limited U.S. contributions to the IHP. The available funds enabled the National Committee to support participation by U.S. scientists in some IHP-sponsored conferences and to partially support a few small IHP projects. As usual, USGS scientists were among the leaders in making these limited contributions. The funding support from the Department of State continued at a low level well beyond 1994.

Education and training of foreign participants—The Water Resources Division has been active in the education and training of foreign participants in water-related subjects since the 1940's. During the years Philip Cohen was Chief Hydrologist, these activities continued, largely through specialized courses at the National Training Center (NTC) and through on-the-job training in District Offices. During 1981–94, 356 individual trainees from 63 countries received a total of nearly 3,000 weeks of training with WRD.

Much of this training was provided through a course initiated in 1972 and offered annually or biennially through 1981. In 1982, this "Techniques of Hydrologic Investigations for International Participants" course was presented at Colorado School of Mines in Golden, Colo., through contractual arrangements with WRD retirees, with Ivan Johnson as course coordinator and OIH providing administrative support. In 1983, the course was moved to the NTC in Denver, where it was offered annually through 1991.

During its 20-year history, this course attracted an annual average of about 18 trainees from 11 countries. By 1992, although applications remained numerous, funding support for potential attendees had become inadequate. The course was last held in 1991.

A major training effort in 1992 brought 33 USAID-supported scientists from the Ground Water Board of India to WRD District Offices for an average of 16 weeks each of on-the-job training. This program, administered by Daisie Oden in IWRP, was originally

proposed by senior Ground Water Board officials who had worked with and been favorably influenced by P.H. Jones, J.R. Jones, N.E. McClymonds, E.A. Sammel, R.H. Johnston, and other USGS scientists who had worked in India during the 1960's and 1970's.

SCIENTIFIC PUBLICATIONS AND DATA MANAGEMENT (1979–84)/ SCIENTIFIC INFORMATION MANAGEMENT (1984–94)

By Douglas R. Posson, Tom H. Yorke, John E. Moore, James F. Daniel, and Robert J. Dingman

The office of the Assistant Chief Hydrologist for Scientific Publications and Data Management (SP&DM) changed substantially as the Water Resources Division and the other Divisions of the USGS migrated from a mainframe computing environment to a distributed computing environment. In 1979, virtually all the hydrologic data collected by District personnel were processed on a mainframe computer in Reston, Va. By 1995, all the data processing and data management were done at the District level, and much of the data were being provided to users through the Internet.

The following individuals held management positions and were responsible for helping move WRD toward a solid footing in data management in the 21st century.

Assistant Chief Hydrologist for Scientific Publications and Data Management
- Robert J. Dingman 1981–82
- James E. Biesecker 1982–85

Assistant Chief Hydrologist for Scientific Information Management
- James F. Daniel 1985–94

Deputy Assistant Chief Hydrologist
- Solomon M. Lang 1979
- John E. Moore 1980–89

Branch of Computer Technology
- Ronald J. Jones 1983–86
- Gary C. Cobb 1986–94

Automatic Data Processing Section
- Charles R. Showen 1979

National Water Data Exchange Program
- Melvin D. Edwards 1979–87
- James S. Burton 1989–94

WATSTORE Program
- Charles R. Showen 1982–87

Reports Section
- Granville A. Billingsley 1980

Branch of Scientific Publications
- Eugene R. Hampton 1982–93

National Water Use Program
- William B. Mann 1981–86
- Wayne B. Solley 1987–94

Distributed Information System
- Douglas R. Posson 1984–86
- Charles D. Nethaway 1986–92
- Gloria J. Stiltner 1992–94

National Water Information System
- Arthur Putnam 1987–88
- Thomas H. Yorke 1990–94

The Assistant Chief Hydrologist for SP&DM was responsible for the development of computer technology and final approval and review of reports for the Water Resources Division.

This office developed hardware and software for Headquarters and District Offices. A major effort was placed on selecting a computer contractor, training, and distributing the computers to the District Offices. It was during this period that the National Data Management System was planned and developed. Emphasis was placed on access to the data by District Offices, reduction of cost to obtain the data, and time to obtain the data.

In 1981 the responsibility for report approval by WRD was transferred from R&TC to SP&DM. The Branch of Scientific Publications evaluated and approved interpretive reports for Open-File Reports, Water-Resources Investigations, Professional Papers, and Water-Supply Papers. A major effort was put to revitalizing the Water-Supply Paper series (WSP's) to its previous status as the major publication of the Division. The more significant technical papers were directed to this series.

William Mann transferred from Wisconsin to SP&DM in 1981 to head the Water Use Program, replacing Fred Ruggles, who retired. Mann was assisted by Charles Merk and later by Wayne Solley. The Water Use Program developed a data-storage and retrieval system for Districts to use in managing their

water-use information and aggregating it for publishing the 5-year water-use report.

SP&DM played a key role in inaugurating and preparing the National Water Summary Water-Supply Paper. The National Water Summary described hydrologic events and water conditions for the water year, provided a State-by-State overview of specific water issues, and identified ground-water contamination and acid rain as two pressing water-resource issues. John Moore and Edith Chase were assigned full time to this project from 1982 to 1984. The office was responsible for the review of articles coming from the Districts and preparation of articles on hydrologic conditions. The first summary was completed on schedule. It was delivered to James Watt (Secretary of the Interior) by Philip Cohen, David Moody, and John Moore.

The first of six studies of major regional aquifer systems was published in 1984. The series was begun in response to the droughts in the late 1970's to assess the discharge-recharge dynamics, hydrogeologic, and chemical controls governing response of the aquifer systems to stress and to develop computer simulation models.

As a result of reorganization in the Department of the Interior in 1981, the Water Resources Research Institute and the Water Resources Scientific Information Center (WRSIC) abstracts function were reassigned to WRD. It should be noted that WRD was where Luna Leopold intended this group to be housed when he pushed for the creation of this program in the 1960's.

The Environmental Affairs Program (EAP), responsible for overseeing review of Environmental Impact Statements, was assigned to the USGS and reassigned to WRD. Senior people in the Department of the Interior and some of their staff were transferred to WRD. The WRSIC and EAP, along with OWDC's National Water Data Exchange (NAWDEX), were combined to form the Branch of Water Information Transfer (BWIT) under the former Director of the Office of Saline Water, Gary Cobb. The Institutes were housed within Research & Technical Coordination.

Thus, SIM comprised three Branches: Scientific Publications, Computer Technology, and Water Information Transfer. It stayed basically in this configuration until 1994.

The computational workload of the USGS Water Resources Division prior to 1982 was accomplished by accessing the central USGS mainframe computer in Reston, Va., and a variety of local mainframe computers available from universities, research laboratories, and military installations. Remote Job Entry (RJE) terminals were installed in Region and District Offices to submit batch jobs to the mainframes and to receive printed output. The first minicomputer installed in a WRD Field Office was used by hydrologist Arlen Harbaugh to control ground-water models in the Long Island Subdistrict Office in Mineola, N.Y.

In 1976, hydrologist Jesse M. McNellis of the Kansas District and computer systems analyst Douglas R. Posson of the New Mexico District prepared a minicomputer feasibility study that included a cost/benefit analysis with support from District Chiefs Joe Rosenshein (Kansas) and Bill Hale (New Mexico). Assistant Chief Hydrologist (ACH) for Scientific Publications and Data Management (SP&DM) George Whetstone and his Deputy, Solomon Lang, approved of this exploration of the potential for stand-alone computers in Field Offices, as did subsequent ACH, SP&DM Philip Cohen. Stanley M. Longwill, a ground-water modeler from the National Research Program (NRP) joined the team to organize the effort. An October 1977 Request for Proposals resulted in the acquisition of three minicomputers for the Kansas (November 1978) and New Mexico (January 1979) District Offices, and the Northeastern Regional Research Office. Contracting Officers Bill Abbott and Bud Pratsch from the Administrative Division Office of Procurement and Contracts guided the process.

USGS Open-File Report 80–326 "The Use of Minicomputers in a Distributed Information Processing System—A Feasibility Study," by Longwill, McNellis, and Posson, and the May 1981 report "A Feasibility Study to Support Distributed Information Processing for the Water Resources Division," by Longwill, McNellis, and Posson, documented the experience with the three minicomputers and made the case for a Divisionwide implementation of distributed processing. The 1981 report presented a cost-benefit study commissioned by ACH, SP&DM Cohen and performed by Len Gordon in the USGS Director's Office and an extensive compilation of the data needs of the WRD. Fifty percent of WRD's computer workload could be attributed to data collection, data entry, and database management. The report documented technical requirements to distribute large databases,

including WATSTORE (the Water Data Storage and Retrieval System), GWSI (the Ground-Water Site Inventory database), NWUDS (the National Water Use Data System), NAWDEX (the National Water-Data Exchange) and other national data sets. Forty percent of the workload was due to hydrologic studies including models (hydraulic, rainfall-runoff, groundwater flow), graphical applications, and related publications. Ten percent were to support administrative processes such as cost accounting, time and attendance, and program planning.

In 1981, with concurrence of the Department of the Interior's Office of Information Resources Management and the USGS Director's Office, Chief Hydrologist Philip Cohen authorized the preparation of a procurement document to acquire a Distributed Information System of networked computers and related software and training for installation throughout the Division.

Robert Dingman, ACH for SP&DM, and subsequently Jim Biesecker enlisted Standley Longwill to lead the RFP team, which included McNellis and Regional Computer Specialists Jim Bergmann (Southeastern Region), Alf Janssen (Western Region), Charles Nethaway (Northeastern Region), and Douglas Posson (Central Region). Key assistance was provided by experts in the WRD database management systems (Claud Baker, Roger Booker, Norm Hutchison, Dave Maddy, Charlie Merk, Charley Morgan, and Neil Stuthmann). Expertise from the USGS Computer Center Division was provided by Jim Hott and Frank Pitts.

On January 18, 1982, the USGS issued RFP 8722 to procure up to 75 minicomputer systems for installation in WRD Headquarters, Research, Region, District, and Subdistrict Offices. Extensive benchmarks were conducted at all companies submitting technically acceptable bids. In September 1982, the largest competitive contact ever within the Department of the Interior was awarded. Contracting Officers Phil Baldwin and Tim Vigotsky from the Administrative Division Office of Procurement and Contracts guided this procurement.

The Distributed Information System (DIS) Network Analysis and Operations Program was established December 14, 1982. This was requested by Assistant Chief Hydrologist for Operations Tom Buchanan to the USGS Assistant Director for Administration. The same package also established the Office of Computer Technology (OCT). J. Ronald Jones was the first Chief of OCT. Gail Kalen became the first DIS employee in January 1983.

Douglas Posson, acting Chief of the incipient program since June 1982, was selected as the first Chief of the DIS Program (April 1983 through January 1986). Charles Nethaway became the first Chief of the DIS Systems Programming Unit (SPU), and Arlen Harbaugh was the first Chief of the DIS Applications Assistance Unit (AAU). The SPU was responsible for technical issues related to the computers, their operating system and its updates and maintenance, telecommunications and networking technologies (initially X.25), and the training of and assistance to the individual site administrators in WRD offices. The AAU oversaw procurement, development, and(or) migration of applications software that is national in scope, utility, or importance for use by WRD scientists, technical staff, and managers. While nearly all software applications were actually developed by Field, Region, Research, or Headquarters staff in the WRD programs, AAU assisted those doing the development with training programs, quality assurance, a busy Help Desk, and frequent consultations with nearly every office in WRD.

The DIS established a Technical Advisory Committee (TAC) composed of the four Regional Computer Specialists (Jim Bergmann of Southeastern Region; Merritt Blalock of Northeastern Region; Alf Janssen of Western Region; and Jeff Miller of Central Region) plus Mike Hathaway of the Florida District as an at-large District representative; representatives from a District in each Region, initially Richard Hollway of Oregon, Jon Scott of Oklahoma, Mike Shapiro of Illinois, and George Karavitis of the Tampa, Fla., Subdistrict); and topical representatives from the WATSTORE Program, initially Roger Booker and Dave Maddy. The TAC was instrumental in guiding the evolution and rollout of hardware, software, and telecommunications technologies and in designing training programs for WRD staff nationally. The OCT also established a DIS Planning and Implementation Committee (PIC) chaired by J. Ronald Jones, and initial members Jeff Armbruster of Georgia, Bob McNish of Arizona, Don Vaupel of New Jersey, and Dan Bauer of Missouri. The PIC advised OCT and the DIS Program staffs on policy issues, funding priorities, program planning, staffing, and coordinating District planning processes.

The DIS Program had three major priorities: (1) procurement and installation of computers, peripheral

equipment, terminals, and telecommunications in WRD offices; (2) training of site administrators and end users on the new equipment and software; (3) migration of key applications software from the USGS mainframe and other sources to the new minicomputer systems.

Training was given to site administrators through a series of DIS National Site Managers' meetings. The first two (organized by Pat McAlwee and Jo Porter), March 12–16, 1984, in Lakewood, Colo., and October 28 through November 1, 1985, in Hyannis, Mass., focused on training on the new hardware and operating system. The third, organized by Daphne Chinn, now called the National Computer Technology Meeting (NCTM), met June 9–12, 1987, in Atlanta, Ga., widened the audience to computer professionals and scientists who used the computers from across the country and the other USGS Divisions. The DIS network became GEONET and had been expanded for use across the USGS. The fourth meeting, May 6–11, 1990, in San Antonio, Tex., focused on the migration from DIS (minicomputers) to DIS-II (workstations and servers). At the sixth meeting, May 17–20, 1992, in Norfolk, Va., the NCTM was attended by 320 computer professionals and scientists. The focus was training in the DIS-II operating system. Keynote speakers included Associate Director of the USGS, Doyle Frederick; Chief Hydrologist, Phil Cohen; Assistant Director for Information Systems, Jim Biesecker; Chief of the National Mapping Division, Lowell Starr; and the Chief Executive Officer of Data General Corporation. Colleen Babcock led the organization for each NCTM starting with the fourth. Organizers had much help from throughout the WRD.

The DIS Program also provided training to 2,200 WRD staff in nearly every Field, District, Region, Research, and Headquarters office. Most training was given by field personnel selected to specialize in topics ranging from hardware, telecommunications, and the full range of general-purpose and hydrologic applications. Some training was given at the National Training Center in Lakewood, Colo., in more than 100 sessions available to all USGS staff. Both to control costs and to reach as many WRD staff as possible, the majority of training was given in District Offices by DIS Program members and the national training team. Over the life of the DIS Program, more than 100 field personnel were enlisted to become the DIS experts on each training subject. They acted as onsite trainers when needed and also as the person to contact to solve problems that might arise. The PIC and TAC worked together to identify training needs in the field and to train the trainers so that the whole of WRD could be trained when and where needed.

In February 1983, the DIS Program established a newsletter, DIScussions. Wanda Meeks had the enviable task of being the first editor of DIScussions. After the first several issues, she was succeeded by Jo Porter. During the period 1983–92, 30 issues of the newsletter were distributed to nearly every WRD employee. The newsletter was used in part to share information about the progress and plans for DIS implementation. It was also used as an educational tool, with literally hundreds of articles on various features of the DIS hardware, telecommunications, and software. For example, it provided tutorials on the use of E-DOC, the DIS electronic mail and document-distribution application, and Continuum, the DIS electronic bulletin board. It provided articles on DIS technologies to help the users become more familiar with computer terminology as it applied to their situations. It was used to advertise the availability of training classes at the NTC and in District offices. It gave current information for WRD employees to contact the experts when they had questions.

The primary reason to have computers in the Districts was to give better access to data, data processing, and modeling applications to the scientific staff. The Chief Hydrologist was keenly interested in bringing standard software to every WRD office so that the technical standards developed for WRD data collection, data processing, and modeling would be identical in every office. Therefore, once the systems were installed, connected to each other with a network, and the staff trained on their use, the migration of hydrologic applications was the top priority. The Applications Assistance Unit of the DIS Program worked closely with Charlie Showen and members of the Automated Data Section to migrate the huge databases of the National Water Information System (NWIS), including WATSTORE (surface-water and water-quality data), NWUDS (water-use data), GWSI (ground-water data), and NAWDEX (the National Water-Data Exchange), to the computers.

The AAU also assisted many in the WRD modeling community to migrate the models from the mainframe environment to the minicomputers. WRD scientists quickly adapted models to the computers. By the end of 1984, hydrologic models such as WRD's

Ground-Water Flow in Three Dimensions, hydraulic models including Rainfall-Runoff models, the Step-Backwater model, and statistical and graphical applications were up and running on the network. WRD procured general-purpose applications to assist scientists in development of new modeling applications. Statistical packages, including P-Stat, SPSS, and SAS, were made available to every WRD office, as were word processing (WordMarc) and spreadsheet (20/20) and graphics applications such as DISSPLA, TELAGRAF, and Cuechart. A relational data-management package, INFO, facilitated data analysis.

In late 1983, Chief Hydrologist Phil Cohen decided to have WRD sponsor an exhibit at the 1984 Louisiana World Exposition (LWE '84). The exposition would run from May through November 1984. The theme of LWE '84 was "The World of Rivers—Fresh Water as the Source of Life." Gary Cobb, Chief of the Branch of Water Information Transfer, was selected to lead the overall LWE '84 effort for WRD. The DIS LWE '84 design team (Jim Bergmann, Merritt Blalock, Charles Eschelman, Richard Hollway, Arlen Harbaugh, Jesse McNellis, Douglas Posson, Walt Rennick, and Jon Scott) joined with Bill Shope's Satellite Data Relay project on the WRD team. They organized a computer-based display of real-time streamflow data from all 50 States via satellite. Data were transmitted from each streamflow-gaging site using the GOES satellite to Wallops Island, then to Reston. In Reston the data were processed at WRD's LWE '84 exhibit. DIS staff had programmed the computers to display current streamflow, historical high- and low-flow data, and a variety of graphics depicting the geographic and hydrologic history for each site. Visitors would step up to a touch-sensitive pad, select their State or rivers of interest, and view the graphical results projected onto very large screens above their station. During the 6-month exhibit, more than 50 computer professionals and 24 District Chiefs from across WRD participated in the site administration of the LWE '84 exhibit. In the first month, more than 878,500 visitors queried the system. By the close of the LWE '84 in November 1984, the visitor count was projected to exceed 700,000. The Chief Hydrologist and Director Dallas Peck were interviewed about the exhibit and the work of WRD on the New Orleans NBC affiliate WDSU.

In 1985, the DIS Program sponsored the procurement of the first Geographic Information System (GIS) packages from the Earth Science Research Institute (ESRI). On the advice of an ad hoc technical team assembled by Bob Pierce (Georgia District) and Walt Rennick (DIS Program), WRD purchased a license for five seats of ARC/Info. Installed in four Districts and Headquarters, the GIS quickly proved its value. By the end of 1986, an additional 20 licenses had been acquired, and the WRD users of the DIS network became the center of GIS processing within the USGS.

In 1985, Jim F. Daniel became the new ACH, SP&DM. His office was renamed the Office of Scientific Information Management (ACH, SIM) in 1987. Early in 1986, Charles Nethaway was selected to lead the DIS Program and Gloria Stiltner was selected as Chief of the Systems Programming Unit. Nethaway and Stiltner remained in these offices through 1991.

Computational capacity had grown enormously in WRD. Demand for computers grew even faster. Driven by traditional database and modeling applications, the demand really increased with the widespread use of GIS software and its large and diverse spatial datasets. Although initially developed on minicomputers, the ARC/Info software migrated more to desktop workstations as the stations grew in reliability and power and became less costly. UNIX became the preferred operating system environment for the GIS workstations because it was a public-domain open operating system rather than a proprietary operating system. DIS traffic volume on GEONET averaged approximately 1.5 billion characters per month between 1984 and 1987. By 1990, daily traffic volume had grown to 3 billion characters per month.

In the spring of 1987, a meeting of the TAC and the WRD regional computer specialists was held in Portland, Oreg. It became clear that the older DIS technology, though still robust and in use across WRD, would be unable to meet WRD's computing requirements into the 1990's.

In 1988, Jim Fulton became head of the Applications Assistance Unit. During this period, the DIS Program took advantage of new technical developments in minicomputer and networking technologies to enable faster access to ever-larger data bases, and to speed up performance of the minicomputers for modeling applications. The concept of client-server computing became, if not the new standard, then the new target for distributed computing. The DIS Program personnel researched evolving networking standards and made the decision to migrate GEONET into GEONET-II by using the new TCP/IP protocol.

This, together with the advent of high-speed desktop workstations, set the stage for what was to become DIS-II.

Tom Buchanan (ACH,O) and Isabelle Halley des Fontaines led the development and implementation of an extensive suite of administrative applications, AFIMS (Administrative and Financial Information Management System), to support managers, programs, and plans of WRD. AFIMS provided functionality for personnel, time and attendance, budget planning, project management, financial management, facilities, the safety program, and more. Implemented on the DIS network, AFIMS was used by every Administrative Officer and clerk in WRD and by many other field and Headquarters managers and project staffs.

In response to the growing demand for computational capacity for GIS and desktop workstations, for ever-faster models and data bases, and for AFIMS, the Chief Hydrologist and ACH, SIM asked the DIS Program to develop an RFP issued in February 1989 to replace the network minicomputers with a new generation of computer hardware, software, and telecommunications. The workstations, networking, and software would be made available to all of USGS. Further, options were built into the procurement that would make the contract available to other bureaus in the DOI. A new contract, once again the largest competitive procurement ever executed in the DOI, was awarded in December 1989.

Hardware for DIS-II included workstations, high-resolution monitors, magnetic- and optical-disk drives, line and laser printers, tape drives, scanners, and Ethernet Local-Area Networks (LAN's). Software included UNIX, FORTRAN, and C programming languages and telecommunications for LAN's and GEONET-II. Applications software included INGRES (a relational data base-management system), STATIT (for statistical analysis), FrameMaker (for publication of documents), TACTICIAN (a spreadsheet), CorelDraw (a graphics package), and GIS (ARC/Info). Major applications were to be ported to the DIS-II workstations including the National Water Information System-II, a new Administrative Information System to replace AFIMS, and an electronic mail system.

WRD began the implementation of DIS-II in November 1990. Early in 1991, Gloria Stiltner was selected as Chief of the DIS Program. Jim Tessler became Chief of the System Programming Unit, and Jim Fulton continued as Chief of the Applications Assistance Unit.

Offices in Colorado, Michigan, Oregon, Pennsylvania, and Virginia were selected as "Pioneer Sites" and were the first to receive the new systems. By September 1991, four Pioneer Reports (later termed Technical Reports) were issued and distributed to potential users of the systems throughout DOI. A major training program was started to facilitate the migration of the users from the previous operating system to UNIX, to move the NWIS data bases and WRD models from the minicomputer to the workstation environment, and to teach staff how to take advantage of the new tools and technologies of the client-server model. By October 1992, 1,637 workstations and 67 servers had been installed in offices around the country.

On October 8, 1992, the DIS Program was awarded the Government Computer News Agency Award. Given once each year for "demonstrated record of excellence in the application of computer technology," the award cited WRD as "the driving force behind this success story of providing improved public service through the use of information systems." The award concluded that "the USGS insists that the users be an important aspect of the entire procurement from start to finish. Feedback from the scientists, engineers, and others within USGS ***has been very positive. This was due to the fact that it was their input which helped provide systems that are meeting their requirements.*** Other agencies could benefit from the example the Department of the Interior and the USGS have set for a successful IRM implementation within the Federal government."

Employees in the reports and information sections included Edith Chase, Allen Sinnott, Thomas Woodard, Lois Fleshmon, Faulkner B. Walling, Caroll W. Saboe, Richard C. Murray, Kathleen T. Iseri, Humbert S. Revel, Irving G. Grossman, Claire B. Davidson, Frances B. Davison, Carolyn L. Moss, Joan M. Rubin, Perry G. Olcott, David A. Aronson, Charles Novak, Henry J. Oswick, Owen O. Williams, Donald J. Dolnack, Gerald L. Thompson, Darwin F. Alt, Thomas Ross, Hai C. Tang, Sandra L. Holmes, Raymond A. Jensen, Michael W. Page, John T. Campbell, George L. Knapp, Clifford A. Haupt, Robert R. Reynolds, George H. Chase, George E. Stoertz, Seymour Subitzky, Martin Weiss, Priscilla W. Woll, Edward W. Pickering, William Cogger, Billy Colson,

Celso Puente, Frances Buchanan, James O. Whitney, Arlen Harbaugh, Stanley M. Longwill, Chester Zenone, Steven D. Craigg, and Judy D. Fretwell.

Employees in the data management and computer support sections included Robert B. Wall, Gayle G. Gillingham, Norman E. Hutchison, Neil G. Stuthmann, Roger E. Booker, Charles F. Werk, George R. Dempster, Curtis L. Sanders, Lari E. Lopp, David Maddy, Charles O. Morgan, Gail E. Kalen, Arlen W. Harbaugh, Walter L. Rennick, Misia W. Mercer, Darcy Person, Kerie Hitt, Thomas C. Wood, Carl W. Cardin, Gerald L. Thompson, Susan M. Trapanese, Leslie W. Lenfest, Jeffrey D. Christman, Robert F. Wakelee, Thomas G. Ross, Patrick K. Simmons, Ruth E. Thornberg, John C. Briggs, James L. Fulton, Douglas D. Nebert, David W. Stewart, David R. Boldt, Josephine L. Porter, Daphne C. Chinn, Doreen Lucas, Patricia M. McAlwee, James L. Kiesler, Robert L. Moffatt, James E. Paschal, Pierre B. Sargent, Nelson E. Williams, Candice M. Bostwick, Stephen J. Cauller, Stephen E. Hammond, James R. Kirk, Robert P. Mayer, William R. Roddy, Lee E. Trotta, Eric J. Wilson, James L. Fulton, Mark G. Negri, and Jeff Tessmer.

WATER ASSESSMENT AND DATA COORDINATION

By David A. Moody

In 1994, the Office of the Assistant Chief Hydrologist for Water Assessment & Data Coordination (ACH/WADC) consisted of three units: the Office of the Assistant Chief, the Branch of National Water Summary (NWS), and the Office of Water Data Coordination (OWDC). This chapter traces the history of the "water assessment" activities of the office, especially the development of the *National Water Summary* series of reports and supporting data bases, the application of GIS to this series of reports, and the effects of the project on the technology used to produce publications of the Water Resources Division (WRD). The "data coordination" component of the office is described first because the Office of Water Data Coordination (OWDC) had its beginnings in 1964 and laid the foundations for many of the Division's outreach activities in the 1990's.

OFFICE OF WATER DATA COORDINATION

Since its creation in the mid-1960's, the OWDC has played a useful, if at times controversial, role in improving access to Federal water information and in coordinating government water programs. During the Cohen years, despite constrained budgets and FTE ceilings faced by many WRD programs, OWDC managed to hold on to its existing funding and carry out an extensive program of coordination activities. By the early 1990's, OWDC had convinced the Office of Management and the Budget (OMB) to strengthen its responsibilities in the areas of water information coordination, water-quality monitoring methods, and information clearinghouse operations. The office played a major role in strengthening relations with the U.S. Environmental Protection Agency (USEPA) and with other Federal and State agencies engaged in monitoring water quality.

Office of Management and the Budget Circular A–67

On August 28, 1964, the Bureau of the Budget (BOB), subsequently renamed the Office of Management and the Budget (OMB), issued Circular A–67 that assigned the task of coordinating the data-collection activities of Federal agencies to the Department of the Interior. The Secretary of the Interior delegated this task to the USGS, which, in turn, established OWDC within the WRD.

O. Milton Hackett, the first Chief of OWDC, became the Associate Chief Hydrologist to Chief Hydrologist E.L. "Roy" Hendricks in 1968 and was replaced by Russell H. "Hal" Langford. With the appointment of Philip Cohen as Chief Hydrologist in April 1979, Langford was selected as Associate Chief Hydrologist, and Porter E. Ward was subsequently appointed Office Chief (table 1).

During the 1980's, OWDC's responsibilities under OMB Circular A–67 were defined as follows:

- Assures effective management of Federal programs to meet the national requirements for water-resources information.
- Maintains a central catalog of information on water data for the Nation.
- Prepares the annual *Federal Plan for Water Data Acquisition.*

- Coordinates the planning, design, and documentation of national water-data and information networks.

Data coordination during this period continued to be carried out by the activities of two committees: the Interagency Advisory Committee on Water Data (IACWD) and the Advisory Committee on Water Data for Public Use (ACWDPU). Both committees met annually to advise the Secretary of the Interior on water-data acquisition activities of the Federal Government.

Representatives of approximately 34 Federal agencies participated on the Interagency Advisory Committee on Water Data (IACWD). By 1994, the IACWD had over two dozen subcommittees and working groups involving more than 200 Federal agency personnel. This committee did much of the development work on water data acquisition standards and recommended methods, and implemented many of the recommendations made by ACWDPU.

ACWDPU had up to 27 members who represented interests of State and local agencies, technical and professional societies, universities and the private sector. The Secretary of the Interior appointed the Committee members. Because the Committee was chartered by the General Services Administration (GSA) under the Federal Advisory Committee Act (FACA), its charter had to be renewed every two years.

These coordination committee activities were supplemented by the efforts of WRD Regional Program Officers who also served as OWDC field coordinators in the preparation of the *Federal Plan for Water Data Acquisition*, and by various projects sponsored by OWDC to support its mission. In addition, important water-data coordination activities took place at the District level between State water agencies and the local representatives of Federal agencies as part of the day-to-day planning and operation of the Federal-State Cooperative program of water resources investigations and other Federal Agency (OFA) program work. Some Districts held annual information coordination meetings; this was encouraged and occasionally funded by OWDC. However, OWDC funding did not permit OWDC to support a formal nationwide coordination program at the District level.

The various committees, subcommittees, and working groups, WRD Program officers, and District field coordination efforts assisted OWDC in implementing recommendations of the advisory committees, coordinating the preparation and updating of the annual *Federal Plan for Water Data Acquisition,* and

Table 1. Office of Water Data Coordination Personnel, 1979–94 (dates shown after organizational units are the periods during which particular subunits of OWDC were in operation)

Chief, OWDC
- Russell H. ("Hal") Langford 1968–1979
- Vacant 1979–1980
- Porter E. Ward, Acting 1981
- Porter E. Ward 1982–85
- Edgar A. Imhoff 1985–86
- Donald K. Leifese, Acting 1986–87
- Nancy C. Lopez 1988–1994

Assistant Chief
- A. Ivan Johnson 1971–80
- Jim W. Geurin 1981–83
- Nancy C. Lopez 1983–86

Chief, Network Planning & Evaluation Unit (1968–82)
- F. Paul Kapinos 1976–80
- Vacant 1980–82

Chief, Network Planning & Evaluation Section (1987–92)
- Donald K. Leifeste, 1987–88
- Bruce Parks, 1988–92

Chief, Program Coordination & Information Unit (1975– 85)
- John E. Wagar 1975–80
- Warren E. Hofstra 1981–84
- Vacant 1985

Chief, Coordination & Information Section (1987–94)
- Douglas D. Manigold, 1987–88
- G. Douglas Glysson, 1988–94

Chief, Technical Coordination Unit (1983–85)
- Donald K. Leifeste, 1983–85

Chief, Intergovernmental & Public Liaison Unit (1983–85)
- Edgar A. Imhoff, 1983–85

Others who served in staff positions in OWDC included
- Louis W. Cable
- Jerry E. Carr
- Paul V. Dressler
- Madge O. Ertel
- Robert E. Hammond
- David E. Hoglund
- George L. Knapp
- Bernard A. Malo
- Rebecca Phipps
- Gloria J. Stiltner
- Terry H. Thompson

engaging in outreach and special studies to support the Coordination of National Water Data Program.

When Porter Ward retired in 1985, he was replaced by Edgar A. Imhoff as OWDC Chief. A year later, Imhoff was asked by the Department to lead the San Joaquin Valley Drainage program in California. About the same time, Nancy C. Lopez, the Assistant Chief of OWDC, took an assignment as the USGS representative on the staff of the Assistant Secretary for Water and Science at the Department of the Interior in Washington, D.C. Donald K. Leifeste served as Acting Chief of the OWDC until her return in the fall of 1987. With a number of important positions vacant because of personnel ceilings and hiring restrictions, OWDC was moved first to the Office of the Assistant Chief Hydrologist for Research and Technical Coordination (ACH/R&TC) led at that time by Marshall E. Moss, and then merged with the new Office of the Assistant Chief Hydrologist for Water Assessment and Data Coordination (ACH/WA&DC) headed by David A. Moody in order to bring together a number of outreach and coordination activities of WRD. Nancy Lopez returned to WRD from her downtown assignment in August 1987, and she was appointed Chief of OWDC. She quickly moved to expand the scope and visibility of OWDC's activities among Federal and non-Federal agencies and to sponsor a number of pilot studies that supported the mission of the office and make the best use of limited personnel resources.

In December 1991, Circular A–67 was updated and replaced by OMB Memorandum No. 92–01 (M–92–01). In this memorandum to the heads of Executive agencies, OMB reaffirmed the need for water-data coordination activities, expanded the office's mandate, and renamed the program, the Water Information Coordination Program (WICP). Activities conducted by OWDC during 1979–94 are discussed below.

Hydrologic Unit Maps

One of the first activities of OWDC after it was established in 1965 was to define the Nation's hydrologic units and to coordinate and standardize their names, codes, and boundaries with Federal and State agencies. These maps serve a vital role in the coordination process by enabling data-collection activities such as streamflow stations or field studies to be associated with a hydrologic unit and provided a hierarchical coding scheme for use in storing and retrieving metadata about data-collection activities. These data-collection activities of the USGS and other Federal agencies were listed in the "Catalogue of Information on Water Data" that became the principal data file of the National Water Data Exchange (NAWDEX) in 1976. Hydrologic Unit Maps were published for each State at a scale of 1:500,000. The Hydrologic Unit Codes (HUC's) and unit names were adopted as a Federal Data Processing Standard (FIPS) by the National Bureau of Standards (NBS). It is hard to remember how important such efforts were to the development of water-data storage and retrieval systems on mainframe computers before the advent of desktop computers, geographic information systems (GIS), the Internet, and the World Wide Web.

During 1979, OWDC held discussions with the Chief, Automatic Data Section, about potential applications of a digital cartographic data base to WRD programs and the water-data coordination activities. At that time, the Geography Program of the Land Information and Analysis Office (LIA) was preparing an early Geographic Information System (GIS) consisting of land use/land cover, political boundaries, drainage, and other features at a scale of 1:250,000. In 1980, OWDC digitized the Hydrologic Unit maps, and Oak Ridge National Laboratory edited the files for use as a base map in their efforts to subdivide the United States into ecological units. The National Mapping Division (NMD) also prepared a digital coverage of the 21 major river basins and their subdivisions as part of the National Map series (1:7.5 million) of thematic maps.

Duane F. Marble, professor of geography, on detail to the Geography Program from the University of Buffalo, researched the current and future needs for mapping and automated cartography for OWDC, NAWDEX, National Assessment, and other programs of WRD. In his report, he recommended walk-in GIS laboratories where users could have access to large plotters and other image display equipment. He also advised OWDC on some of the difficulties that needed to be corrected in the Hydrologic Unit Map digital files.

The Hydrologic Unit map of Alaska and a Hydrologic Unit Map of the Continental United States (in two sheets) was published as a U.S. Geological Survey Special Map at a scale of 1:2 million in 1988. Corrections were made to some of the State maps, which were then reprinted as part of the maintenance

program for the map series. In 1989, USEPA adopted the HUC's as part of the River Reach file structure which allowed facilities, such as discharge pipes, dams, and data-collection points on streams, to be placed in upstream or downstream order. In 1990, the USGS-SCS (Soil Conservation Service) Coordinating Committee developed a Memorandum of Understanding to implement a strategy to subdivide HUC's into smaller watershed units to meet the needs of SCS State programs. By 1994, the HUC's and maps were extensively used by Federal and State agencies to locate water and water-related information and program activities.

National Water Data Exchange (NAWDEX)

Throughout the 1980's, OWDC continued to work with NAWDEX on the Master Water Data Index (MWDI) because of its importance to the national water-data coordination effort. As the MWDI file was separate from WRD's WATSTORE and USEPA's STORET system, it became increasingly difficult to keep the MWDI updated. Data were transferred from WATSTORE to STORET. STORET was then used to update the MWDI, but this updating process frequently failed to occur. Douglas B. Manigold worked with the Office of Scientific Information (SIM), the Regions, and four Districts (Alabama, Idaho, Illinois, and New Mexico) to determine whether the MWDI reflected the current state of data collection and to recommend improvements. In 1988, Bruce Parks developed a GIS application to plot data-collection sites retrieved from NAWDEX onto a variety of base maps to assist Districts in their analysis of their data-collection networks.

Developing Water Information Acquisition Standards

OWDC published the first edition of the *National Handbook of Recommended Methods for Water Data Acquisition* in 1972. In 1977, the Handbook was reprinted as a looseleaf notebook with revision and updates for six chapters with the remaining four chapters completed in 1978–79. Subsequently, an 11th chapter on water-use information was added in 1988 and other chapters updated as technology advanced. All of the chapters have been revised, some several times between 1977 and 1988 (table 2). More than 10,000 copies of the handbook have been distributed nationally and internationally.

In 1988, Jerry E. Carr met with USEPA's Environmental Monitoring Systems Laboratory staff in Las Vegas, Nevada, to discuss support of the American Society of Testing and Materials (ASTM) development of ground-water sampling standards. Subsequently in 1989, OWDC jointly sponsored the ASTM D18.21 project with USEPA and the Department of the Navy to accelerate the development of these standards (table 3). Carr worked with WRD ground-water personnel and represented the USGS on the ASTM working groups.

Because water-quality sampling is often for a specific purpose, questions were raised during the design of the National Water-Quality Assessment Program (NAWQA) about the suitability of using State and other agency data for water assessments. To examine this issue, OWDC sponsored pilot studies during 1985–87 in three districts (Colorado, Ohio, and Oregon) to determine the extent to which water and water-related data collected by public agencies for various purposes and using various methods can be aggregated for use in answering questions of national scope concerning water-quality conditions and trends. The Districts estimated the total expenditures for water-quality data collection and analytical work and compared available data to five screening criteria. Only 15 percent of the measurements and analyses in Colorado and Ohio met the screening criteria judged necessary to include the measurements in a consistent data base appropriate for addressing questions pertinent to regional and national water-quality assessments. Few data were available about toxic metals and organic chemicals, and less than 10 percent of the States' total water-data holdings dealt with ground water.

Table 2. National Handbook of Recommended Methods for Water Data Acquisition

Chapter	Publication Date	Revision Date(s)
Introduction	1977	1980
1. Surface Water	1977	1980, 1987
2. Ground Water	1977	1980, 1988
3. Sediment	1978	1988
4. Biology and Microbiology	1977	1983
5. Chemical Quality	1977	1982, 1984, 1989
6. Soil Water	1978	1982
7. Basin Characteristics	1978	1981
8. Evaporation/Transpiration	1977	1982
9. Snow and Ice	1979	1981, 1988
10. Hydrometeorological Observations	1977	1980
11. Water Use	1988	Online

Table 3. ASTM D18.21 Standards for Ground-Water Sampling

.01 Surface and Borehole Geophysics
.02 Unstaturated Zone Monitoring
.03 Monitoring Well Drilling & Soil Sampling Practices and Procedures
.04 Determination of Hydrogeologic Properties
.05 Monitoring Well Design and Construction
.06 Monitoring Well Maintenance Rehabilitation and Abandonment
.07 Ground Water Sample Collection, Handling, and Field Analysis
.08 Design and Analysis of Hydrogeologic Data Systems
.09 Ground Water Monitoring in Karst Terrain
.10 Modeling

Development of Regional and Federal Plans for Data Acquisition

The *Federal Plan for Water-Data Acquisition* provided information on water-data acquisition activities, programs, and plans so that officials in other agencies and departments could analyze water-data needs for the fiscal year currently being planned. Generally published in the fall, the Federal Plan was also an annual report to OMB on coordination activities during the year. For example, the FY 1987 *Federal Plan* (published in late 1985) provided an overview of major Federal water-resources responsibilities, summarized coordination activities for the year, including synopses of the annual meetings of the IACWD and ACWDPU and their subcommittees, described adjustments made to the surface-water, ground-water, and water-quality data-collection programs in 1985, and included a budget outlook for FY 1987. An appendix contained descriptions of individual Federal agency data needs (base program and changes for 1985–87) and future data needs and plans (1987 and beyond). The inclusion of budgetary data in the report raised concern by some agencies that OMB might use this information to adversely affect their programs, but these fears were never realized.

Assistance to WRD Program Implementation

In response to the recommendations of the advisory committees, the OWDC helped implement the following WRD programs between 1979 and 1994:

- National Water-Use Information Program (NWUI)
- River Quality Assessment Program (RQA)
- National Stream Quality Accounting Network (NASQAN)
- National Water Data Exchange (NAWDEX)
- National Water Summary (NWS)
- National Water-Quality Assessment Program (NAWQA)

Such assistance took the form of developing standards, managing outreach activities, and sponsoring program briefings for agencies using the IACWD and ACWDPU members as contacts. OWDC also provided support to the coordination of ongoing WRD programs, such as the Federal-State Cooperative programs and Federal data-collection programs.

Inter-Agency Committee on Water Data (IACWD)

The IACWD implemented recommendations of the ACWDPU and carried out many of the coordination activities initiated by OWDC under OMB Circular A–67. Chief Hydrologist Phil Cohen chaired the committee, and the Chief of OWDC was the Committee's executive secretary. Annual meetings centered about topical themes that were driven by the Federal Government's response to legislation and current events. Table 4 lists the meetings, locations, and topical themes for 1979–94.

In 1990, IACWD had five subcommittees and a number of working groups. The structure of the IACWD and key personnel, including the names of USGS representatives, are listed in table 5.

Working groups were added or deleted as the need arose for groups to accomplish specific tasks. A number of Subcommittees, such as the Subcommittee on Automatic Data Systems, were phased out in the mid-1980's. Selected accomplishments of the subcommittees are listed below.

Subcommittee on Ground Water

- Published *Federal Ground Water Projects Directory* (1986).
- Prepared the *Federal Glossary of Selected Terms: Subsurface Water Flow and Solute Transport* (1989).
- Improved standardization of sampling methods for ground-water quality by organizing a half-day session at a 1991 ASTM Symposium on Field Methods for Ground-Water Contamination Studies and their Standardization.

Table 4. Themes and discussion topics of Interagency Committee on Water Data (IACWD) meetings, 1979–94

Year	Meeting	Location	Purpose and Focus
1978	13th Meeting	Gatlinburg, Tenn.	Federal Plans/Needs for Water Data; Interagency Task Force on Monitoring.
1980	14th Meeting	Falls Church, Va.	Federal and Non-Federal Water Data Programs (joint with ACWDPU).
1981	15th Meeting	Charleston, S. C.	Automated Data Collection and Networks.
1982	16th Meeting	Virginia Beach, Va.	Information Management Systems.
1983	17th Meeting	Gettysburg, Pa.	Federal Water Resources Studies & Programs—Emphasis on Data Programs.
1984	18th Meeting	Williamsburg, Va.	National Data Needs; Hydrologic Forecasting; Water Data Coordination.
1985	19th Meeting	Knoxville, Tenn.	Federal Ground-Water and Water-Quality Efforts; Uses of Water Data.
1987 (May)	20th Meeting	Charlottesville, Va.	National Water-Quality Information Activities (joint with ACWDPU).
1987 (Dec)	21st Meeting	Reston, Va.	Multipurpose Stream-Gaging Networks.
1988	22nd Meeting	St. Michaels, Md.	Nonpoint-Source Pollution.
1989	23rd Meeting	Hershey, Pa.	Federal Interagency Sedimentation Project (FISP) and Standards Development.
1990–91	(No information)		
1992	Business Meeting	Reston, Va.	Federal Agency Reports; first report of the Intergovernmental Task Force on Monitoring Water Quality (ITFM).
1994	Business Meeting	Falls Church, Va.	National Spatial Data Infrastructure; FY 95 Federal Agency Outlooks.

- Promoted with USEPA the adoption of a minimum data set of data elements for ground-water data collection in 1989.

Subcommittee on Hydrology

- Revised guidelines for Determining Floodflow Frequency Working Group, Bulletin 17B, in 1982.
- Established probability of a Probable Maximum Flood ad hoc working group to compare methods by which different agencies calculate the probability of the probable maximum flood. The ad hoc working group produced its report in 1985.
- Flood Warning and Preparedness Plans Working Group published *Guidelines on Community Local Flood Warning and Response Systems* (1985) and drafted a brochure to help local officials to determine when flood-warning systems and flood-preparedness plans would be useful (1989).
- Small Urban Watersheds Working Group compiled an annotated bibliography on hydrologic models used to analyze floodflow frequencies for small urban watersheds in 1989.
- Network Analysis Working Group prepared an issue paper on reductions of the national stream-gaging station network and the loss of surface-water quantity information: *Surface Water Quantity Information: Needs, Constraints, and Recommendations for Action* (1993).

Subcommittee on Sedimentation

- Continued to publish *Notes on Sedimentation Activities,* published annually since 1946 and the 5-year report, *Sediment Deposition in U.S. Reservoirs*.
- Organized the Fourth Interagency Sediment Conference, "Sedimentation – Friend or Foe" in Las Vegas, Nevada, March 24–26, 1986.
- Organized a Symposium on Bridge Scour in 1988.
- Organized the Fifth Federal Sedimentation Conferences in 1991. The conference has been held periodically over the past 40 years and every 5 years since 1941.
- Funding of the Federal Interagency Sedimentation Project became increasingly uncertain during the late 1980's, and activities had to be scaled down. In 1992, the U.S. Army Corps of Engineers' Waterways Experiment Station agreed to provide core funding for the project, and it was relocated from St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minn. to Vicksburg, Miss.

Historical Note on the Subcommittee on Sedimentation

The Subcommittee on Sedimentation of the IACWD has its origins in the Inter-Departmental Committee on Sediment Sampling and Sampling Techniques, established by several Federal agencies in 1939, to standardize sediment-measuring techniques used to provide design information for dams and reservoirs. This committee jointly sponsored an interagency

Table 5. Inter-Agency Committee on Water Data (IACWD) Structure and Personnel in 1990

Inter-Agency Committee on Water Data (IACWD)

Chair: Philip Cohen,USGS

Alternate Chair and Executive Secretary: Nancy C. Lopez, OWDC

Subcommittee on Ground Water

Chair: Thomas Nicholson, NRC

Vice Chair: Larry Mann, USGS

Liaison: Madge Ertel, OWDC

USGS Representative: Larry J. Mann, USGS

Subcommittee on Hydrology

Chair: Janet Herrin, TVA

Executive Secretary and Liaison: Bruce Parks, OWDC

USGS Representative: William B. Mann IV, USGS

Working Groups

Network Analysis – Chair: John Schaake, NWS

Satellite Telemetry – Chair: William Shope, USGS

Flood Warning and Preparedness Plans – Wayne Graham, Bureau of Reclamation

Hydrologic Radio Frequency – Chair: Eugene A. Stallings, NWS

Guidelines for Determining Flood Frequency Flow (Bulletin 17B) – Wilbert O. Thomas, USGS

Small Urban Watersheds – Chair: Daniel M. Cotter, FEMA

Subcommittee on Sedimentation

Chair: C. Don Clarke, SCS

David A. Farrell, ARS

Liaison: G. Douglas Glysson, OWDC

USGS Representative: Charles W. Boning, USGS

Working Groups

Technical Committee on Sedimentation – David W. Hubbell, USGS

Fifth Federal Sedimentation Conference Planning – Robert T. Joyce, TVA

Subcommittee on Water Data and Information Exchange

Chair: James F. Daniel, USGS

Vice chair: Eugene A. Stallings, NWS

Executive Secretary: James Burton, USGS

Liaison: Madge Ertel, OWDC

USGS Representative: J. Ron Jones, USGS

Subcommittee on Water Quality

Chair: Berlie Schmidt, CSRS

Executive Secretary: G. Douglas Glysson, OWDC

USGS Representative: David A. Rickert, USGS

Working Groups

Biological Assessment—Mary Gessner, F and WS

Screening Techniques – Bruce Newton, USEPA

Nonpoint Source of Pollution – Douglas J. Growitz, OSM

Subcommittee on Water Use

Chair: Robert Delk, BIA

Executive Secretary and Liaison: Madge Ertel, OWDC

USGS representative: Wayne B. Solley, USGS

research project at the Iowa Institute of Hydraulic Research. On April 14, 1946, the Subcommittee on Sedimentation of the Federal Interagency River Basin Committee (FIABRC) took over the duties and projects of the earlier committee.

In 1948, the interagency research project moved from Iowa to the St. Anthony Falls Hydraulic Laboratory in Minneapolis. The Interagency Committee on Water Resources (IACWR) replaced FIABRC in 1954 and granted a new charter to the Subcommittee on Sedimentation.

The Water Resources Council (WRC) replaced IACWR in 1965, and the Subcommittee on Sedimentation became Sedimentation Committee of WRC. WRC terminated its technical committees in October 1977, leaving the Sedimentation Committee without a parent organization. Members of the committee strongly believed that this cooperative interagency effort should continue because of the need for coordination of Federal activities in sedimentation.

At the 13th annual meeting of the IACWD on September 15, 1978, the Committee agreed to sponsor the Subcommittee on Sedimentation as one of its subcommittees. In 1992, the Subcommittee on Sedimentation arranged for the transfer of the Federal Interagency Sedimentation Project from St. Anthony Falls to the U.S. Army Corps of Engineer's Waterways Experiment Station in Vicksburg, Miss. Over the years, the project has designed, tested, and manufactured standardized suspended sediment and water-quality samplers for use by Federal agencies and others.

Source: Office of Water Data Coordination, 1990, *Water Data Coordination Directory FY 1990*, Reston, Virginia.

Subcommittee on Water Data and Information Exchange

- Technical Working Group developed a Standard Hydrometeorological Exchange Format (SHEF), obtained a review of its data elements by Federal agencies, and adopted it for interagency use.
- Prepared promotional brochure describing existing hydrometeorological data systems and designed computerized index of databases.
- Reviewed USEPA River Reach file to determine if data elements can be standardized for use by other Federal Agencies in 1989.

Subcommittee on Water Use Information

- Developed Chapter 11 on Water Use for the Handbook of Recommended Methods.
- Advised the Bureau of Census on data elements and questions for their 1987 Census of Irrigation and Farm and Ranch Irrigation Survey

Advisory Committee on Water Data for Public Use (ACWDPU)

The Advisory Committee on Water Data for Public Use (ACWPDU) is an advisory committee established to provide advice to the Secretary of the Interior on the water-data coordination program operated under Circular A–67. USGS Director Dallas L. Peck chaired the ACWPDU. Nancy C. Lopez served as Executive Secretary during the late 1980's and 1990's. The operations of the committee came under the requirements of the Federal Advisory Committee Act (PL 92–463) on March 8, 1988, when the first committee charter was filed with OMB. Under the requirements of the Act, the Charter of ACWDPU must be renewed every 2 years in March by the Secretary of the Interior.

The themes of the annual meetings of the Committee were driven by current events, legislation, and program proposals of the WRD and other agencies. The Committee provided an opportunity to develop support for new programs from a number of important water organizations. In many cases, the Committee itself developed recommendations that later became program initiatives. Table 6 lists the organizations that were members of the ACWPDU in 1992. Table 7 lists the themes and locations of annual meetings between 1979 and 1994.

Ad Hoc Working Group on Stream-Gaging and Water-Quantity Issues

- Inter-State Council on Water Policy (ICWP) Position Paper on the National Stream-Gaging Program (September 1996).

Office of Management and the Budget Memorandum M–91–01

In the spring 1991, the Clean Water Act came up for reauthorization. The House Committee on Public Works and Transportation and the Senate Committee on Environment and Public Works held hearings. The

Table 6. Members of the Advisory Committee on Water Data for Public Use (ACWDPU) in 1990

American Society of Civil Engineers (ASCE)
American Society for Testing and Materials (ASTM)
American Water Resources Association (AWRA)
American Water Works Association (AWWA)
Association of America State Geologists (AASG)
Association of State and Interstate Water Pollution Control Administrators (ASIWPCA)
Association of Western State Engineers (AWSE)
Chemical Manufacturers Association (CMA)
Council of State Governments (CSG)
Freshwater Foundation
Interstate Conference on Water Policy (ICWP)
National Association of Conservation Districts (NACD)
National Water Resources Association (NWRA)
National Water Well Association (NWWA)
University Council on Water Resources (UCOWR)
Water-pollution Control Federation (WPCF)

administration's position was not to develop its own bill but to assist the Congress in refining the proposed legislation. USEPA established a number of Federal working groups to address different aspects of the bill and circulated background papers for discussion.

The proposed legislation expanded the support of the Section 305(b) State water-quality monitoring process using Federal monitoring programs, addressed responsibilities for water-quality monitoring and data collection, established a Water Quality Monitoring Council led by USEPA that would coordinate Federal monitoring programs to make sure that they met State needs, and included initiatives on a variety of other issues that would directly affect USGS programs and the relationships between the USGS and its State cooperators.

At the same time, the charter of the ACWDPU had expired. In March 1991, the USGS sent a request to renew the ACWDPU charter to Interior Secretary Manual Lujan, Jr. The Secretary approved the renewal of the charter of the Committee and forwarded the charter to the General Services Administration (GSA) for concurrence. GSA did not act on the Secretary's request because OMB was reviewing existing circulars with the intent of reducing the number of circulars and advisory committees throughout the Federal Government. Then the USGS learned that OMB intended to rescind Circular A–67. This would have reduced the authority of the Department of the Interior to coordinate water data only within the Department of the Interior unless OMB provided the Secretary with alternate and equivalent authority. In November 1991, the USGS requested that Secretary Lujan send another request to renew the charter of the ACWDPU and to establish an ACWPU Subcommittee on the National Water-Quality Assessment Program. The justification of the ACWDPU was based on the growing importance to the Federal Government of State and local agency water-quality data-collection programs and the

Table 7. Themes and discussion topics of selected meetings of the Advisory Committee on Water Data for Public Use (ACWDPU), 1979–94

Year	Meeting	Location	Purpose and Focus
1979	13th Meeting	Salt Lake City, Utah	Review of Administration and Interagency Water Data and Coordination Efforts.
1980	14th Meeting	Falls Church, Va.	Federal and Non-Federal Water Data Programs (joint with the Interagency Committee).
1981	15th Meeting	New Orleans, La.	Federal-State Coordination Process; Changing Priorities in Non-Federal Water Programs.
1982	16th Meeting	Kansas City, Mo.	Review of Federal Water Data Coordination Programs; USGS Research on Hazardous Waste.
1983	(no information)		
1984	18th Meeting	Nashville, Tenn.	Panels on Ground-Water Protection; Real-Time Hydrologic Systems; Hydrologic Information for Decisionmaking.
1985	19th Meeting	San Diego, Calif.	Panels on Role of USGS in Ground-Water Protection; Maintaining Integrity of the Nation's Streamflow Database; Improving Integrity of the Nation's Surface-Water Quality Database.
1987	20th Meeting	Charlottesville, Va.	National Water-Quality Information Activities (joint with Interagency Committee).
1988	21st Meeting	New Orleans, La.	Water Resources Aspects of Climate Change.
1989	22nd Meeting	Orlando, Fla.	Partnerships for Water Information Coordination.
1990	23rd Meeting	Portland, Oreg.	Water Resources Information for Confronting Natural Hazards.
1991	24th Meeting	Bloomington, Minn.	Water Resource Information Needs for Wetlands and Habitat Management.
1992–94	(no information)		

need for interagency and intergovernmental coordination to assure that available resources were used to meet as many information needs as possible.

Once WRD learned that OMB intended to rescind Circular A–67, Philip Cohen, David Moody, and Nancy Lopez met with OMB officials to brief them on the need for continued coordination authority at the Federal level. OMB concurred that alternate authority was needed. Although OMB rescinded Circular A–67, on December 10, 1991, OBM issued memorandum M–92–01 on the "Coordination of Water Resources Information." The memorandum reaffirmed the need for the coordination of water information and designated the USGS as the lead agency for the Water Information Coordination Program (WICP). The memorandum covered all aspects of freshwater (and estuarine) information including water-resources appraisals, assessments, and investigations. Water-resources research was not included.

Major objectives for the WICP were

- To implement procedures for water information coordination at national, interstate, and State levels.
- To plan, design, and operate a national program of water-data collection and analysis that meets the priority needs of Federal and non-Federal agencies for water information.
- To develop standards, guidelines, and procedures for the collection, analysis, management, and dissemination of water information.
- To establish a National Water Information Clearinghouse.
- To facilitate the interagency reviews of plans for the initiation or expansion of Federal agency water information programs.
- To evaluate existing water information programs and identify modifications needed to respond to changes in legislation, technology, and other conditions.
- To conduct a nationwide review and evaluation of water-quality monitoring activities and prepare a report to OMB by December 10, 1992.

In mid-December 1991, the Chief Hydrologist appointed a WRD ad hoc committee consisting of Verne R. Schneider, Robert M. Hirsch, James F. Daniel, and Stanley P. Sauer to review OMB Memorandum M–92–01 and advise the ACH/WA&DC on its implementation. The committee saw the document as an important opportunity for the USGS to work with other Federal agencies and the States to improve water information programs. The Committee specifically recommended the formation of a single advisory committee that would meet more often to deal with specific decisions and continuation of an active standards setting program for data collection, especially coordination with the OMB Circular A–16 Committee on spatial data. The Committee also recommended that the WICP support a National Clearinghouse entity that made extensive use of existing WRD information dissemination activities.

On October 14, 1992, the Assistant Interior Secretary for Water and Science chaired the first meeting of a cabinet-level, WICP Steering Committee to give the program visibility within the Federal agencies. The Steering Committee met again on December 8 to approve the charter for the group.

Intergovernmental Task Force on Monitoring Water Quality (ITFM)

While participating in a USEPA Working Group on Monitoring as part of the Clean Water Act Reauthorization process in the spring of 1991, David Moody discussed the relationship of USGS and USEPA in carrying out the various components of the proposed legislation with Geoffrey H. Grubbs, Director of the USEPA's Assessment and Watershed Protection Division. Grubbs encouraged the USGS to take the lead in coordinating and planning water-quality monitoring programs, something that he believed was not included in USEPA's legal mandate. By April 1991, the USGS and USEPA had initiated discussions to develop a strategy to solve a number of pervasive problems associated with water-quality monitoring activities.

Subsequent discussions with other Federal and State agencies led to general agreement that a joint task force was needed to improve water-quality monitoring. The Intergovernmental Task Force on Monitoring (ITFM), established as a unit of the IACWD, began working in January 1992. The ITFM agenda took into account the OMB directive for the Water Information Coordination Program (WICP) to conduct a nationwide review and evaluation of water-quality monitoring activities and to report with recommendations to OMB by December 1992.

The ITFM was composed of 16 representatives of Federal, State, and interstate governmental agencies with approximately 80 additional Federal and Sate members participating in four task forces.

ITFM was chaired by Elizabeth Jester Fellows, Chief, Monitoring Branch, Office of Wetlands, Oceans, and Watersheds (OWOW), U.S. Environmental Protection Agency. David A. Rickert, Chief, Office of Water Quality, WRD, served as vice chair during 1992–93. Bernard A. Malo was Executive Secretary. James E. Biesecker served as co-chair from 1994 to 1995, and Edward N. Pickering was Executive Secretary. P. Patrick Leahy represented the National Water-Quality Assessment Program (NAWQA) on the ITFM from 1993 to 1995.

The mission of ITFM was to develop and initiate implementation of a strategic plan to achieve effective collection, interpretation, and presentation of water-quality data and to improve the availability of information for decision making at all levels of government. To do this the ITFM set out to develop a monitoring framework that would

- Meet the objectives of various monitoring activities in an effective manner.
- Better integrate monitoring efforts.
- Use available resources more effectively.
- Provide comparable data and consistent reporting of status and trends for water quality.

The ITFM identified the customers of monitoring data as legislative bodies, regulatory agencies, resource management agencies, municipalities, industries, environmental groups, and the public.

Five task groups were created:

- Framework Task Group
- Environmental Indicators Task Group
- Data Collection Methods Task Group
- Data Management and Information Sharing Task Group
- Assessment and Reporting Task Group

Secretary Manual Lujan, Jr., transmitted the first report of the ITFM to OMB on January 19, 1993, and OMB approved its release to the public *(Ambient Water-Quality Monitoring in the United States: First Year Review, Evaluation and Recommendations*). During 1993, the ITFM requested the ACWDPU to review the first-year report. The ITFM also held public meetings to obtain comments from municipal utilities, environmental groups, and volunteer monitoring groups. USGS and USEPA regional staffs met with State and other Federal agencies in each of the 10 Federal regions to discuss monitoring problems and opportunities and the ITFM recommendations.

Senator Robert Graham, Chairman of the Senate Subcommittee on Clean Water, Fisheries, and Wildlife, Committee on Environment and Public Works, requested that the ITFM report to him changes that the ITFM felt should occur in the Clean Water Act reauthorization to meet the new monitoring and information needs of a watershed protection approach. The ITFM response to Senator Graham stressed the importance of reliable monitoring information with which to measure progress towards goals; nationwide collaboration to ensure the most efficient use of monitoring resources; implementation of a monitoring strategy that specifies roles for Federal, State, Tribal, and local agencies; and the use of performance-based methods; and the establishment of biological reference conditions on streams.

Subsequently, the ITFM issued second- and third-year reports with technical appendixes detailing the work of the task groups and pilot studies. The reports developed the building blocks of a national, integrated, voluntary, monitoring strategy that included:

- A charter for a permanent National Water Quality Monitoring Council to guide implementation of the strategy.
- A framework for monitoring water quality.
- Environmental indicators to measure improvements in compliance with State-designated water-quality uses of water bodies.
- Method and Data Compatibility Board to foster the development and use of performance-based methods for data collection and analysis that will assure the production of compatible water information by different organizations.
- Use of the Ecoregion concept, reference conditions in a water body, and index calibration.

The final report, *Strategy for Improving Water-Quality Monitoring in the United States* was published in February 1995.

The success of the ITFM was in large measure due to the energy and enthusiasm of Elizabeth Jester

Fellows of USEPA who joined Nancy C. Lopez and the OWDC staff in nearly weekly meetings to review the progress of the ITFM, the support of USGS and USEPA leadership, and the spirit of cooperation between the USGS, USEPA, and the State agency personnel who participated in the study.

BRANCH OF NATIONAL WATER SUMMARY

The National Water Resources Assessment

WRD's Water Resources Assessment program had its origins in the National Water Resources Assessment of the U.S. Water Resources Council (WRC). In 1974, during the preparation of the *Second National Water Resources Assessment*, the Council asked WRD to participate in the studies being conducted in each Water Resources Region and to provide surface-water statistics, estimate ground-water depletions, identify sediment problems, and prepare Hydrologic Unit Maps for each Water Resources Region. Solomon M. Lang, the WRD point of contact with the Council, expressed concerns about the short time period (2 months once funds became available) for preparing surface-water statistics and also about potential problems with the quality assurance of the statistics. In the fall of 1976, Henry C. ("Charlie") Riggs and Solomon M. Lang assisted WRC in preparing a contract with Leo Beard at the Texas Center for Water Resources to evaluate the hydrologic data base for the 1975 Assessment, create a surface-water data base for selected areas, and develop "proposed procedures, methodologies, and implementation strategies for future updating of the data base and for determination of surface water flows normalized to future and natural conditions." Edith B. Chase was detailed to the WRC to assist with preparing the National Assessment. WRC published the *Second National Water Assessment* in December 1978.

As a result of recommendations in the Beard study, the WRC and the USGS continued discussions about the role of the USGS in future assessments. In February 1978, Chief Hydrologist Joseph S. Cragwall, Jr., invited WRC Director Leo M. Eisel to Reston to discuss how to proceed in coordinating and planning WRD's role in future assessments for FY 1980 and beyond. Joe Cragwall asked David W. Moody, a staff scientist in his office, to prepare a memorandum of understanding (MOU) with the Council. In May 1978, the USGS signed an MOU with the Council that affirmed the intention of the WRC and the USGS to coordinate their activities and defined USGS contributions to a program of continuing assessment. These contributions included

- Estimates of surface- and ground-water resources.
- Estimates of water withdrawals, consumption, and in-stream water requirements.
- Characterization of the quality of surface water and ground water and the effect on quality of use.

Water-use forecasts, adequacy analyses, and problem identification were left to WRC.

WRD reprogrammed $100,000 to support a study of methods for Water Resources Assessment by the New England River Basin Commission, one of the most innovative river basin commissions at the time. In June 1981 they completed their final report, *Water Resources Assessments: Principles for Design and Implementation.* This report laid the groundwork for many of the ideas and themes for the Water Resources Assessment program in WRD over the next decade. In addition, Harold Thomas and Myron B. Fiering at Harvard University conducted a research project on the development of National Water Accounts that was jointly supported by the USGS, WRC, and the Office of Water Resources Research and Technology (OWRT). A third project was undertaken with Resources for the Future (RFF) to link water-use estimates to the RFF Network Model, an analytical tool that RFF used to evaluate the environmental impacts of major pieces of legislation such as the Farm bill.

President Jimmy Carter's Water Policy Message to Congress on June 6, 1978, emphasized water conservation, changes to the WRC's principles and standards for Federal water project planning, and Federal-State Cooperation. This was based on a water policy review by the WRC, OMB, and the Council on Environmental Quality (CEQ) during 1977. One action taken by the President was to establish a Water Policy Task Force of Federal, State, and local representatives to examine water-related problems, help implement water policy initiatives, and make recommendations. The Task Force produced a variety of reports on topics such as the implementation and compliance with environmental statutes, inclusion of ground-water supplies within the overall framework of water project planning, maintenance of in-stream flows, and adjudication of water rights. The WRC moved ahead with a budget amendment for FY 1979

that requested more personnel to carry out the President's directives, and WRD considered how its FY 1980 program could support the President's Water Policy. Part of WRD's response was the proposal for a National Assessment of Water Supply and Demand program that would bring together the growing National Water Use Data Program with a continuing program to develop water-supply statistics at the hydrologic unit scale. The program products were aimed at meeting the commitments of the USGS-WRC MOU.

President Ronald Reagan took office in 1981. One of the early actions of his administration was to announce his intent to abolish the WRC and eliminate Federal support of most of the 21 regional river basin commissions on the grounds that water management was a State responsibility. The Department of the Interior created an Office of Water Policy (OWP) to carry on the water policy activities of Council. WRC staff were dispersed to a number of agencies during 1982.

Kerie J. Hitt, a technical writer/editor, came from the Council to work for the USGS. One afternoon, Hitt, Edith Chase, and David Moody visited the Council Offices at 2120 L Street in Washington, D.C., to meet with Gary Cobb, Acting Director of the Council, in an attempt to rescue any records from the dumpster that might be useful in WRD's Water Resources Assessment program. Furniture and filing cabinets were literally being carried out the door as they tossed folders into boxes and rolled the "mechanicals" of base maps into map tubes. Of particular interest was the "Water Resources Development Map of the United States" that Kerie Hitt had been working on while at the Council.

This map, completed by Kerie Hitt at the USGS, published in 1984 as a Special Map, *Surface-Water and Related Land-Resources Development in the United States and Puerto Rico* at a scale of 1:3,168,000, showed the location of Federal and non-Federal dams and reservoirs with over 5,000 acre-feet of storage, aqueducts, Federal irrigation projects, navigation channels, SCS projects, and other features. WRD Districts were helpful in updating the U.S. Army Corps of Engineers Dam file that was used as a data source for the map and in verifying the location of other features. During the late 1980's, virtually every office in the Federal Government or in Congress that had responsibilities for water resources had a copy of the "Water Resources Development Map" on its wall.

USGS National Water Assessment Program

In November 1980, Warren Viessman, Jr., of the Congressional Research Service, published a report for the Senate Committee on Environment and Public Works: *Assessing the Nation's Water Resources: Issues and Options.* In his report, Viessman concluded that a continuing assessment process was needed and would be useful to provide policy guidance to the Nation's water-management efforts. He recommended that an agency such as the USGS be assigned the "data-base model" responsibility of an assessment. In budget hearings during the spring of 1982, Congressman Yates closely questioned the USGS Director about the Administration's decisions to abolish the OWRT and WRC. The Director communicated this information to Interior Secretary James Watt and alerted the Department to the potential role of the USGS in future assessments.

Secretary Watt argued before Congress that the WRC was no longer needed and that the recently established Cabinet Council on Natural Resources and Environment would provide the necessary interagency coordination of Federal water policy. The Interior Secretary chaired the Council.

On May 27, 1981, Gary Caruthers, Assistant Secretary for Land and Water Resources, asked the WRD to assist him in preparing a briefing of the Water Subgroup of the Council on Natural Resources and the Environment (CNRE) including notes, visual aids, and a briefing book that he could distribute. David Moody and Edith B. Chase assembled an outline and distributed it to the Division and Regions on June 1. Fran Davison and Carolyn Moss prepared the illustrations and briefing boards used in the report. Betty Jean Hawes and Janice Hall typed many drafts. The 107-page report, *The Nation's Water Resources: Facts and Issues,* described the current water situation and the 1980–81 drought, and provided an overview of major water problems with some specific examples and case studies. This report was very well received at the Department of the Interior and marked the beginning of the National Water Summary.

National Water Summary 1983

Persistence in budgetary requests paid off, and the National Assessment of Water Supply and Demand program received its first budget authority in FY 1981. In FY 1983, the program was renamed the Water

Resources Assessment program. Moody, assisted by Thomas Chaney and Edith Chase, continued to work on putting together tools for use in the assessment activity.

Several pieces of legislation proposed the establishment of a National Board on Water Policy that would conduct national assessments. The Water Resources Assessment program staff worked with USEPA to develop the River Reach file and incorporate into it low-flow statistics from District reports and basin characteristics from the WRD Basin Characteristics File. Bruce L. Foxworthy in the Washington District undertook a prototype Regional Water Resources Assessment of the Snake River Basin. A major question to be answered by the study was how much existing water information in the basin could be used to make a water-resources assessment and to determine historical trends of streamflow and water quality.

During 1982, the USGS had a Secretarial Management-by-Objective (MBO) to prepare a report summarizing the Nation's major water problems to be submitted to the Department's OWP by March of 1983. The report was to educate the public as to the distribution and magnitude of the Nation's water problems and identify emerging issues that might require the development of water policies or other actions by State or Federal agencies. WRD District offices were asked to prepare short, State-by-State reports and maps showing the location and areal extent of the issues described. Upon consultation with Tom Bahr, Director, OWP, and with Gary Carruthers, Assistant Secretary of Land and Water, a more ambitious project was outlined to Secretary Watt consisting of an annual report on national water conditions during the past year and analyses of specific water problems of current interest. OWP would then forward the report to the Secretary with policy recommendations before its release.

In addition to the report, the USGS would develop a Water Resources Information System (WRIS) that would utilize the capabilities of a geographic information system (GIS). Chief Hydrologist Phil Cohen appointed an Ad Hoc Water Resources Assessment Committee (Gordon B. Bennett, James E. Biesecker, Gary D. Cobb, Nicholas C. Matalas, and Marshall E. Moss) chaired by Joseph S. Cragwall, Jr., to assist David Moody and Edith Chase in developing plans for such a system. Charles J. Robinove's interest in the melding of remote sensing and geographic information systems (GIS) led to the proposal of the Fox River Basin in Wisconsin as a demonstration basin for the application of GIS to the presentation and analysis of water data for assessments. On December 9, 1982, Moody arranged for a briefing of the Headquarters staff by Jack Dangermond of the Environmental Systems Research Institute (ESRI) about the GIS software, ARC/INFO, that his firm had recently developed for possible use in the Water Resources Assessment program. ARC/INFO was installed on the Division's computers in July 1984.

In January 1983, Secretary Watt requested a press release and briefing on the Water Resources Information System to support Water Resources Assessments along with remarks that he could present to the Cabinet Council on Natural Resources Meeting. Coordination with other Federal agencies would be handled through the Inter-Agency Committee on Water Data (IACWD). WRD and OWP briefed Secretary Watt on the proposed *National Water Summary 1983*. The next few months were spent briefing Federal agencies and various associations on "Reporting on the Nation's Water Resources: Process and Products," including the National Academy's Water Science and Technology Board, and acquiring feedback and commitments from agencies to participate in the process and review products. In May 1983, the Districts were asked to prepare State water-issue summaries and maps. These were to be prepared based on guidelines and examples of issues prepared by the New Jersey District. By June, the Systems Analysis Group had prepared a work plan for assessment products that was of great use in planning future activities of the Water Assessment Program. Especially helpful were suggestions for the use of innovative graphics to display hydrologic information. Edith B. Chase served as senior editor for the report, and Joan M. Rubin was graphics editor and book designer.

In October 1983, the USGS briefed Secretary Watt on the 1983 *National Water Summary* and later briefed Secretary William Clark, his replacement, in December. A press briefing was held on January 22, 1984, to announce the publication of the *National Water Summary 1983: Hydrologic Events and Water Issues* (USGS Water-Supply Paper 2250) and its companion volume *Water in America* prepared by OWP. A briefing and distribution plan was developed with the assistance of Donovan B. Kelly, K. Mitchell Snow, and Talmadge "Tom" W. Reed in the Director's office and Porter E. Ward and Edgar A. Imhoff in the

Office of Water Data Coordination (OWDC). Copies of the publication were sent to members of Congress, heads of Federal agencies, and the governors of each State. This was followed by more than 20 presentations to water organizations in Washington and visits to members of the Advisory Committees arranged by OWDC to obtain comments and feedback on the work plan for the 1984 *National Water Summary*. Each District prepared its own press release and distributed copies of the Summary to its major cooperators.

Virtually all members of the technical staff at WRD Headquarters, especially the Branch of Publications, under the direction of John E. Moore and Eugene Hampton, Regional report and discipline specialists, and most significantly, District personnel worked on some aspect of the first National Water Summary. Such an effort would not have been possible without the wholehearted support of the Chief Hydrologist and the commitment of the entire Division to see the project through.

OFFICE OF WATER ASSESSMENT AND DATA COORDINATION

A more formal management structure was needed to design and coordinate future Summary reports. To this end, in late 1983, the Office of National Water Summary and Long Range planning was established in the Office of the Chief Hydrologist with David Moody as Chief, Thomas H. Chaney, and Janet Nokes Arneson as Secretary. Edith B. Chase, who had been on detail to the project for nearly 2 years, was officially transferred to the new office along with Kenneth J. Lanfear and John N. Fischer in 1985, and Kerie J. Hitt in 1986. In less than a year after the office was established, Jack Fischer was selected as Assistant Chief Hydrologist for Program Coordination and Technical Support (AS/PC&TS), and shortly thereafter he was made Associate Chief Hydrologist.

In early 1987, WRD created the Office of the Assistant Chief Hydrologist for Water Assessment and Data Coordination (AS/WA&DC) to bring together a number of outreach activities associated with the National Water Summary and information coordination activities of OWDC, continue development of the Water Resources Information System, now renamed the Interpretative Water Information System, and continue to facilitate the formulation of long-term goals and objectives for WRD. Moody became the Assistant Chief Hydrologist for the office, and Ethan T. "Tim" Smith was transferred from the Director's office to be Deputy Chief. Donald L. Leifesky acted as Chief of OWDC until the return of Nancy C. Lopez in the fall of 1987 from her assignment as USGS representative on the staff of the Assistant Secretary for Water and Science.

Richard W. Paulson was selected as Chief of the Branch of National Water Summary (BNWS) in 1987 and Jerry E. Carr, former District Chief of Oklahoma, was brought in to provide a field perspective on the Summary. Patricia S. Greene joined the National Water Summary team in 1991, as did Judy D. Fretwell in 1992. John C. Kammerer provided part-time assistance as a temporary employee during 1992 while he updated his fact sheet on the Nation's longest rivers. Toni M. Johnson transferred from the Division's Program Office to work on outreach aspects of the National Water Summary in 1993. These arrangements continued through the end of 1993 when Paulson retired and was replaced by Jo Ann Macy, District Chief of Indiana, in April of 1994.

Of particular importance to the conception, design, and implementation of the *National Water Summary* reports between 1985 and 1994 was the Headquarters Branch of Publications, the Publication Services Unit (later the Cartographic and Publications Program) of the Wisconsin District, under the supervision of Gregory J. Allord, and the Colorado District Publications Section headed by John S. Williams. Over a period of 8 years, Richard Paulson melded the personnel in these organizations into a closely knit and highly motivated team committed to producing a quality product.

David Moody and Edith Chase retired in at the end of April 1994. Table 8 lists a few among the many Division personnel who worked to produce the National Water Summary series of reports from 1983 through 1994.

Activities of the of the Office of the Assistant Chief Hydrologist

With the creation of the ACH/WA&DC, David Moody spent increasing amounts of time on developing relationships with other Federal agencies, developing outreach activities and other Division programs, providing staff assistance to the Chief Hydrologist during meetings with non-Federal organizations, such as the Association of State Geologists, and reviewing and preparing comments on water legislation for the

Table 8. National Water Summary staff and supporting personnel, 1983–94 (dates shown after organizational units are the periods during which particular subunits were in operation)

Office of the Chief Hydrologist (1979–83)	Assistant Chief Hydrologist for Water Assessment and Data Coordination (1987–94)	Office of National Water Summary and Long-Range Planning (1984–86)
David W. Moody, Staff Scientist (1979–83)	David W. Moody, Chief (1987–94)	David W. Moody, Chief (1984–86)
Thomas Chaney (1982–83)	Ethan T. Smith (1987–94)	John N. Fischer (1985)
John C. Huang, Student (1980 – 83)	Toni M. Johnson (1993–94)	Kenneth J. Lanfear (1985–86)
Betty Jean Hawes (1980 – 83)	J. Ronald Jones (1992–93)	Edith B. Chase (1985–86)
Janet Nokes Arnson (1980– 83)	John C. Kammerer (1992)	Kerie J. Hitt (1986)
Janice A. Hall (1983)	Janet Nokes Arneson (1987–94)	Janet Nokes Arneson (1984–86)
	Helen F. Ipsaro (1993–94)	Marguerite J. McCausland (1985–86)
	Branch of National Water Summary (1987–94)	
Richard W. Paulson, Chief (1987–93)	Edith B. Chase (1987–94)	Judy D. Fretwell (1992–94)
Jo Ann Macy, Chief (1994)	Jerry E. Carr (1987–88)	Patricia S. Greene (1991–94)
Kenneth J. Lanfear, Assist Chief (1989–94)	Kerie J. Hitt (1989–91)	Michele E. Lewis (1988)
	National Water Summary Support Personnel 1983–94	
Gregory J. Allord	Bruce L. Foxworthy	Jamaica Pettit
David A. Aronson	Michael D. Frost	Robert R. Pierce
Byron N. Aldridge	Jack H. Green	Phillip J. Redman
Robert C. Babeck	Donald A. Goolsby	Robert S. Roberts
James F. Bailey	Pat Griffith	Leslie J. Robinson
Gina P. Barker	Eugene R. Hampton	James P. Rounds
Emma-Lee Beagle	Richard A. Herbert	Joan M. Rubin
Christine M. Bebow	Donald E. Hillier	Dianne A. Shugrue
Linda Britton	Ira M. Hubert	Wayne B. Solley
Deborah Brown	George A. Irwin	Andrew M. Spieker
Francis L. Buchannan	Linda Jacobsen	Vernon B. Sauer
Robin Bunch	Barbara A. Jenkin	Jackie Savage
John R. Burt	Marshall E. Jennings	Arthur G. Scott
David A. Carlson	Richard H. Johnson	Lucille A. Strassman
Jerry E. Carr	Mary A. Kidd	Hyla H. Strickland
Linda K. Channel	Gary D. Latzke	Eric D. Swain
Lanna J. Combs	Allan C. Long	Edward J. Swibas
Timothy D. Covington	Shirlie McManus	Wilbert O. Thomas, Jr.
Roz D. Czajkoski	John S. McLean	Michael Turtora
Wendy J. Danchuk	Christine B. Mettel	Kenneth L. Wahl
Steven H. Denowski	Shirly Milton	John Watermolen
Nancy M. Dudley	Jennifer S. Norton	Wayne E. Webb
Elizabeth A. Enright	Daisie Oden	John S. Williams
John M. Evans	Perry G. Olcott	James O. Witmer
Kathleen Fitzgerald	Robert J. Olmstead	Katherine A. Wolf
Sharron D. Flagg	James E. Peters	Tracy J. Yager

Director's office. Of particular importance was the close relationship developed with the U.S. Environmental Protection Agency (USEPA) that led to quarterly meetings of the Chief Hydrologist and James R. Elder, Director of USEPA Office of Ground Water and Drinking Water and members of their staffs. Jerry Carr assisted the USEPA in organizing a workshop on "Hydrologic Mapping Needed for Ground-Water Quality Management" in 1988 and in implementing a number of the provisions of a 1986 MOU with WRD

related to the protection of the Nation's ground-water quality.

Tim Smith, Deputy Chief of the Office, worked on developing information on emerging water issues, preparing and updating the WRD objectives document, updating WRD activities briefing documents, and maintaining liaison with the Council of Environmental Quality (CEQ) on their trends and indicators project. He represented the office on many USGS and interagency committees.

Toni M. Johnson expanded the outreach activities of the office in 1993 on behalf of the Division, a task that she approached with energy and creativity. Judy Campbell Bird was contracted to develop a report on outreach activities for the Division's program, which she completed in November 1993. Her focus was on getting WRD-produced information into the hands of those who needed it. In 1993, the USGS joined The National Geographic Society and The Conservation Fund in the "Geography of Freshwater Initiative." This led to the publication of a special issue on water of the Society's research journal, *Exploration & Research*. The special issues included a map insert entitled "Water Resources: Reflections on a Critical Resource." Ken Lanfear worked closely with the National Geographic Society editors to make appropriate GIS coverage available to them. Much of the information on the map came from the National Water Summary reports.

J. Ronald Jones joined the office in 1992 to review and analyze new legislation, a task that he performed until his retirement in 1993. During 1992 and 1993, the Clean Water Act Reauthorization was at the forefront of water legislation. USEPA chaired an Interagency Working Group on Clean Water Act Reauthorization and established a number of subgroups. Moody represented the USGS on the Monitoring Assessment Subgroup and co-chaired it with the NOAA representative. DOI set up its own Working Group and Subgroups on which a number of Division personnel served. Several provisions in the proposed legislation called for the creation of a water-quality monitoring board and other program coordination mechanisms that duplicated the efforts authorized by OMB Memorandum M92-01 that established the Water Information Coordination Program (WICP) and the Interagency Task Force on Monitoring (ITFM).

Interpretive Water Information System (IWIS)

One of the original objectives of the Water Resources Assessment program was to establish a water information system that would support a National Assessment program. With the demise of the U.S. Water Resources Council at the end of Fiscal Year 1982, the focus of the information system became supporting the National Water Summary and the information needs of other assessment activities in the Federal Government. Early experiments, led by Charles J. Robinove, to develop a GIS for the Fox-River Basin in Wisconsin led to the conclusion that GIS was a central tool to aid in the selection, analysis, and display of water information; to synthesize and integrate data sets from many different sources; and to reduce the labor required to produce publication-quality maps. From 1985 onward through 1994, Kenneth J. Lanfear spearheaded the development of ARC/INFO applications for the Water Resources Assessment program and for other Division activities. Efforts by the Branch of National Water Summary and the OWDC were relatively successful in assembling national data sets to apply to the preparation of future National Water Summaries, to the analysis of water data networks, and to the preparation of reports for publication. As a by-product, Lanfear and Kerie J. Hitt assisted other Division programs and other Divisions with GIS applications. For example, the office assisted the Geologic Division in digitizing the "Geologic Map of the United States" and the "Quaternary Sediments Map of the Northern United States."

An early objective of the system was to calculate simple water balances on the basis of Water Resources Subregions. The challenge was to get complete nationwide coverage based on reliable, quality-controlled data. This often meant applying a specific analytical approach to data retrieved from WATSTORE. In some cases, such as evaporation losses or interbasin transfers, data sets did not exist. Bruce Parks developed an application of ARC/INFO to extract and plot information about data collection sites from files in the National Water Data Exchange (NAWDEX) as a tool for use by the Districts in analyzing information about their networks.

The IWIS, developed by Ken Lanfear, was used to answer requests from agencies such as USEPA National Laboratories, USEPA headquarters, the Department of Agriculture, and Environment Canada.

The system provided support of initial analyses of pesticide occurrence by NAWQA and assisted a number of individual research projects. One problem that was never resolved was how to maintain and update an increasingly large number of products with limited funds and personnel once they got out of date. Table 9 lists the major data sets and GIS coverages in the system.

National Water Summaries 1984–94

While the ink was still wet on the 1983 National Water Summary, the staff of the Office of National Water Summary put a process in place that provided a template for most of the other Summaries: (1) selection of the National Water Summary theme based on inputs from the WRD, the information needs of other Federal agencies, discussions with the OWDC Federal and non-Federal advisory committees, and National Water Summary staff perceptions of important issues before Congress in the next few years; (2) preparation of a report outline and guidelines for authors of topical articles and the individual State reports including prototype State reports from one or two Districts; (3) discussion of the guidelines at an authors' conference; and (4) an editors' and illustrators' conference to discuss the graphic design of the report and special requirements. The report was divided into the "front

Table 9. List of data bases and ARC/INFO coverages developed by the Water Resources Assessment Program

Geographic Units
State and county boundaries, streams, water bodies, census tracts, zip codes (1:2 million scale)
Hydrologic cataloging units and codes (1:2.5 million scale)
Environmental Protection Agency Reach File (1:500,000 scale)
Natural Resources Conservation Service Land Resources Areas (1:7.5 million scale)
Environmental Protection Agency EcoRegions (1:7.5 million scale)
Wetlands of the United States (1:2 million)
Surface-Water Supply Characteristics
Average precipitation contour maps (1:2 million scale)
Average runoff contour maps (1:2 million and 1:500,000 scale)
Interbasin transfers between Water Resources Subregions (INFO data base) (1985)
Dams and reservoirs over 5,000 acre-feet capacity (INFO data base) (based on U.S. Army Corps of Engineers dam file)
Evaporation from lakes and reservoirs over 5,000 acre-feet capacity
Major aquifer boundaries (1:2 million) (from National Ground Water Atlas)
Ground-Water Supply Characteristics
Public water-supply wells, location, and characteristics
Estimated average long-term depletion from aquifer storage by Water Resources Subregion
Water-Quality Characteristics
Point and nonpoint pollution source loadings (resources for the future)
Pesticide application rates (25 pesticides by crop and county) (resources for the future)
Surface-water quality trend data base
Ground-water quality data base
Sediment runoff characteristics of the United States
History of pollution loads in the Hudson River Basin 1880–1980
Ancillary Information
Point population files (Census data)
Hazardous waste sites and landfills (locations and density per county)
County statistics file (Census data) (1200 parameters)
Acid rain pH contours for United States
Geologic map of the United States
Surficial sediment map of glaciated parts of the United States

end" of hydrologic event descriptions and articles on significant water topics and the "back end" of individual State reports prepared by the Districts. Subsequent National Water Summary reports are listed in table 10.

Initially, the Headquarters publication staff prepared most of the front-end graphics and many of the State report maps, and the Geologic Division did the report layout. In the 1984 report on ground-water resources, Allord's group in Wisconsin used existing State base-map materials to prepare the principal aquifer maps for each State. Computers were used to draw hydrographs for water levels in wells.

In the 1985 report on surface-water resources, the State base maps were replaced by shaded-relief maps derived from the National Mapping Division's shaded-relief map of the United States. The Wisconsin Publications Unit made extensive use of GIS to overlay precipitation and runoff contours over the shaded-relief image maps. Water-Resources Region and Subregion boundaries and the location of dams were created from the hydrologic unit map of the United States. The illustrations in this report took on a distinctly modern appearance. The Florida District also provided assistance in preparing illustrations.

The 1986 report on ground-water quality drew on GIS coverages of county boundaries, population density, waste sites, landfill sites, and other data derived from various Federal data bases for the State presentations. Computers were also used in the hydrologic condition maps. Even so, many illustrations for the 60 figures in the front end of the report required manual preparation. Similarly, the 1987 Summary on water supply and use made extensive use of computers to create chloropleth maps showing State water withdrawals by county and pie charts showing withdrawals by hydrologic units and aquifers, and the "octopus" diagram showing freshwater sources, uses, and disposition by State.

By 1988, the National Water Summary reports encountered significant delays in publication. The time required to prepare the many illustrations in the report and to review the text, especially reviews by other Federal agencies, and to edit the text had increased and could not be offset by increases in computer use for the preparation of illustrations.

In mid-1988, the National Water Summary depended upon a growing number or organizational units for assistance.

- Office of the Assistant Chief Hydrologist for Program Coordination and Technical Support (ACH/PC&TS) – formed a partnership with BNWS to conceptualize and develop technically sound approaches to a particular water theme of the National Water Summary.

- Office of the Assistant Chief Hydrologist for Scientific Information Management – reviewed National Water Summary manuscripts for editorial, technical, and policy content on a priority basis and prepared graphics and typesets the front part of the report.

Table 10. List of National Water Summary reports

1983	*National Water Summary 1983 – Hydrologic Events and Issues* (published January 1984), U.S. Geological Survey Water-Supply Paper 2250, 243 p.
1984	*National Water summary 1984 – Hydrologic Events, Selected Water-Quality Trends, and Ground-Water Resources* (published May 1985), U.S. Geological Survey Water-Supply Paper 2275, 467 p.
1985	*National Water Summary 1985 – Hydrologic Events and Surface-Water Resources* (published September 1986), U.S. Geological Survey Water-Supply Paper 2300, 506 p.
1986	*National Water Summary 1986 –Hydrologic Events and Ground-Water Quality* (published October 1988), U.S. Geological Survey Water-Supply Paper 2325, 560 p.
1987	*National Water Summary 1987 – Hydrologic Events and Water Supply and Use* (published June 1990), U.S. Geological Survey Water-Supply Paper 2350, 553 p.
1988–89	*National Water Summary 1988–89 – Hydrologic Events and Floods and Droughts* (published December 1992), U.S. Geological Survey Water-Supply Paper 2375, 591 p.
1990–91	*National Water Summary 1990–91 – Hydrologic Events and Stream Water Quality* (published December 1993) U.S. Geological Survey Water-Supply Paper 2400
1996	*National Water Summary – Wetland Resources* (published 1996) U.S. Geological Survey Water-Supply Paper 2425, 431 p.

- WRD Districts – Prepared one or more State reports for the Summary.
- Wisconsin District Federal Series Reports Unit – Prepared graphics for the State reports and edited the text.
- Colorado District Federal Series Reports Unit – Prepared some graphics for the front part reports and edited the State reports.
- Montana District – Assisted in editing the State reports.
- Pennsylvania District – Compiled an annual list of the 50–100 most important hydrologic events in the United States each year.
- WRD District detailees – District authors prepared front-part technical articles and provided detailees to edit, type, and prepare illustrations.
- Geologic Division – Reviewed the State reports and front-part articles as part of the manuscript approval process and assisted in the review of the material for the printer.

The resources of organizations, such as the Colorado Federal Reports Unit, were increasingly stressed by the arrival of other reports that had high density of graphics from the National Ground Water Atlas, the Regional Aquifer-System Analysis (RASA) program, and the National Water-Quality Assessment (NAWQA) Program. Even if sufficient funds had been available, personnel ceilings prevented the hiring of additional people. Additionally, level year-to-year Water Summary budgets and inflation eroded the financial and human resources available to prepare the reports among all the organizations cited above, and especially exacerbated the problem of underfunding District authors.

Several options were presented to the Director and the Chief Hydrologist for changing the format of the report, and there was general consensus that the best approach was to go to a biennial report beginning with the 1989–90 report. Overall, the approach was less expensive and put fewer demands on the Division's publication preparation resources, but it still preserved the spirit of the report.

The 1988–89 report on floods and droughts was an ambitious undertaking requiring the listing of major floods and droughts for each State for the period of record, and maps showing the areal extent of five major floods. Annual peak discharges were plotted for the period of record along with the flows representing the 10-year and 100-year recurrence intervals for five or six gaging stations. Similarly, for droughts, maps showed the areal extent of five selected droughts in the State and graphs showed the annual departure of flows from the average mean discharge. Droughts were classified as having recurrence intervals of less than 10 years, 10 to 25 years, or more than 25 years. These displays resulted in 20 to 25 pieces of art work for each State or approximately 1,000 illustrations for the State reports in addition to the 76 figures in the front end of the report.

The 1990–91 report on stream water quality was probably the most technically complex of the National Water Summary series of reports. Firstly, a technically consistent water-quality data base had to be created from WATSTORE. Secondly, agreement had to be reached with the Office of Water Quality as to appropriate statistical procedures for computing trends for specific periods of record for specific conductance, dissolved oxygen, dissolved sulfate, dissolved nitrite plus nitrate, total phosphorus, dissolved solids, suspended sediment, and fecal coliform bacteria. Box and whisker diagrams were created for all analyses in selected drainage basins in each State to capture the geographic variability of water quality. The methods used to select the stations and analyze the data were published by Kenneth J. Lanfear and Richard B. Alexander as U.S. Geological Survey open-file reports.

An unanticipated by-product of this effort was the discovery that metals and trace-element data in WATSTORE could not be used in the report because of apparent contamination due to inappropriate field data collection and analysis techniques. This led to a revision of field and analytical procedures and improvements in quality control of the data.

Wetland resources were the theme of what became the eighth and final report in the series. The report was published in 1996 without a hydrologic events section and no date on the cover. In 1994, the report was well under way. The State maps were based on a manuscript map of wetlands in the United States developed by Thomas H. Dahl of the U.S. Fish and Wildlife Service. Gregory J. Allord digitized the map and prepared a GIS coverage. The report contained an overview of wetland resources with articles prepared by members of the National Biological Service, the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the U.S. Environmental Protection

Agency, the U.S. Geological Survey, the University of Texas, and a private firm. The State maps showed the distribution and classification of wetlands in each State, their hydrologic setting, and trends in acreage.

The National Water Summary reports served many uses by State and Federal agencies. They served as references for the Congressional Research Service in fielding inquires. They became required reading in university survey courses on water resources. One innovation pushed forward by the Summary staff was the production of offprints of the State reports at the end of the press run. Agencies distributed these separate State Summaries as to their constituencies and, in some cases, bound together sets of Summary State reports to make a mini-atlas of the State's water resources. Finally, a number of nongovernmental organizations used the information in the reports for their programs.

In February 1994, the National Water Summary staff representing Branch of National Water Summary, the Branch of Scientific Publications, the Cartographic and Publications Program of the Wisconsin District, the Colorado District, and the New Hampshire District met to reinvent the National Water Summary. The reinvention team considered the market and readership for the report series, ways of reducing the size of the report, approaches to speeding up report preparation, and the effect on costs and resources of expected advances in report preparation and printing technology. The team also met with the Chief Hydrologist to select the topics of the next two future National Water Summaries – "Review of Water Issues," update of the 1983 National Water Summary, and "Water in Urban Areas," an expansion of the Water-Supply Paper 1812, *Public Water Supplies of the 100 Largest Cities in the Untied States, 1962,* published in 1964 and authored by Charles N. Durfor and Edith B. (Becker) Chase. The team felt they had assembled a plan that would bring the biennial reports back on schedule and within the available resources of WRD by using increasingly sophisticated technologies for the preparation of illustrations and the printing of the report.

By the end of 1993, Richard W. Paulson had assembled a closely knit and highly motivated team of professionals who strongly believed in the importance of the National Water Summary and who were committed to producing a high quality report. Their enthusiasm and spirit made the National Water Summary possible. However, staff retirements, budget reductions, and personnel restrictions of the mid-1990's took their toll. With the publication of the eighth National Water Summary on wetland resources, the "encyclopedia of water" came to an end.

NORTHEASTERN REGION

By Stanley P. Sauer

INTRODUCTION

The Northeastern Region was composed of 19 Northeastern States and the District of Columbia for the period of this history, with a population well in excess of 40 percent of the total for the United States. The 19 States in 1979 were Connecticut, Delaware, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Wisconsin. During the early 1990's, in conjunction with a WRD reorganization of management structure, Kentucky was transferred to the Northeastern Region from the Southeastern Region, and Minnesota was transferred to the Central Region. Ten of the States were individual Districts, with two multi-State Districts. Delaware, Maryland, and Virginia and the District of Columbia formed the Mid-Atlantic District; Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont made up the New England District.

The WRD National Research Program was under the direction of the Regional office at the beginning of this history but was soon separated administratively to be under the guidance of the newly established office of the Assistant Chief Hydrologist for Research. The day-to-day contacts and cooperation between the National Research Program personnel and the Region and District offices continued at a high level throughout the period of this history.

NORTHEASTERN REGION OFFICE STAFF

The 12-District Northeastern Region was headquartered in Reston, Va., during this history. James E. Biesecker was Regional Hydrologist until the end of 1981, when he accepted a position in WRD Headquarters. Stanley P. Sauer replaced Biesecker as Regional Hydrologist in 1982. Sauer served until he retired in 1993. He was replaced by William J. Carswell, who served as Regional Hydrologist to the end of this period of history. Francis T. Schaefer served as Assistant Regional Hydrologist and Delaware River Master from the beginning of this history until 1986 when he retired after 50 years of service. Sauer served as Delaware River Master from 1986 until his retirement in 1993, at which time Carswell was appointed and served to the end of this history and beyond. Porter E. Ward served as Program Officer, and his reassignment to the Office of Water Data Coordination (OWDC) early in 1980 created a vacancy on the Regional Staff. Herbert J. Freiberger, Staff Hydrologist during the first half of 1980 assumed some of the Program Officer duties until his transfer to Maryland as District Chief. Dennis J. Sulam replaced Freiberger in January 1980 as Staff Hydrologist. Sulam's tenure spans this history and beyond. Jerald F. McCain transferred from the Colorado District in late 1980 to serve as Program Officer. He served in this capacity until 1986, when he assumed the additional duties of Assistant Regional Hydrologist. McCain continued with this arrangement until he retired in 1988. Lawrence A. Martens replaced McCain in 1988 and served until 1992 when he retired. David Grason transferred from Maryland to replace Martens in late 1992. Serving as Assistant Program Officer during this period were Kathleen R. Wilke, 1981 to 1986, and James G. Peters, 1986 to 1992. Wilke transferred to the Colorado District, Peters to Maryland.

Management positions titled "Area Hydrologist" were created in 1991 and filled by Donald E. Vaupel, Herbert J. Freiberger, Catherine L. Hill, Ivan C. James, and Daniel P. Bauer. These positions were abolished in 1996.

The National Water-Quality Assessment Program established Regional managers on the staff. Mark A. Ayers, 1991–94, and Michael C. Yurewicz, 1994 to the end of this history and beyond, served as NAWQA managers. Stephen K. Sorenson served as Staff Biologist for this program from 1992 to the end of this history and beyond. Stephen B. Smith provided biological liaison with Biological Resources Division from 1994 to the end of this history and beyond.

The discipline specialists during this period were: Ground Water—Ren Jen Sun, 1980–81; Lindsay A. Swain; 1981–88; Michael G. McDonald 1988–90; Kenneth J. Hollett, 1991–93; and Albert T. Rutledge, 1993 to the end of this history and beyond. Water Quality—Herman Feltz, 1980–82; Wayne E. Webb, 1982 to the end of this history and beyond. Surface Water—James F. Bailey, 1980–85; Arthur G. Scott, 1985–93; Terrance E. Lamb, 1993 to the end of this history and beyond. The technical specialists left the Region for different reasons. Sun and Hollett transferred to Division positions; Swain transferred to a project assignment; McDonald resigned. Feltz transferred to a Division assignment; Bailey and Scott retired.

Report review was handled by W.D.E. Cardwell, 1980–82. When Cardwell retired, David A. Aronson took over report review duties from 1983 to the end of this history period and beyond.

Computer Specialists were Charles E. Nethaway, 1980–83 (reassigned to Division assignment); Michael G. McDonald, 1983–88 (reassigned as Ground Water Specialist); and Merritt E. Blalock III, 1989 to the end of this history and beyond. Computer assistance to Regional staff and others was provided by Victor Lira and then Kimberly P. Griffin.

Administrative support was provided by Katherine L. Jeffries, 1980–82, and Nancy C. Bley from 1982 to the end of this history period and beyond. Others involved in administrative activities were Judith Campton, Margaret Martin, Anthony Cannarsa, Kathleen Shevlin, Nancy Knicely, Patricia Smith, Myrna Hajduk, Nancy Hill, Christine Craun, Aledra Cramer, Jacqueline Johnson, Sharla Pierce, Michael Smith, Brenda Elsea, Scott Padgett, Richard Dolinger, and Harriet Moran. The administrative staff ranged from three to six positions over this period.

The Secretary to the Regional Hydrologist was Margaret Martin until 1982, followed by Irene Girard from 1982 to 1992 and Alicia Taylor from 1993 until

the end of this history period. Other support activities were provided by Anne Bissett, Karen Wrenn, Joy Kelly, Patricia Butler, Julie Taylor, Deborah Bernd, Virginia Morgan, Marilyn Snyder, Yvonne Kidwell, Paula Sharp, Vonda Davies, Jane Rose, Barbara Taylor, Georgia Diersing, Sarah Griffin, and Aloma Perdichizzi. At any one time the staff ranged from three to six secretarial/clerical positions.

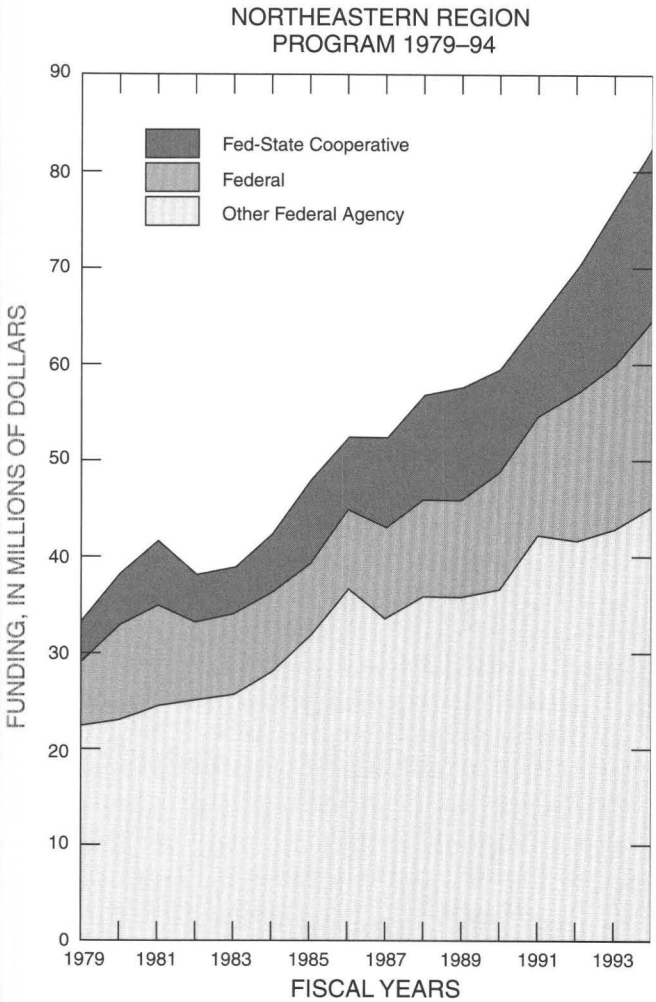
Human Resources activities were handled by Cynthia Lewis and Linda Rann, with assistance over time by Sarah Griffin and Aloma Perdichizzi.

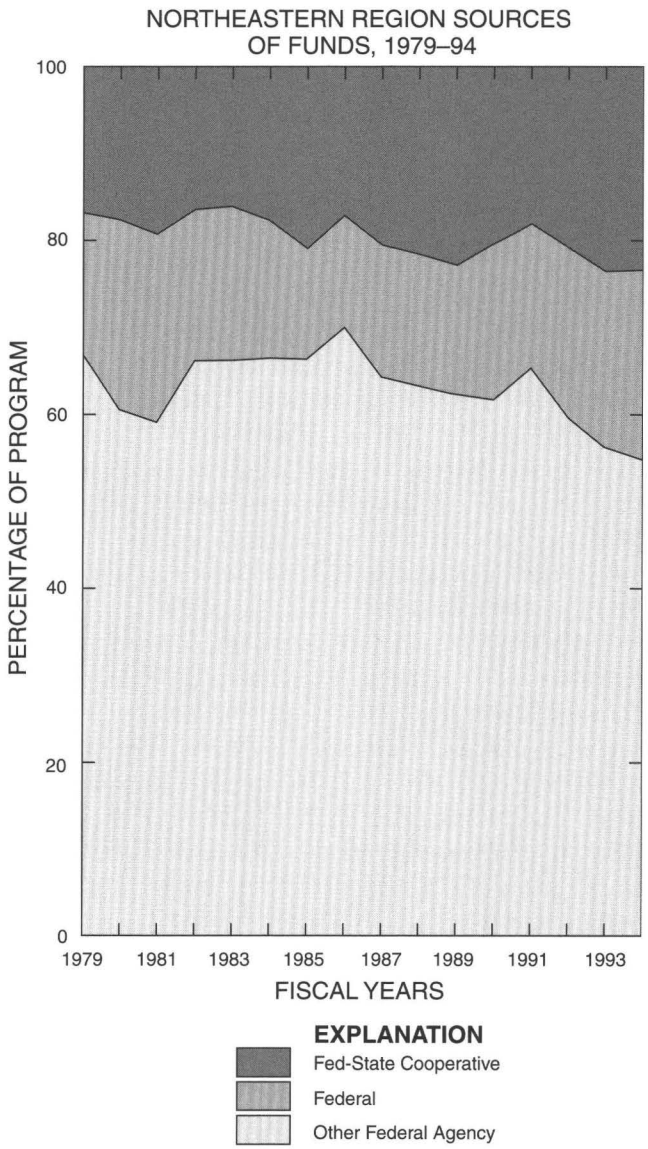
Safety issues were handled as a collateral duty by various Northeastern Region staffers.

PROGRAMS AND FUNDING

Aggregate program funding for the Districts in the Northeastern Region during the fiscal years 1979–94 demonstrated a pattern of steady growth as the Federal, State, and local agencies sought to address the many water-resources issues with the help of the scientific expertise of the WRD. The following graph illustrates the funding progress during the period:

Direct appropriations to the WRD for the Federal program varied somewhat, as is typical. At the beginning of the period, substantial appropriations for the Coal Hydrology Program, which was initiated after the energy crisis of the early 1970's, added significantly to the programs of those Districts in States with coal resources. Funds for this program were reduced at a rapid pace beginning in 1982, resulting in budgetary problems for those same Districts, as well as numerous partly completed projects and reports. The relocation of personnel because of downsizing was also a problem. Later in this period, appropriations for the Federal program were significantly increased. The National Water-Quality Assessment (NAWQA) and





Toxics programs were initiated and ramped up as the awareness of the public and their elected officials was elevated regarding the many problems and concerns related to water quality and contamination issues. The Regional Aquifer-System Analysis (RASA) program funding reached the maximum level during this time. Funding for RASA, however, started declining during the latter part of this period as studies were being completed. Other Federal program funding was relatively stable during this period, which resulted in a general reduction of activity owing to the effects of inflation. Federal program funds, as a percentage of the Region totals, reached a maximum of 22 percent in 1980, declined to less than 13 percent in 1985, then again approached the 22-percent level in 1994. The percentage of funds during this period, by source, is illustrated in the graph: Funds transferred to WRD by other Federal agencies (OFA) exhibited a general pattern of growth throughout the period. At the beginning of this history, OFA funding was about 17 percent of the aggregate total, with significant emphasis on the collection of basic records of streamflow and water-quality information. Assistance to OFA's was provided for a wide range of other water-resources problems and issues, including coal hydrology, surface-water and ground-water contamination problems, quantity and quality of flow into the Great Lakes, International Boundary waters along the Canadian border, flood-plain mapping and management, and contamination and restoration issues on military facilities. By the end of the period, OFA funding represented nearly 24 percent of total funds as the Installation Restoration Programs of the Department of Defense received significant emphasis. The changes in both amounts and percentages of OFA funding are shown in the two funding graphs.

The Federal-State Cooperative (Coop) program funding continued to be the backbone of operations in the Northeastern Region for the period and exhibited steady and substantial growth. The Coop program funding ranged from a low of less than 55 percent to almost 70 percent of total program funds. The changes in both amounts and percentages of Coop program funding are shown in the two funding graphs. The content of the Coop program in the Northeastern Region reflected the wide range of issues confronting the State and local government agencies in the region, ranging from the responsibility to ascertain and document the quantity, quality, and availability of water resources to highly specific and technologically advanced studies of various hydrologic processes. Reverse flow funding, wherein the WRD entered into cooperative agreements with State and local governments to undertake hydrologic studies, and transferred some of the Federal matching funds to the local entity to perform the work, was in place at the beginning of the period. This approach was initiated during the 1970's as highly restrictive personnel ceilings prevented the WRD from accomplishing all the investigations requested and funded through the appropriations process. This process was discontinued early in the period of this history due to reduced appropriations as well as management and quality-control issues. The WRD Water Use program was well developed early in this period, with a significant part of the work being accomplished by the State cooperating agencies. This procedure worked very well for the entire period of this history.

The State and local cooperating agencies in the Northeastern Region requested assistance from the WRD on a wide range of issues, many of which required a very high level of scientific expertise to accomplish the project objectives. As a result, the Districts in the Northeastern Region competed very successfully in the Merit Project competition on a Divisionwide basis. There were many instances of the State and local government agencies offering significantly more funds for programs than could be matched with available funds from the WRD. A number of entities provided funds to WRD that were not matched; that is, they provided in excess of 50 percent of the funding for project activity or data collection. Unmatched funding increased significantly in the latter part of this history and was particularly noteworthy in New Jersey, where a large bond issue had been passed with funds to be used for the development of water resources throughout the State. Part of those funds were allocated for water-resources investigations to ensure the optimum use of funds for development. The New Jersey District undertook a significant part of those investigations with unmatched funds from the State.

MANAGEMENT AND PERSONNEL ISSUES

From 1979 to 1994 there were substantial changes in program and budgetary issues in the Northeastern Region. Personnel and fiscal resources available for the District programs varied considerably from State to State. Many of the States in the western

part of the Region struggled for financial resources for much of this time. States in the Eastern part generally had sufficient fiscal resources but had a difficult time recruiting technical personnel to meet the program requirements caused by the increased demand for water-resources investigations. Program growth resulted from funding increases by the States through the Federal-State Coop program, the expansion of federally funded programs from Congressional appropriations, and funding from other Federal agencies, particularly the Department of Defense Installation Restoration programs. A paramount issue was the increased role in defining and resolving water-resources problems requested of WRD by the Congress, the States, and other Federal agencies while dealing with very restrictive policies on personnel ceilings imposed by the Congress and the Department of the Interior.

The recruitment of highly skilled hydrologists and technicians to address the increasingly complex problems undertaken by the Districts was especially difficult because of entry-level government salaries that were generally not competitive with private industry and highly restrictive policies on hiring permanent, full-time personnel. This led to a variety of approaches to fill the dire needs for dedicated, highly trained individuals to address the staffing requirements in the Districts. These approaches unfortunately also led to inequities in the types of appointments for hydrologists, hydrologic technicians, and support personnel, with a high percentage of full-time positions being held by hydrologists and with substantial numbers of technician and support personnel filling part-time or temporary positions. As could be expected, this led to morale problems in many of the Districts that were not resolved for a number of years. The Regional Office undertook a number of efforts to ameliorate the inequities in types of appointments, and most inequities were eliminated by the late 1980's.

Early in this period, the Regional Hydrologist established a Federal Women's Program (FWP) Advisory Committee to assist in the management of the Northeastern Region FWP and to meet periodically with the Regional Hydrologist to discuss issues of particular interest and concern to women employees in the Region. The Advisory Committee initially consisted of women in Hydrologist positions but was soon expanded to include women in other occupational specialties such as Hydrologic Technicians, Secretaries, and Administrative positions. The program assisted in the development of skills and capabilities of women in the Northeastern Region work force and helped to develop leadership skills, with some members of the Advisory Committee later advancing into senior leadership positions at both the Division and Bureau levels. To address morale and other issues, a Hydrologic Technicians Advisory Committee was established during the mid-1980's by the Regional Hydrologist. The committee provided considerable assistance to the Regional Office in identifying critical issues and developing approaches to resolve those issues. The Research Grade Evaluation Guide (RGEG), a system of evaluating the appropriate grade level for a scientist based on his or her technical contributions and achievements, was made available to qualified hydrologists in the District offices early in the period of this history. Despite initial problems and some resistance, the program became quite popular as it provided a mechanism for advancement in grade within a District on the basis of scientific contribution and not on organization grade structure.

Every effort was made to keep staffing at the Regional Office to a minimum in order to most effectively utilize Technical Support funding. The positions of Assistant Regional Hydrologist and Program Officer were combined in 1986 in order to reduce staffing. This change worked very effectively for the remainder of the period of this history. The other three Regions did not follow this staffing strategy.

A major concern and consideration for Regional management during the period of this history was the viability of the smaller Districts. This issue was of concern in other Regions as well. The Regional Hydrologist appointed a committee in 1988, consisting of eight senior managers from Districts in the Region and a senior representative from each of the other three Regions, to address the issue. The committee, using the USGS mission statement as a guide, defined an acceptable District program as "a program that possesses or can readily acquire and maintain the personnel, equipment, and support facilities necessary for the successful development and execution of relevant and comprehensive water-resources data collection and interpretive programs in a timely manner and in response to rapidly changing local and national needs." Over time, a number of approaches were considered to enable this "acceptable" status in all District operations. Technical enhancement of personnel and computational resources, as well as program content, was a paramount issue.

These issues were debated at length at the WRD Senior Staff level. The NAWQA Program was being funded and organized at that same time. The issue of having a sufficiently trained and experienced work force at all locations to successfully execute this program was a significant concern for the WRD Senior Staff and the Regional staffs. The combination of these issues resulted in the establishment of the "Area Hydrologist" concept to address the viability issue and subsequent WRD reorganization that implemented the Area Hydrologist positions. There was considerable resistance to this reorganization, both within WRD and the State and local cooperating agencies, as could be expected for any change of this magnitude. The concept was never implemented to the full extent of the original plan. The Region sought ways to improve this operation and to make it more acceptable to all concerned. This reorganization remained in place until the end of this history period but was eventually abandoned. Despite the shortcomings of this organizational approach and resistance to it, it did result in significant improvements in the technical capabilities of many Districts as well as a different thought process regarding the requirements of a fully functional District operation.

All things considered, the period 1979–94 was a time of significant change in the Northeastern Region in programs and personnel. The technical capabilities and available fiscal resources of the Districts were strengthened considerably. This can be attributed entirely to the individuals at all levels in the organization who worked tirelessly and selflessly for the betterment of the WRD and their respective organizational units.

CONNECTICUT

By Robert L. Melvin

ORGANIZATION AND PERSONNEL

Connecticut began this period as a District with David McCartney as District Chief. The only Connecticut office was in the U.S. Post Office Building at 135 High Street in Hartford. Staff totaled 30 employees, most of whom were hydrologists and hydrologic technicians. In 1982 the office moved to the Abraham A. Ribicoff Federal Building, also in Hartford. The following year (1983) the Connecticut District ceased its independent existence and became the Connecticut Office within the New England District, led by Ivan C. James. Another reorganization in 1991 resulted in Connecticut once again becoming a District, so Chester E. Thomas, Jr., the Office Chief, became District Chief. Another organizational change occurred in 1992 when the District geophysical unit was placed within the Northeastern Region and the following year was reconstituted as the Branch of Geophysical Applications and Support, a part of the Office of Ground Water.

The Connecticut staff is described without reference to title changes that accompanied the transitions from District to State Office and back to District. David McCartney was the District Chief from 1980 to 1983 when he transferred to the New England District headquarters in Boston, Mass. In 1984 Thomas assumed the leadership of the Connecticut office and held this position through the rest of this period. The assistant District Chief position was limited to Thomas's tenure (1980–83) as the position was abolished with Connecticut's integration into the New England District. The responsibility of managing Connecticut programs was shared by the District (Office) Chief and the Chiefs of the Hydrologic Studies Section and the Hydrologic Surveillance (Data) Section after 1983. The relatively small size of Connecticut's staff resulted in several personnel reassignments as programs changed. Consequently, many hydrologists spent some time in both the Studies and the Surveillance Sections during this period.

The Administrative Services Unit was led by Dorothy C. LaBella (1980–88), Mary White (1988–91), and Cynthia (Cindy) M. Blanchette (1991–94). Others who served in the Administrative Services Unit during this period were Theresa (Terri) A. Alexander, Jaclyn M. Bialy, Gail S. Dunlop, Barry L. Hubbard, Jeanine G. Mullin, Helen Rinaldi, Michelle E. Walker, and Alison Zorba.

This period saw several changes in computer operations starting with the transition from large mainframe computers to minicomputers in 1983. Finally, in 1993, servers and workstations replaced the minicomputers. A collection of personal computers also were used in both office and field settings, particularly for analyses of geophysical data. The New England District Office was responsible for most computer operations until 1991 when the responsibility was transferred to Jacob Bohr.

Hydrologic Surveillance (Data) Section.—The Section was mainly composed of hydrologists and

hydrologic technicians. Section Chiefs included Chester E. Thomas, Jr., until 1985 and Michael A. Cervione until his retirement in 1994. A small drilling support unit was transferred to the Surveillance Section from the Hydrologic Studies Section in 1986. This unit was made up of drill rig operators and helpers under the direction of James W. Bingham. Others assigned to the Surveillance Section for all or part of this time were Milan Beres, Jr., Jacob R. Bohr, Steven F. Boske, Douglas A. Brinton, John F. Burns, Robert J. Carr, Eugene F. Cobbs (drilling unit), Terrance M. Collins, Jan M. Czeczotka, Bruce R. Davies, Roger L. Freeman (drilling unit), Timothy W. Frick, Illene T. Gasperini, Richard J. Gelting, Elizabeth E. Gillespie, Joseph W. Gillis, Stephen R. Gorin, Howard E. Harrison, Denis F. Healy, Beatrice B. Hicock, Harry A. Hitchcock, Gary A. Johnson, David S. Kagels, Stephen S. Kiesman, William F. Kiesman, Scot Kuhn, Lawrence A. Morey, Jonathan Morrison, Brendan F. Moynihan, Jeffrey C. Murray, John A. O'Brien (drilling unit), John R. Organek (drilling unit), Andrew S. Parsons, Thomas L. Pintavalle, Robin W. Ploss, Stephen E. Reale, George P. Rigatti (lead hydrologic technician), Helen E. Robinson, Allison J. Rosof, Richard A. Roy, Barry C. Sattin, Michael P. Sears, Robert R. Sebastianelli, Thomas P. Shepard, Gregory J. Toussaint, Elaine T. Trench, Jeffrey A. Walker, Joe C. Wallace, Lawrence A. Weiss (surface-water specialist), and Scott E. Wing.

Hydrologic Investigations (Studies) Section.—Robert L. Melvin served as Section Chief from 1980 until his retirement in May 1994. A total of 41 people worked in the Studies Section during this period. Michael A. Cervione left in 1985 to head the Data Collection and Analysis Section, Frederick (Pete) P. Haeni left in 1992 to become Chief of the new Geophysical Studies Section, and Stephen J. Grady transferred in 1992 to the new Connecticut Basin NAWQA Study Section. Besides conducting hydrologic investigations, this Section included staff that were responsible for report preparation and review, a drilling support unit that provided drilling and other services to Connecticut and to several other Districts in the Northeastern Region, and a geophysical support unit that provided support and training to many Districts as well as conducting applied research in surface geophysics.

Other staff who served in the Investigations Section were James T. Adamik, Alan P. Augustine (drilling support), Nels E. Barrett, Milan Beres, Jr., James W. Bingham, Janice M. Chappell, Roland E. Cromwell, Karl J. Ellefson (geophysical support), Laurence D. Fredericks (drilling support), Richard J. Gelting, Deborah G. Grantham (geophysical support), Elinor H. Handman, Howard E. Harrison, Robert Hastillo, Denis F. Healy, and Gary R. Johnson.

Geophysical Studies Section.—This Section was spun off from the Hydrologic Studies Section in 1992 under the direction of Pete Haeni. In 1993, recognizing the national role in surface geophysics that this group had attained, it was removed from the District and placed under the Office of Ground Water. Subsequently, this Section became the Branch of Geophysical Application and Support. Personnel in the Section during its brief history as part of the Connecticut District included Roland E. Cromwell, Michael D. Knoll, John W. Lane, Jr., David A. Lieblich, Gary Placzek, and William M. Watson. All had previously been part of the Hydrologic Studies Section.

Connecticut Basin NAWQA Section.—This Section was also created in 1992 at the onset of the Connecticut Basin NAWQA study that was headquartered in the New England District Office. Stephen J. Grady headed the Section, assisted by Christopher R. Hudon.

FUNDING AND COOPERATION

As shown in the table of funds, the Federal-State Cooperative (Coop) program did not increase substantially until 1994 when a large bridge-scour project began. During the rest of this period the program funding was cyclic, declining in 1983–85, rising in 1986–89, and then experiencing a general decline until 1994. Other Federal agency (OFA) programs showed large but inconsistent growth, increasing almost tenfold during the period. The large OFA increases were from the U.S. Environmental Protection Agency for geophysical investigations and research and for hydrologic and geologic characterization of waste-disposal sites.

The Federal (Fed) program also had substantial growth in this period, but not in a consistent manner. Funding increased greatly from 1986 to 1990 when the District was actively participating in studies for the Toxic Substances Hydrology Program and the Northeast Glacial Aquifers RASA Project, as well as conducting a program of support, training and research in surface geophysics for the Office of Ground Water.

Connecticut District funds for fiscal years 1979–94

Fiscal year	Federal	OFA	State	Federal matching	Total
1979	107,400	159,300	445,400	436,800	1,148,900
1980	89,100	53,200	548,400	485,100	1,175,800
1981	204,600	68,900	485,000	489,200	1,247,700
1982	47,400	45,400	543,500	516,800	1,153,100
1983	150,400	120,100	520,200	517,100	1,307,800
1984	267,500	141,700	538,500	500,800	1,448,500
1985	383,900	276,500	542,100	535,900	1,737,400
1986	453,700	351,100	526,600	512,500	1,843,900
1987	610,800	248,000	584,800	573,800	2,017,400
1988	560,800	337,600	649,800	614,400	2,162,600
1989	522,100	378,100	726,400	587,700	2,214,300
1990	536,800	383,700	635,200	593,900	2,149,600
1991	248,900	267,100	588,500	559,900	1,664,400
1992	288,600	470,600	595,200	514,300	1,868,700
1993	297,000	656,900	519,400	475,800	1,949,100
1994	294,700	497,300	1,236,200	449,800	2,478,000

The decreased funding from 1991 to 1994 was largely due to completion of the RASA project in 1990 and the Toxics program studies in 1991.

Cooperation with the Connecticut Department of Environmental Protection (DEP), U.S. Army Corps of Engineers, Federal Emergency Management Agency (FEMA), Town of Fairfield, and the cities of New Britain and Torrington continued throughout this period. A long-term cooperative program with the Connecticut DEP to evaluate peakflows and floodflows ended in 1986 but was subsequently replaced with projects to assess bridge scour. Other cooperative programs of more limited duration were conducted with the Federal Highway Administration, Federal Bureau of Investigation, Connecticut Agricultural Experiment Station, the University of Connecticut, the Midstate Regional Planning Agency, the Northeast Connecticut Regional Planning Agency, the South-central Connecticut Regional Water Authority, the Lake Waramaug Interlocal Commission, the Lake Waramaug Task Force, and the towns of Enfield, Manchester, Meriden, Norwalk, Ridgefield, Simsbury, Southbury, South Windsor, Stonington, and Woodbury.

SUMMARY OF PROGRAMS

Hydrologic Data Collection

During the period between 1980 and 1984 the baseline data-collection activities remained fairly constant. Total data-collection activities, however, varied considerably as several data-intensive investigative studies were initiated and completed. In addition, significant rainfall in June 1982 (12 to 16 inches in 24 hours at some stations) resulted in major floods in parts of southern Connecticut. Peak flows were measured at 30 sites, requiring extensive data collection. Consequently, annual data reports were not always completed on time. Chester E. Thomas, Jr., and Michael A. Cervione, Jr., oversaw the preparation of the annual data report, assisted by other staff—most notably Weiss, Healy, Kenneth P. Kulp, Bohr, and Bingham. Cliff Keune and Barbara Korzendorfer prepared the camera-ready copy for publication.

The period also saw changes in field instrumentation, particularly to support the demand for real-time streamflow data and event-related water-quality sampling and analysis, and in computer technology and applications. Data-collection platforms and satellite telemetry increased throughout the streamflow network, starting with stations operated for the Corps of Engineers and National Weather Service. George Rigatti and Bruce Davies made many improvements to field instrumentation and worked closely with the Hydrologic Instrumentation Facility during this period.

Streamflow-gaging stations.—The District operated approximately 53 continuous-record stations and 44 crest-stage, partial-record stations in 1980. The District also operated four tidal stations (three stage and one tidal volume) and seven peak discharge

stations. Storm rainfall data were collected at six of the gaging stations. The continuous-record stations had decreased to 44 by 1994, with a major decline at the end of water year 1981 when 7 stations were discontinued. The crest-stage and peak-discharge stations were discontinued at the end of water year 1984, but 16 to 41 partial-record stations were in operation during the remainder of this period.

Streamflow-gaging stations in Connecticut were operated for various purposes during this period, including assessment of water resources, operation of reservoirs or industries, flow forecasting, water-quality characterization, conformity to compacts and regulatory requirements, and research. Increasing use was made of the streamflow stations to support water-quality studies, including suspended-sediment and acid-deposition studies conducted by Kulp. The information content of the Connecticut streamflow network was evaluated by Weiss in 1983 (Connecticut Water Resources Bulletin [CWRB] 36) while the cost effectiveness of the network was evaluated by Shepard and Weiss in 1988.

Water-quality stations.—The surface-water quality network in 1980 was composed of 53 stations, including 46 at streamflow stations, 5 at lakes and reservoirs, and 2 at harbors. Most of these stations were operated in cooperation with the Connecticut Department of Environmental Protection (DEP), and the principal use of the data was to support the programs of both the Federal and State Clean Water Acts. The basic network was extensively modified at the end of water year 1987 when many stations were relocated and in 1991 when several stations were discontinued. The funding for this network did not keep pace with inflation. Consequently, by 1994 the total number of stations had declined to 31, which consisted of 14 located at streamflow stations, 15 at ungaged sites on streams, and 2 on lakes and reservoirs. A compilation of the basic network data collected from 1973 to 1985 prepared by Healy and Connecticut DEP staff was published in 1994 (CWRB 44).

Besides the basic network stations, water-quality data were collected at a number of other surface-water sites for ongoing investigative studies. The number of these "miscellaneous sites" generally ranged from 5 to 27 between 1980 and 1994. In 1989 and 1990 samples from 49 public recreational lakes and ponds were collected and analyzed as part of a cooperative study with the Connecticut DEP. Lakebed sediments from 12 of these lakes and ponds were also analyzed. The information was published in a data report authored by Healy and Kulp (WRIR 95–4098).

There was no baseline ground-water-quality network in Connecticut during this period, and all the data were collected during various investigative studies. Ground-water-quality data were collected from 34 wells and 1 spring in 1980. Most of these data represented analyses of samples collected only once during the year. The number of ground-water samples that were analyzed and the frequency of sampling increased greatly in 1986, reaching a maximum of 220 sampled wells in 1988. This increase in activity resulted from the initiation of investigative studies of pesticides and natural radionuclides in ground water and the relations between land use and ground-water quality. From 1990 to 1992, after completion of these studies, no ground-water-quality data were collected. Activity increased in 1993 and 1994 due to the Connecticut Basin NAWQA study.

The increased complexity and scope of sampling techniques and analytical capability during this period also is noteworthy. Samples in the early 1980's were collected from existing wells by using simple sampling equipment and protocols, and analyses were commonly restricted to major and minor inorganic constituents. By the mid-1980's rigorous specifications for well casing, screens, and pumps were part of many studies.

Precipitation-quality stations.—Precipitation quality was measured at one to five sites from 1982 to 1991 as part of a cooperative program with the Connecticut DEP. These sites were intended to assess atmospheric deposition chemistry and distribution in the State. Each station was equipped with automated samplers that were activated at the start of a precipitation event.

Fluvial-sediment stations.—In 1980, suspended sediment samples were collected daily at two sites on the Yantic River and Muddy Brook. These stations were operated as part of a cooperative study with the Connecticut DEP to determine daily and annual sediment loads from several diverse basins in the State. Three additional daily suspended-sediment stations were added to the network during this period—each was operated for 5 to 7 years. Special data collection for this network included automatic samplers that periodically collected samples during periods of peak discharge. All samples were analyzed for suspended sediment concentrations by the USGS Sediment Labo-

ratory in Harrisburg, Pa. By 1994 this study had ended, and suspended-sediment data were only collected at four NASQAN sites and at miscellaneous NAWQA sites.

Ground-water observation wells.—In 1980 the statewide network, maintained in cooperation with the Connecticut DEP, included 59 observation wells. Water-level data from all these wells were used to assess natural changes in ground-water storage within the State's major hydrologic units. Measurements were made weekly, bimonthly, or monthly by USGS personnel, paid and voluntary observers, and DEP staff. Automatic recorders were used infrequently to determine if pumping or other phenomena had affected water levels. The network was evaluated by Melvin (WRIR 85–4079), who made recommendations for changes to the number and distribution of observation wells and the frequency of measurement. Subsequently, several wells were discontinued and a program was developed to add wells in major hydrologic units within each of Connecticut's climatic zones. Most of the expansion occurred from 1992 to 1994, and in 1994 the statewide network included 91 wells and the frequency of measurement was biweekly.

Water-use data.—The water-use program, established in cooperation with the Connecticut DEP, continued throughout this period. Much of the information was collected by DEP staff, funded by "reverse" Coop money. Summaries of freshwater withdrawals and use in both 1985 and 1990 were published (OFR 88–457 and WRIR 93–4010), and the data also were used in regional and national reports. Work began in the early 1990's on compiling, analyzing, and automating site-specific data on public-supply and industrial water use.

INTERPRETIVE STUDIES

Cooperative ground-water investigations.—The availability of water from stratified-drift aquifers and the effects of withdrawals on the hydrologic system continued to be the focus of most ground-water investigations. Most of these investigations also included some characterization of water quality and(or) the likely effects of development of ground water on water quality. Studies were conducted in cooperation with the Connecticut DEP and the towns of Ridgefield, Simsbury, Southbury, Stonington, and Woodbury. A digital flow model was used in the Pomperaug River Basin by David L. Mazzaferro, and analytical flow models were used by Grady in the Titicus River Basin, by Martha F. Weaver in southwestern Connecticut, and by Melvin and Bingham in the Farmington River Basin. Mazzaferro, in a cooperative study with the Connecticut DEP, also used digital models to investigate the areas that contributed water to pumping centers (WRIR 87–4124).

Water quality was the focus of two important cooperative ground-water studies conducted during this period. The first of these investigated the occurrence of pesticides in the soil, unconsolidated sediments, and ground water in both agricultural and nonagricultural areas. The work involved District staff and scientists from the Connecticut Agricultural Experiment Station and Connecticut DEP. The results of this study were published in 1991 (CWRB 42). The second water-quality study was concerned with the occurrence, distribution, and possible health effects of natural radionuclides in ground water. It was conducted by Healy and staff of the Connecticut DEP and the Connecticut Department of Health Services.

Cooperative studies related to the geology and hydrology of till, the most common surficial deposit in Connecticut, were initiated in response to waste-disposal concerns. An initial survey of information on the hydraulic characteristics of tills in southern New England, conducted by Melvin and DeLima (Rhode Island Office), was supported by the U.S. Environmental Protection Agency. This led to more comprehensive studies of till hydrology conducted in cooperation with the Connecticut DEP. Robert Melvin and Janet Stone, with colleagues from Geologic Division, completed a study of thick tills in Connecticut that included an assessment of factors that could affect disposal of low-level radionuclides in till areas (OFR 92–43). Melvin and colleagues from Geologic Division and the University of Connecticut also studied the hydraulic properties of tills derived from sedimentary rocks in central Connecticut.

Additional ground-water studies were conducted in cooperation with the Connecticut DEP during this period. Handman described simple methods for delineating recharge areas to stratified-drift aquifers (WRIR 83–4230) to assist the State's 208 Program. The use of electromagnetic geophysical techniques for defining areas of ground-water contamination caused by landfills was investigated by Grady (CWRB 41). John R. Mullaney investigated the local hydrogeology and ground-water flow system in a

riparian area. The information from this study, published in WRIR 94–4255, was an essential component of an experiment by University of Connecticut researchers to evaluate the effects of changes in riparian land use on water quality.

Cooperative surface-water investigations.—Surface-water cooperative investigations were limited during this period. The most extensive was a 10-year study of the effects of urbanization on flood characteristics of small streams by Weiss (WRIR 89–4167). Weiss also studied rainfall-runoff relations in the Hop Brook Basin and, together with Sears and Cervione, conducted hydraulic modeling of two brooks in Meriden, Conn.

Streamflow regionalization studies, begun by Mendall Thomas as part of the Connecticut Valley Urban Area Project in the 1970's, were continued in cooperation with the Connecticut DEP. Cervione and Melvin described a method for estimating the 7-day, 10-year low flow at ungaged sites on unregulated streams (CWRB 34). This method was adopted for regulatory programs by the Connecticut DEP. Subsequently, Cervione and Weiss worked with staff of the Rhode Island Office in a study of low-flow characteristics of Rhode Island streams. The evaluation of the information content of the surface-water gaging network that was previously cited (CWRB 36) and work done for the RASA program also developed techniques for estimating streamflow characteristics at ungaged sites.

The cooperative program of flood studies with the Federal Emergency Management Agency (FEMA) was active throughout this period. Hydraulic and hydrologic analyses of streams in several Connecticut towns were conducted and the results were subsequently incorporated in FEMA's flood-insurance reports.

Cooperative water-quality investigations.—District hydrologists conducted several cooperative water-quality studies during this period, in addition to the water-quality component of the previously cited ground-water investigations. Two studies of polychlorinated biphenyls (PCB's) in the Housatonic River were conducted in cooperation with the Connecticut DEP. In the first study, Kulp and Connecticut Agricultural Experiment Station and DEP scientists examined the distribution and transport of PCB-contaminated sediments in the river. A subsequent study by Kulp evaluated PCB concentrations and transport between 1984 and 1988 (WRIR 91–4014).

Other water-quality studies done in cooperation with the Connecticut DEP during this period included an analysis of trends in surface-water quality from 1969 to 1988 by Trench (WRIR 96–4161) and analyses of suspended-sediment characteristics of streams in different regions of the State by Kulp (CWRB 39 and 43). Kulp and Grayson also completed a water-quality study of the Lake Waramaug Basin in cooperation with the Lake Waramaug Interlocal Commission and Lake Waramaug Task Force, and Kulp conducted a study of water quality in the town of Wilton.

Regional aquifer studies.—The multi-District study of the Northeast glacial aquifers started in 1983 and involved several Connecticut staff over a 7-year period. The Connecticut District contributed hydrogeologic data and maps in initial phases of the study. Because of the large workload, Mazzaferro was assigned to the RASA core staff and aided in preparing interim and final reports. One of the principal products of the study, a Professional Paper describing the application of surface-geophysical methods to investigations of glacial aquifers (PP 1415–A), was prepared in the Connecticut District by Haeni. District staff also contributed to streamflow regionalization studies directed by RASA staff.

Surface-geophysics support program.—In 1980 the District began a program to support the use of surface-geophysical methods in hydrologic studies within WRD. The program was directed by Haeni and funded by the Office of Ground Water. As the program expanded, other Federal agencies also provided cooperative funds. In 1992 the program was moved from the Connecticut District and placed within the Office of Ground Water. The main objectives of the program were to select surface-geophysical methods applicable to hydrologic studies and purchase the equipment needed for each technique, to make information, training and equipment available to WRD project chiefs, and to investigate new techniques that are potentially useful.

The surface-geophysics program was enormously successful in developing the use of surface geophysics throughout the Division. Training modules were developed by Haeni and other members of the geophysical support unit. Each training module included instructional material in the form of journal articles and TWRI's such as the TWRI on seismic refraction by Haeni, formal training courses, field equipment and interpretive computer programs, and direct technical assistance to District, Region, and

Research staff. The geophysical support unit also conducted experiments in field application of ground-penetrating radar (GPR), borehole radar, and electromagnetic, seismic-reflection, and seismic-refraction techniques as part of District investigative studies.

The Federal Highway Administration (FHWA) became a cooperator in investigations of the use of surface geophysics to detect scour holes or filled scour holes near bridges. Several field experiments were conducted at Connecticut bridges and later at bridges elsewhere in the country. Reports by Gorin and Haeni (WRIR 88–4212), Haeni and Gorin, Haeni and Plazek, and Haeni, Plazek and Trent described the use of seismic and GPR methods for investigating bridge-scour phenomena.

USEPA technical assistance programs.—Two programs to provide technical assistance to the USEPA started in 1992. The first provided geophysical technical assistance to USEPA Region V and included purchasing and setting up geophysical equipment, training personnel, conducting special studies, and reviewing reports and proposals dealing with geophysics. The work was directed by Haeni and continued after the geophysical studies section was transferred to the Office of Ground Water.

The second technical assistance program integrated geologic, hydrologic, and geophysical studies to characterize the regional geohydrology of Superfund sites in Connecticut. These studies were designed to assist the USEPA in defining the scope of subsequent remedial investigation/feasibility studies. Melvin and Stone, assisted by staff of the geophysical studies and the hydrologic surveillance sections, were responsible for this program. Reports were prepared for two studies (WRIR 93–4138 and WRIR 94–4237), and work began on a third study during this period.

Land-use/water-quality program.—The USGS Toxic Substances Hydrology Program supported investigations of relations between land use and ground-water quality in Connecticut from 1981 to 1991. Grady served as Project Chief for these investigations that focused on water quality in stratified-drift aquifers located in areas of differing land uses. The results of these studies were regionally significant, and the results were reported in USGS publications (WRIR's 87–4005, 88–4220, and 91–200 and WSP 2381) and symposia proceedings.

National Water-Quality Assessment Program.—The USGS NAWQA study of the Connecticut, Housatonic, and Thames River Basins was initiated in 1991. The objective was to describe trends and current water-quality conditions in these basins. The study, headquartered in the New England District Office in Massachusetts, was under the leadership of Steve Garabedian. Grady was given responsibility for the ground-water part of the study and a NAWQA section was established in the Connecticut office. Activities during this period consisted largely of the review and analysis of existing data and some collection and analyses of surface-water and ground-water samples. Extensive pesticide samples were collected from the Norwalk River in 1993 and 1994 during less extensive sampling of other Connecticut rivers.

ILLINOIS

By Larry G. Toler and G. Wayne Curtis, including information provided by Robert R. Holmes, Jr., and Illinois District Staff. Reviewed by Mary L. Garrelts, Retiree, and Angel M. Martin, Jr., Pat Mills, Audrey Ishii, Tom Wicker, and John Mauer, Illinois District staff.

INTRODUCTION

The period 1979–94 was one of rapidly changing technology in the Illinois District. A single computer station with card-reading capabilities evolved into computer terminals on most desks which, in turn, gave way to personal computers with capabilities for data collection and processing, report processing and publishing, complex modeling of streams and ground-water systems, and administrative record keeping. Changing technology in data collection and processing was notable in many ways. Some slope stations for measuring streamflow were replaced by acoustic velocity meters (AVM), some manometers for sensing water levels were replaced by pressure transducers, and punched tape automatic data recorders (ADR's) for recording information were being replaced by remotely interrogated electronic data loggers with associated decreases in lost record. The acoustic Doppler current profiler (ADCP) drastically reduced the manpower required for measuring discharge of large rivers. The precision of analyses of constituents in water increased, and analyses were performed in suites, which increased the number and accuracy of constituents detected. Many of the above technologies also apply to ground-water systems to

provide real-time data and faster dissemination of information. Methodologies to characterize the subsurface, such as seismic reflection and borehole radar, are now used in Illinois and elsewhere, and nonintrusive means of measuring water withdrawals are invaluable to the projections of ground-water use.

Appreciably large hydrologic events in Illinois were primarily floods during 1979–94. Discharge recurrence intervals of greater than 100 years in central and northern Illinois were observed at some sites in 1981, 1982, 1986, 1987, and 1994 and along the Mississippi River and its tributaries in 1993. Some major events were human induced and, in 1992, the District assisted the U.S. Army Corps of Engineers (Corps) in monitoring water levels and detecting leaks from the Chicago River to the tunnel system under downtown Chicago after the tunnels were flooded by damage from construction activities.

Some tragedies or near tragedies occurred during the period. In October 1979 John Gray came in contact with a 7,200-volt power line while handling sheet metal on top of the gaging station on Spring Creek at MacFarland. He received second-degree burns on his hands and feet, from which he fortunately fully recovered. During August 1985, Howard Allen succumbed to a heart attack. Also, during 1985, David Moffett lost a lengthy battle with leukemia, and in 1991 Albert (Bill) Nyberg died of a brain tumor.

ORGANIZATION AND PERSONNEL

Infrastructure

In 1979, the District Office was located at 605 North Neil Street, and storage facilities in miniwarehouses were at 1408 Anthony Drive, both in Champaign. In February 1981, the District Office moved to the fourth floor of the Champaign County Bank Building at 102 East Main Street in Urbana. Warehousing and official vehicle parking spaces in Urbana were located one block east of the District Office on the northwest corner of Water and Vine Streets. Both of the Urbana facilities were used through 1991. A Subdistrict Office was located on the campus at Northern Illinois University at 629 Lincoln Terrace in DeKalb until 1992 when it was moved off campus to 1420 Sycamore Road. One Field Headquarters was in the Federal Building at 105 South Sixth Street in Mt. Vernon, and a second Field Headquarters shared office space with the District headquarters office.

DISTRICT ORGANIZATION

The District organization in 1979 had Administrative, Publications, and Computer Units, each reporting directly to the District Chief. The Publications and Computer Units were combined into one Unit, the Publications and Data Management (P&DM) Unit, in 1982. Two sections, the Investigations Section and the Network Operations Section (renamed the Operations Section in 1991), also reported directly to the District Chief. An Assistant District Chief, who also was Network Operations Chief, was part of the organization from September 1979 until 1982. Discipline specialists commonly were included in the District Chief's staff but usually had collateral duties as Project Chiefs or Unit supervisors. The Administrative Unit provided clerical duties for the District Chief and staff until a District Secretary was hired in July 1981. The Subdistrict Office in De Kalb reported to the District Chief, as did National Water-Quality Assessment (NAWQA) Program units, which were formed in the Urbana Office. The first NAWQA Unit was formed in 1989 to study the Upper Illinois River Basin (UIRB), and a second NAWQA Unit was formed in 1994 to study the Lower Illinois River Basin (LIRB).

The Urbana and Mt. Vernon Field Headquarters and a third Field Headquarters that organizationally was located for a short period in Springfield, all reported to the Chief, Operations Section. A one-person Field Headquarters operated in 1982 in conjunction with an ongoing project at Sheffield and reported to the Chief, Investigations Section.

PERSONNEL

Many of the personnel listed below worked at different times in two or more of the organizational units. Except for a few instances, they are listed only in the last unit for which they worked. The listing includes all employees generally categorized as Professional, Technical, Administrative, Clerical, Aids, and Hydrologic Field Assistants. Many in the Aids and Technical categories and a lesser number in the administrative categories were students from the University of Illinois, Parkland Community College, Northern Illinois University, and Rend Lake Commu-

nity College. A total of 324 employees worked in the District during the period. The number of employees at selected times during each year ranged from a high of 87 in 1981 to a low of 61 in 1994 and averaged 72.

Office of the District Chief. Larry Toler was appointed District Chief in February 1979 and retired at the beginning of 1988. Marvin Sherrill was Acting District Chief during much of 1988 until Richard P. Novitski transferred from New York and was District Chief until June 1990. Stephen Blanchard was appointed District Chief in February 1991 and served through the end of the period. G. Douglas Glysson was Assistant District Chief from September 1979 until early 1982, when he transferred to Reston, Va. The position of Assistant District Chief was not filled thereafter. Linda Saban, Elizabeth Weldon, Barbara Cook, and Donna Ayers were secretaries to the District Chief during the period.

Discipline specialists during the period were G. Wayne Curtis, Allen Noehre, David Stedfast, and Kevin Oberg for Surface Water; James Foster, Barbara Ryan, Chuck Avery, and Angel Martin for Ground Water; and Leonard Frost, John Colman, Richard Coupe, and Paul Terrio for Water Quality. Others attached to the District Chief's staff for short periods were Kenneth Potter, Gary Balding, Bill Morrow, Alana Ferguson, and Patricia Leff.

Helen Larson led the Administrative Unit during 1979–84: Joe Tripp, 1985–86; Alice Sabatini, June 1987 to June 1989; Mary Beth Kowalski from late 1989 to July 1991; and Susan Kell, 1991–94. Others who served in the Administrative Unit were Diane Ackerson, Amy Caldwell, Joanna Combs, Georgia Diersing, Les Dippel, Karen Dunn, Erin Gaines, Donna Hector, Sue Janssen, James Kratz, Patricia Lee, Terrance Leftridge, Cathy Leslie, Catherine Robbins, Robin Smalley, Dee Thornton, Evelyn Tilpe, Bobbie Vincent, and Jaqueline Wright.

Mary Garrelts led the Publications Unit until it was combined with the Computer Unit in May 1982. The Computer Unit was formed late in 1979 with Joan Rudnicki as Chief. Curtis Smith replaced Rudnicki in March 1981. Allen Noehre was named Chief of the newly combined P&DM Unit in May 1982, succeeded in April 1984 by Leonard Frost. Frost transferred to the New York District in December 1986, and the Unit Chief position was vacant until 1991 with Mike Shapira responsible for computer activities and Garrelts responsible for publications. In 1991, Richard Phipps was Acting Chief, P&DM, and Angel Martin was Acting Chief during 1992–94. Other employees in P&DM were Terri Arnold, Margaret Barnes, Lisa Bell, Patricia Bronson, Kenneth Buja, John Burkey, Judith Burtle, Kathleen Davy, Thomas Decanio, Joy deVries, Dean Essig, Miq Hanna, J. Lee Harrington, Vicki Higdon, A.H. Joubert, Matt June, Michael Kwok, Brian Luebbers, Karel McAllister, G.F. McQuary, Robin Moss, Karen Murphy, David Ramsey, Sherry Reeves, Roxanne Reiter, Ann Ricker, Nancy Rogers, Russel Sorber, Rebecca Storm, Kathryn Tonsor, Mary Vogel, Beth Weldon, Donna Wilson, and Jordan Wong.

De Kalb Subdistrict. The De Kalb Subdistrict Office was responsible for hydrologic data collection and special projects in the northern part of the State. Allen Noehre was the Subdistrict Chief until May 1982, when he transferred to the District Office. Howard Allen was Subdistrict Chief from May 1982 until August 1985 when he succumbed to a heart attack. The Subdistrict Chief position was vacant until Jo Ann Macy transferred to the De Kalb Subdistrict from Pennsylvania in December 1988 and again after she left the District in July 1991. Tom Richards was Acting Subdistrict Chief from August 1985 to December 1988 and from July 1991 to June 1992 when he transferred to Florida. Tom Wicker was Acting Subdistrict Chief from June 1992 through the end of the period.

Other employees in the DeKalb Subdistrict Office during 1979–94 were Sarah Avang, Steven Anderson, Richard Becker; Chris Black, Bill Borchardt, Lisa Cann, Myrtyl Ciabattari, Ellen Cowan, Craig Davis, Gregory Fisk, Lucy Freeman, Jean Greensley, Lisa Hansen, Avery Hazelton, Janet Heiny, Cynthia Hovland, Lambok Hutasoit, Larry Jacoby, Robert Kay, Martin Keeley, Thomas Koch, James Krohelski, Russell Lewins, Brenda Lorinser, Lawrence Lynch, Mark Malander, Joel Marko, Heidi Markva, Jennifer Moore, Margaret Moore, David Olson, Catherine Oprins, Gary Perkowitz, Cathy Pourchot, Scott Prinos, Steve Robinson, Martha Rosenquist, Kevin Schnoos, David Schrader, Eric Spande, Kevin Stank, Eleanor Stevens, Paul Taylor, and Lawrence Vendl.

Investigations Section. The Investigations Section was part of the District Office and was responsible for most of the interpretive studies in the District, particularly those for which data were collected as part of the study. Larry Toler was Chief, Investigations Section, until March 1980 when Gary Balding trans-

ferred from Alaska. Balding moved internally to Chief, Operations Section, in March 1982 and Marvin Sherrill was Chief, Investigations Section until he transferred to Texas in March 1989. James Nicholas, Patrick Mills, and Chuck Avery served as Section Chief for various times during April 1989 to June 1990, when Angel Martin transferred from Louisiana and was Section Chief through the end of the period.

A one-person Field Headquarters was at Sheffield during 1982 as part of a project to study a low-level radioactive-waste disposal site. Peter deVries staffed the Field Headquarters and administratively reported directly to the Chief, Investigations Section.

Other employees reporting to the Chief, Investigations Section, at some time during the period were Leslie Adams, John Bartlett, Kevin Beernick, Karen Borg, Jane Borghese, Timothy Brabets, Tim Brown, John Burban, Bill Byczynski, Charles Clark, Gary Cobb, Brett Cole, Eileen Cowhey, John Darcy, Greta Dickerson, Elizabeth Dixon, Jack Drobisz, James Duncker, Chad Dunn, John Earle, Bart Eklund, James Erickson, Tim Faltomier, John Fisher, Ward Freeman, Rene Fuentes, Devin Galloway, George Garklavs, George Gahis, Donald Gerken, Brian Gilpin, Daniel Gmitro, Lisa Goodwin, Julia Graf, John Gray, Laura Harbison, William Harvey, Richard Healy, Angela Herrmann, Philip Hodgson, Vicki Hoogervorst, Jennifer Howard, Steve Hubbard, M.B. Hutter, Kirk Ingemunson, Ralph Iovinelli, Audrey Ishii, Delana Jacobs-Fuller, Eric Johnson, Janet Kania, Robin King, Alan Klinger, James Kwolek, Kirk Langford, Stephen Lardner, J.E. Leslie, Brian Loewen, Gary Mackey, Jason Marquardt, Jay Marr, Roger McFarlane, Laura McGovern, Eric Mears, Mark Mejac, Steve Melching, Patrick Mills, Dave Moffet, Dan Moisson, Melissa Mylin, John Nazimek, Theresa Nelles, James Nicholas, Daniel Oberg, Julio Olimpio, Steven Padovani, Shannon Patterson, Gary Patterson, Charles Peters, Anthony Pulokas, Michael Reade, Aaron Rogers, James Rogers, Stuart Rojstaczer, Jeff Schelling, Leslie Schenk, Steve Shook, Karen Sides, Gregory Sloniger, Steve Smith, John Stamer, D., Carl Steffenson, Robert Striegl, Peter Stump, Mike Svec, James Townsend, Mary Turner, Tracy Vail, David Voelker, Patricia Wagner, Linda Weiss, J.E. Wilder, M.A. Wolff, and Sandra Wyld.

National Water-Quality Assessment Program. The Upper Illinois River Basin (UIRB) was chosen in 1985 to be one of the river basins studied within the NAWQA Program and, in 1989, the NAWQA Unit was formed to handle the increasing workload of that project. Dean Mades was the initial Project Chief, and when he left the WRD for private practice in late 1987, Stephen Blanchard succeeded him. Blanchard was the first Chief, NAWQA Unit, when it was formed in June 1989. In February 1991, Blanchard was appointed District Chief and Arthur Schmidt was named Chief of the NAWQA Unit. In 1993, the Lower Illinois River Basin (LIRB) was seeded for study within the NAWQA Program and in 1994, the NAWQA Unit was split into two Units: the UIRB and the LIRB. Schmidt became Chief, LIRB Unit, and George Groschen succeeded him as Chief, UIRB Unit. Schmidt left WRD for private practice in April 1994, and George Groschen became Chief, LIRB Unit. Stephen Blanchard again assumed the duties of the UIRB. Other employees who worked in the NAWQA Units were Tim Clay, John Colman, Donna Czuba, Faith Fitzpatrick, Jennifer Kupperman, William Meyer, Cathy Nguyen, Sharon Qi, Randy Romack, Peter Ruhl, M.S. Schinzler, B.S. Slavik, Troy Stinsson, Daniel Sullivan, Kelly Warner, and Steve Worsfold.

Operations Section. The Network Operations Section, renamed the Operations Section in 1991, also was located in the District Office and was responsible for all routine data-collection activities, many projects using long-term data bases, and those evaluating methods and procedures of data collection. G. Douglas Glysson transferred from California in September 1979 to be Chief, Network Operations Section. Glysson transferred to Reston Headquarters in 1982 and Gary Balding was made Chief, Network Operations. In June 1987, David Stedfast replaced Balding. Stedfast went to the graduate school program in 1990 and Kevin Oberg was Section Chief during 1990–94.

Others who served in the Operations Section were Kathleen Alberts, Gregory Boughton, Susan Coryell, Richard Coupe, G. Wayne Curtis, Oscar Cwajbaum, Tim Del Sol, Kathleen Fitzgerald, Robert Griffith, James Haworth, Robert Holmes, Gary Johnson, Lenae Joslyn, John LaTour, Timothy Lazaro, Thomas Maloney, Larry Mansue, Katrina Maxwell, John Monkman, Brad Mueller, Parmindeer Patel, Dale Peart, Peeter Pirn, Clifton Pugh, Naila Rafiq, Gerald Ryan, Lance Schideman, Thomas Schiene, Jessie Sterling, Teresa Stroot, Steve Tarte, T.C. Taskerud, Josephine Terrell, Paul Terrio, Paul Welch, Schuy Wilmore, and Elmer Zuehls.

Urbana Field Headquarters. The Champaign Field Headquarters became the Urbana Field Headquarters in February 1981, along with the District Office move to Urbana. The Field Headquarters was responsible for all data-collection activities in the central part of the State. Paul Hayes transferred from Indiana in May 1980 and was Chief, Urbana Field Headquarters, until May 1992 when he transferred to California. John LaTour was Acting Chief until February 1994 when the Urbana Field Headquarters was abolished and all personnel and activities were incorporated into the Operations Section. Those who worked in the Urbana Field Headquarters during the period were Deborah Anderson, Allen Bewsher, Victoria Davis, Michael Deneen, Alan Donner, Walter Gauthier, Marvin Harris, Robin Hatton, Ann Johnson, David LaFont, Edward Magner, Leslie Magnus, Dave Morgan, Andrew Negri, Albert Nyberg, Alan Robl, A.J. Shen, and Sammy Wilbourn.

Mt. Vernon Field Headquarters. The Mt. Vernon Field Headquarters was responsible for all data-collection activities in approximately the southern one-third of the State. Richard Stahl was in charge of the Field Headquarters until he retired in June 1989. John Maurer, who began his career with WRD in Mt. Vernon in 1975, replaced Stahl and was Chief, Field Headquarters, through 1994. Others who worked in the Mt. Vernon Field Headquarters were Richard Chenoweth, Andrew Dailey, Perry Draper, James Dwyer, Robert Eacret, Norman Garner, Jason Hall, Michael Heaton, Norma Kaufman, Joseph Norris, Daniel Olson, John Osterberg, Marvin Pilgrim, and Steven Stammer.

Springfield Field Headquarters. A unique cooperative arrangement with the Illinois Environmental Protection Agency (IEPA) was attempted during 1981–82 to help meet the demands of data collection required in the Coal Hydrology program and by an expanded cooperative network of water-quality stations. Five contractual employees of IEPA worked with WRD employees in the Field Headquarters in Urbana and Mt. Vernon to receive training in the methods of data collection mandated by WRD. The five IEPA employees later were moved into an office in Springfield, which was to be a third District Field Headquarters, staffed by a WRD hydrologist or senior technician who would provide technical leadership. Unfortunately, funding for the Coal Hydrology program diminished before the office was staffed by WRD, the experiment was terminated, and the IEPA employees returned to positions within their agency.

FUNDING AND COOPERATION

Total funding from three sources, Fed (Federal Program), OFA (other Federal agencies) and Coop (shared funding with State and local agencies) as shown in the funding table, increased from about $3.1 million in 1980 to about $4.1 million in 1994. Coop funding nearly doubled, increasing at a near-linear rate from about $1.3 million in 1980 to nearly $2.2 million in 1994. Fed funds were the most variable—higher during 1980–81 and 1987–89 and declining during 1990–94. OFA funding generally was stable for the period 1980–89 but increased steadily during 1990–94. Total funding increased more sharply than normal during 1980–81, reflecting the increases in Fed funding. Except for 1989, total funding showed a generally linear increase for the remainder of the period because of the combined effects of higher Fed funding in 1986–91 and higher OFA funding during 1990–94.

Thirty-three State and local agencies worked with the District to fund activities within the Coop program during the period. Seven State agencies were located in Illinois and one in Wisconsin. There were seven counties, nine cities, seven districts, and two commissions (all entities of State and local govern-

Illinois District funds for fiscal years 1979–94

[Fiscal year funds in thousands of dollars]

Fund source	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	1,258	1,372	1,364	1,470	1,645	1,603	1,622	1,746	1,748	1,739	1,996	2,171	2,128	2,032	2,163
OFA	560	651	567	596	534	906	536	569	673	562	921	1,103	1,436	1,444	1,527
Fed	1,308	1,451	901	896	772	686	891	1,056	1,200	1,125	856	739	573	618	418
Total	3,126	3,474	2,832	2,962	2,951	3,195	3,049	3,371	3,621	3,426	3,773	4,013	4,137	4,094	4,108

Source: Administrative Information System Records 1979–82 and 1986–94, District Program Records 1983–85.

ment). Some of the entities represented more than one agency during the period and some represented more than one Department within an agency. The Illinois State Water Survey (ISWS) began the period as part of the Illinois Institute of Natural Resources but in 1979 was reorganized into the Illinois Department of Natural Resources (IDNR). In 1982 the IDNR became part of the Illinois Department of Energy and Natural Resources and remained so through 1994. The ISWS and the Illinois State Geological Survey (ISGS) also cooperated through the Board of Trustees of the University of Illinois. The Illinois Department of Transportation cooperated through its Division of Water Resources (IDOT–DWR) and its Division of Highways (IDOT–HWY). Other cooperating State agencies were the Department of Conservation, Department of Nuclear Safety, IEPA, and Northern Illinois University (NIU).

Cook, Du Page, Kane, Lake, McHenry, Vermilion, and Winnebago Counties were cooperators during the period.

Nine cities provided some funds to the Coop program: Champaign, Decatur, De Kalb, Elgin, Eureka, Monticello, Oak Brook Village, Springfield, and Urbana.

Two commissions that provided funds were the Boneyard Creek Commission and the Northeastern Illinois Regional Planning Commission.

Seven water conservation or drainage districts supported the Coop program at some time during the period. They were the Kankakee Soil and Water Conservation District, Fountain Head Drainage District, the Metropolitan Sanitary District of Greater Chicago, which in 1989 became the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) and is referred to throughout this report, Bloom Township Sanitary District, Bloomington-Normal Sanitary District, City of Danville Sanitary District, and the Otter Creek Utility District. During 1991–93 the Illinois District cooperated with the State of Wisconsin, Department of Natural Resources, on a project in southern Wisconsin.

Some of the cooperators have had long-term continuing agreements with the District. The largest, in terms of funding, has been IDOT–DWR, which has long supported the stream-gaging program in Illinois and continued its support during 1980–94. Its support of 22 interpretive projects during the period was notable in the increase in the Coop program and in keeping pace with inflationary demands. Additionally, cooperators have supported many and diverse topical projects, interpreting the streamflow data from the network and providing for additional data collection when and where required.

The ISWS also has long supported the stream-gaging activities in Illinois, but its support declined somewhat during 1980–94. During the period, the ISWS also participated in water-quality sampling, sediment sampling, and water-use programs and were allotted credit for services provided on these and other projects. The IEPA provided funding and direct services for the water-quality sampling program, for the water-use data program, and for eight water-quality major-issue projects. The MWRDGC also participated in water-quality sampling and related project activities during 1980–94. During the period, Du Page, Kane, Lake, and McHenry Counties supported projects and data-collection programs, mostly related to rainfall-runoff processes and flooding.

The District provided services to six OFA's during the period. One, the U.S. Army Corps of Engineers (Corps), has four Corps Districts represented in Illinois—two headquartered in Illinois, one at Chicago (Corps–CHI) and one at Rock Island (Corps–RI), one at St. Louis, Missouri (Corps–STL), and one at Louisville, Kentucky (Corps–LOU). Five other Federal agencies represented were the U.S. Department of Housing and Urban Development, Federal Emergency Management Agency (FEMA); the U.S. Air Force Air Mobility Command, Directorate of Environmental Programs (USAF); the U.S. Environmental Protection Agency, Region V (USEPA); the U.S. Fish and Wildlife Service (USFWS); and the U.S. Nuclear Regulatory Commission (USNRC).

The Corps of Engineers has continually funded stream gaging in the Illinois District and, during 1980–94, it funded much of the sediment-sampling program. The Corps also requested assistance on other projects relating to river and lake management and flood-control structures. The USNRC, USAF, and USEPA requested assistance for land-management problems related to waste-site activities. USEPA funding increased steadily from about 1986 and included technical consultation, training, quality assurance, and research projects to assist characterization and remediation of hazardous-waste sites on the National Priority (Superfund) List. USNRC funding was limited to very early in the period, and USAF and USFWS funding began in 1994.

SUMMARY OF PROGRAMS

HYDROLOGIC DATA COLLECTION

Major data bases completed or maintained by the District during the period included discharge data for Illinois streams, river miles and drainage areas of Illinois streams, digitized drainage divides, water-quality data for streams and wells, and a ground-water observation well network. Data reports were published annually in multiple volumes.

The WRD and the IEPA sponsored a meeting of Illinois water-data users in Peoria, Illinois, on February 23–24, 1982. The group agreed on seven major proposals for coordinating water-data collection and dissemination among water-data collectors. Attempts to cooperatively have IEPA assigned hydrologic data collection in an area in central Illinois had to be terminated when funding for coal hydrology programs waned in 1982.

Streamflow Stations. In 1979 the Field Offices were operating 171 continuous-record stations, 135 crest-stage gages (CSG) for partial record, 9 CSG's for stage only, and 3 stations on lakes for stage and content as shown in the table of data-collection sites. The continuous-record discharge stations declined by 31 in 1983 and remained fairly stable at 140–150 through the rest of the period. The CSG program declined sharply to 80 stations in 1980 and to 31 stations in 1981; thereafter, the program was rather stable until 1993 when it declined to 12 stations and remained there in 1994. Project leaders were Curtis (1979–85 and 1987–90, Aehls (1986), Obert (1991), and LaTour (1991–94).

In cooperation with IDOT–DWR, Mades and Oberg formally evaluated the network of streamflow-data stations twice during the period. First, a network of 138 stations operated in water year 1983 was evaluated for the cost effectiveness. Later, they evaluated the 1983 network for its adequacy to meet the various streamflow-information needs.

The first AVM in Illinois was installed in 1984 at a new gaging station on the Chicago Sanitary and Ship Canal at Romeoville, and a second was installed in 1985 at the Illinois River at Havana. In 1979, the District had about 20 telemetry units, mostly data-collection platforms (DCP's), and 16 stations with DCP's were in the Distributed Satellite Telemetry-Data-Handling System. In 1988, CR–10 data loggers with telephone modems were installed at 10 continuous-record stations in northeastern Illinois in cooperation with IDOT–DWR. During the remainder of the period, about 10 data loggers were installed each year and, at the end of the period, most IDOT–DWR stations contained remotely read data loggers. About 1990, the District began to replace manometers with pressure transducers as a means of sensing water levels. Missing record decreased during the period from nearly 10 percent to between 3 and 4 percent.

The acoustic Doppler current profiler (ADCP) was first used in the District in 1993. Oberg became

Data-collection sites

	Fiscal year															
	1979	1980	1981	1982	1983	1983	1985	1986	1987	1988	1989	1990	1991	1992	1994	1994
Surface-water stations																
Sediment	12	32	31	18	8	11	9	9	5	4	4	4	4	4	11	13
Water quality	204	201	207	202	202	204	204	205	206	160	149	155	155	16	8	20
Discharge	171	169	166	172	141	139	140	144	138	139	147	150	148	149	144	148
Stage only	9	8	10	21	23	10	11	10	12	9	8	15	15	11	12	13
Peak stage/Peak discharge	135	80	31	29	28	25	24	24	24	24	23	23	23	21	12	12
Stage and content	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Ground-water stations																
Water levels	85	185	96	113	111	215	255	264	119	24	24	8	7	11	12	13
Water quality	77	144	58	130	128	121	353	889	820	17	17	40	54	47	56	2
Observation wells	3	3	3	3	3	3	3	3	3	3	7	8	7	11	12	13

*Stage only includes both stream and lake sites.

**Source: Water Resources Activities in Illinois Annual Publications.

proficient in its use and by using the ADCP was able to reduce four- and six-person trips on the Illinois River to two people; also, trip times were much shorter. Oberg and David S. Mueller (WRD, Kentucky District) used a broadband ADCP for discharge measurements on the Mississippi River during the major 1993 flood. Oberg and R.B. Jacobson (WRD, Missouri District), in cooperation with IDOT–DWR, assisted the Corps–STL during the 1993 flood to obtain measurements at the Miller City Levee break in southern Illinois. They measured discharge and obtained bathymetric data using the ADCP with concurrent data from a global-positioning-system receiver.

At times, personnel in the data-collection program were asked to perform activities beyond their normal scope. In April 1992, a 100-year-old freight tunnel in downtown Chicago was breached where the tunnel crosses under the Chicago River. Oberg, Duncker, and Schmidt assisted the Corps–CHI in their efforts to plug and dewater the tunnel by installing and operating telemetry gages to monitor water levels. They made velocity measurements in the vicinity of the tunnel breach and used fluorescent dye to check for leaks in the plugs.

Floods and Droughts. Major flooding of Illinois streams occurred in June 1981, December 1982, September–October 1986, August 1987, and April 1994. In 1993, major floods along the Mississippi River and its tributaries caused unprecedented flooding in areas along the Mississippi tributaries in Illinois and adjacent States. Balding, Curtis, Ishii, and Holmes summarized various aspects of some of the major floods.

During June 12–13, 1981, intense and localized thunderstorms caused severe flooding in northeastern Illinois and scattered flooding in northwestern Illinois. Five record discharges were recorded, and floods greater than 100-year recurrence interval occurred at two locations. Three lives were lost and damage was reported to exceed $84 million. Statewide floods in December 1982 resulted from long periods of rainfall in November and early December. Record peak discharges were measured at 17 stations, and peak discharges at five gaging stations exceeded the 100-year recurrence interval. Total damages were estimated at greater than $100 million. Record-setting floods, primarily in the Illinois River Basin during September 26–October 4, 1986, caused peak discharges of record at nine gaging stations, four of which exceeded the 100-year recurrence interval. Storms of August 13–14, 1987, in the Des Plaines River Basin were localized, intense, and of short duration. Runoff resulting from the storms produced record streamflows at 10 gaging stations, and recurrence intervals for peak discharges at 9 stations were greater than 100 years. FEMA's estimate of damage to private property from the storm was $77.6 million. A large spring storm leaving 5 or more inches of rainfall caused record-breaking floods throughout central Illinois during April 12–15, 1994. Records of peak discharge were broken at eight gaging stations, seven of which exceeded the 100-year recurrence interval. Of 22 discharge measurements made at 18 gaging stations, 10 were made within 1 foot of the peak stage.

Flooding on the Mississippi River and its tributaries in the Midwest in the spring and summer of 1993 resulted from record precipitation in the upper Mississippi River Basin and caused peak flows in the Mississippi River at St. Louis, Mo., exceeding the 100-year recurrence interval. Major levee breaks flooded lands adjacent to the river and dumped from 1 to 10 feet of sand on parts of the flood plain. Damages estimated at $20 billion made this flood the costliest in U.S. history. Holmes reported that the Mississippi River transported an estimated 55 million metric tons of suspended sediment past St. Louis.

Statewide drought conditions during the summer months of 1988 caused zero or record-low instantaneous discharges at numerous gaging stations in Illinois. In cooperation with IDOT–DWR, special statewide discharge-measurement/observation trips were made to document summer low-flow conditions. An additional 350 measurements/observations were made at 174 gaging stations.

Water-Quality Stations. The surface-water-quality sampling network that was expanded at the beginning of 1979, with IEPA as the major cooperator, continued with 204 sampling sites visited by personnel from VMD, IEPA, ISWS or Corps–STL. Samples for chemical analyses were analyzed in WRD and cooperator laboratories. The Corps left the program in 1980 and MWRDGC entered the program in 1983 with samplers and laboratory services. The WRD coordinated the surface-water-quality data-gathering efforts among the State, local, and Federal agencies. Efforts were directed toward having all participants use current and uniform sampling, analytical, and data-reporting procedures. All water-quality data were reviewed by WRD, stored in WATSTORE and

forwarded to USEPA for storage in the STORET data base. Parts of the cooperators' work efforts were matched by WRD as direct services.

Quality controls for sampling procedures and analyzing chemical constituents were performed on a continuing basis and consisted of observing sampling procedures and submitting blind samples, concurrent sampling, and split samples. Project leaders during the period were Maloney (1979–81), Fitzgerald (1982–86), Coupe (1987–93), and Terrio (1994). Melching and Coupe reported on the results of analyses of concurrent samples submitted to IEPA laboratories by WRD and IEPA personnel and on split samples, a portion of which was submitted to each WRD and IEPA laboratory.

The ISWS dropped from the program in 1981 because of the extra time and costs associated with quality-control efforts. The MWRDGC entered the program in 1983 with no adjustment in total sites sampled. The program stayed stable until 1988, when about 50 stations were discontinued (see Data-Collection Sites table) at sites where discharge records were not readily available. Another cooperator, DCFPD, entered the program in 1988. Of the remaining stations, 11 were discontinued in 1989 and 6 were added in 1990. In 1992, IEPA and MWRDGC withdrew from the Coop program but continued their own network. In 1994, MCCD became a cooperator with WRD, and the program consisted of 20 sampling sites. Federal funds supported the program during the period through the National Stream Quality Accounting Network (NASQAN) program and at times through the Toxic Substances Hydrology program, the Mid-Continent Herbicide Initiative, and the NAWQA Program.

Tarte, Schmidt, and Sullivan enhanced sampling procedures during the period through the development of a floating sample-collection platform. The sampler was stage activated and best suited to streams with large stage variations. Coupe and Johnson used automatic samplers to sample three stream sites in Illinois for triazine herbicides during storms in the spring of 1990.

Sediment Stations. A few cooperators showed continual interest in sediment concentrations and loads during the period. The Corps was the principal cooperator. Project Chiefs during the period were Lazaro (1979–811), Mansue (1982–87), Zuehls (1988–89), Coupe (1990–93), and Johnson (1994).

Working on the Fed-funded Low-Level Radioactive Waste disposal site at Sheffield, Gray and deVries developed a system to obtain runoff and sediment-transport data from very small areas, on the order of 11 square meters. The device, called a Dekaport Divisor System, was designed to measure runoff from trench covers where access and site disturbance were severely limited.

Ground-Water Stations. There was no WRD program in Illinois before 1982 that was devoted to collecting hydrologic data at ground-water sites. In 1981, WRD and ISWS began a cooperative project to design a ground-water network. Project leaders were Sherrill (1982), Balding (1983–87), and Avery (1988–94). Frost and Sherrill worked with Michael O'Hearn and J.P. Gibb of ISWS to investigate available ground-water-network information in Illinois. They determined that data provided by active networks were inadequate to provide needed information on ground-water quality and water levels in large areas of Illinois and in the major geohydrologic units. In 1982 some Fed funds were made available, and a few wells were selected for making water-level measurements and providing needed information. Subsequently, in 1984, WRD and the IEPA, with assistance from ISWS and ISGS, began a systematic approach to ground-water-quality data collection. During 1980–87, samples were collected from 2,080 public-supply wells and were analyzed for inorganic and volatile organic compounds. Soluble organic constituents were analyzed in water samples from 330 wells. This network accounts for the large number of data sites shown in the Data-Collection Sites table in 1985–87. After 1987, the cooperative network was discontinued. The Fed supported the program for the remainder of the period, during which water levels were measured in about 8 to 13 wells, mostly in the northern part of the State. These wells are included within a larger number of wells in the Data Collection Sites table that also includes wells measured and sampled for special purpose projects.

Water-Use Data Collection and Application. The water-use program in Illinois was new at the beginning of the period. A cooperative effort was maintained with ISWS during the entire period to collect withdrawal data and with IEPA during 1984–94 to collect return-flow data. Project leaders were Curtis (1980–81), Lazaro (1982–85), LaTour (1986–93), and Avery (1994).

In a low-flow investigation of streams in the Kishwaukee River Basin, done in cooperation with IDOT–DWR, Allen and Cowan included an assessment of the contribution of return flows to total streamflow downstream from sewage-treatment facilities during drought periods. As part of the water-use program in cooperation with IEPA, LaTour evaluated the balance between water withdrawals and returns in the Rockford and Kankakee areas. Various methods were used to estimate the different parameters of water-use and return-flow budgets where measurements were not available. Also, in cooperation with IEPA, LaTour investigated the contribution of return flows to streamflow in two rural and three urban stream reaches during 1980–81. Return flows exceeded natural streamflow in each reach during some drought periods.

INTERPRETIVE STUDIES

Surface-Water Hydraulics and Hydrology. Most of the surface-water investigations in the Illinois District during the period related to highway planning and the mitigation of flood damage. Those cooperating with the Illinois District on surface-water related investigations include the Corps, IDOT–DWR, Lake County, and Du Page County. The Corps–RI and IDOT–DWR supported a study by Allen and Cowan that evaluated low flows in the Kishwaukee River Basin in northern Illinois. They evaluated the effect of geology on the 7-day, 2-year and 7-day, 10-year flows after deducting the contributions of wastewater from treatment plants.

Various studies in cooperation with IDOT–DWR attempted to develop means of estimating and improving model parameters needed to synthesize hydrographs for Illinois streams. Graf, Garklavs, and Oberg calculated time of concentration and storage coefficient, two unit-hydrograph parameters, for 98 basins by calibration of the Corps of Engineers' Flood Hydrograph Package (HEC-1), statistically compared the results with values computed by other investigators, and developed estimating equations that included a regional factor. Weiss and Ishii evaluated model parameters for two rainfall-loss computation methods, the Exponential Loss-Rate method (with four model parameters) and Initial and Uniform Loss-Rate method (with two model parameters). They used data from 616 storms at 98 gaged basins in an attempt to develop parameter-estimating techniques for the six parameters but found a large degree of uncertainty in the hydrographs computed using the estimating techniques.

King reviewed more than 7,000 literature citations on the general subject of infiltration for their applicability to the rainfall-runoff process and rainfall-modeling studies. Approximately 1,000 were included in a bibliography on the subject, and a subset of about 300 bibliographic citations were cross indexed according to infiltration-model type and the physical setting of the infiltration study. Schmidt and Romack organized a geographic information system (GIS) data base to apply to investigations of rainfall/runoff model parameters in Illinois. The GIS was used to calculate area-weighted averages for parameters that described the basin characteristics.

Equations for estimating flood-peak discharges and frequencies in Illinois have been revised periodically since 1954 as more years of record become available. Curtis performed this in 1987 for rural streams and related flood-peak discharges for recurrence intervals of 2 to 500 years to drainage area, slope, rainfall intensity, and a regional factor. Allen and Bejcek showed that drainage area, channel slope, and an urbanization factor (percent imperviousness) could be used to estimate peak flows where the basin suffers the effects of urban development. Oberg and Mades evaluated four techniques for estimating generalized skew of the log-Pearson Type III distribution in Illinois. Schmidt examined historical records for indications of nonstationarity of hydrologic processes but found no trends greater than the variability of extreme storms.

Scientists from the ISWS, the University of Wisconsin, and the Illinois District joined efforts, with support from IDOT–DWR and DCDEC, to examine the methodologies of rainfall-runoff modeling for stormwater management. Potter and A. Allen Bradley (University of Wisconsin) studied and evaluated techniques for determining accurate flood-frequency estimates by using hydrologic/hydraulic models in rapidly changing urban watersheds. Turner collected information for verification of a one-dimensional, unsteady-flow model on the Fox River.

In 1985, in response to recent flooding and State legislation, Du Page County implemented a county-wide stormwater-management plan for the county and joined WRD in a cooperative effort to collect and analyze rainfall and streamflow data from three small urban watersheds. Duncker, Vail, and Earle collected data to calibrate a distributed-parameter, contin-

uous-simulation, rainfall/runoff model, in order to simulate stormflow hydrographs for a variety of watershed conditions. Duncker, Vail, and Melching also collected rainfall and streamflow data to calibrate and verify a rainfall/runoff model for an area encompassing three watersheds in Du Page County. Both studies were continuing at the end of the period.

Also continuing into 1995 were studies on peak flows in Lake County and a Flood Warning study in Du Page County, both projects led by Melching, and Bridge Scour project in Illinois led by Holmes.

Illinois River Structures and Flow Ratings. The Illinois Waterway (327 miles) connects Lake Michigan at Chicago Harbor with the Mississippi River at Grafton, Illinois. The waterway is composed of the Illinois, Des Plaines, Calumet, and Chicago Rivers, the Chicago Sanitary and Ship Canal, and the Calumet Sag Channel. The Corps operates eight locks and dams on the waterway and one on the Mississippi River at Alton, Illinois. The Corps–CHI has been charged with accounting for diversion from Lake Michigan and the Corps–Rl regulates the flows downstream from the Chicago Sanitary and Ship Canal. Both Corps Districts need to know the amount of water passing through the control structures under various hydrologic and control structure settings in order to maintain optimum conditions in the watershed.

The amount of water that may be diverted from Lake Michigan to Illinois is established by U.S. Supreme Court decree, and leakage through any control structures is counted against the diversion. Oberg and Schmidt used ADCP's and dye dilution techniques to make 221 measurements of leakage from Lake Michigan at three control structures: the Chicago River Controlling Works, the Thomas J. O'Brien Lock and Dam, and the Wilmette Pumping Station.

The AVM on the Chicago Sanitary and Ship Canal at Romeoville is a key station for measuring diversion of water from Lake Michigan to Illinois. During periods of meter inoperation caused by power surges, barge damage, or other causes, discharge estimates made by the MWRDGC at the Lockport powerhouse, lock, and controlling works were used with a series of estimation equations to approximate the flow at Romeoville.

In 1993, Melching and Oberg compared the operation of two AVM's at the Lockport Lock and Dam. The initial meter operated from June 1984 to November 1988, when it was discontinued because of maintenance problems, and a new and different meter was installed. The relations between discharge at Romeoville and discharge estimates by MWRDGC at the Lockport dam for both meters were comparable. By separating discharge estimates through turbines, lockage, and leakage (TLL) from total discharge estimates consisting of TLL, powerhouse sluice gates, and controlling works, an error relation for the TLL regime was determined that was used to adjust discharges through the sluice gates and(or) controlling works. Equations derived from the adjusted discharges were used to estimate discharge at Romeoville for days when the AVM was not operational.

Mades and others developed methods for computing discharge at Brandon Road Dam on the Des Plaines River and at Dresden Island, Marseilles, and Starved Rock Dams on the Illinois River. Garklavs and others developed methods for Peoria and LaGrange Dams on the Illinois River, and Fisk developed methods for McHenry Dam on the Fox River. The Corps–RI is responsible for operation of all except McHenry Dam on the Fox River, which is operated by the IDOT–DWR.

Both Mades and Fisk used some combination of headwater and tailwater elevations and gate openings for all the dams they studied. Fisk used the ratios of tailwater depth to headwater depth and gate openings to define free-weir flow, free-orifice flow and submerged-orifice flow, and defined discharge coefficients to be used by making discharge measurements under various hydrologic conditions and gate settings. Mades developed a useful tailwater rating for the Marseilles Dam but not for the other three dams because of varying downstream channel-storage conditions and effects of headwater pools of downstream dams.

Garklavs and others used peak discharges at the Peoria and La Grange Dams and channel storages upstream to the next controlling structure to define relations useful for operating the system of locks and dams that would maintain stable pool elevations at various discharges. Storage-discharge relations were linear for ranges in discharge used in the analyses for Peoria and La Grange.

Surface-Water Quality. At the State level, responsibility for surface-water quality lies with the IEPA. Many regional, county, and local agencies, districts, and planning commissions have water-quality programs that interrelate to ensure compliance with programs of IEPA and USEPA. Pollution from

industrial and municipal point sources, and hazardous-waste disposal sites and nonpoint-source pollution as a result of runoff from agricultural lands and construction activities were included in surface-water-quality studies during the period. The IEPA was the cooperator on the following surface-water-quality studies except as noted.

The quality of water during low-flow periods was assessed for Richland Creek in southeastern Illinois, the Sangamon River from Decatur to Riverton in central Illinois, the Du Page River in northeastern Illinois, and Cedar Creek in west-central Illinois near Galesburg. Stainer, W.O. Freeman, Schmidt, and MacFarlane worked in teams to study each of the basins. During each study, measurements were made at low flow and used to calibrate one-dimensional, steady-state, water-quality models. Equations for simulating reaeration rates were chosen by comparing predicted values to measured values using steady-state, gas-tracer techniques.

W.O. Freeman, Schmidt, and McFarlane studied storm runoff in an urban area of Cedar Creek for its effect on runoff water quality and bottom sediment. Striegl and Cowan (WSP 2301) also studied Lake Ellyn in northern Illinois as part of an agreement between USEPA and USGS, for a Nationwide Urban Runoff Program. In cooperation with NIPC, Striegl and Cowan studied the effects of detention storage in the lake. Inflows to the lake and outflow from the lake were compared to show changes in peak flows and most water-quality constituents. Mass-balance relations were used to show the efficiency of the lake in trapping suspended solids, sediment, and sediment-associated metals.

Knowledge of streamflow, traveltimes, and longitudinal dispersion is required to facilitate the development of models applicable to streamflow regulation and control and abatement of accidental pollutant spills. Thus, the Corps–RI supported a study of traveltime and dispersion in the Illinois River led by Zuehls. Graf led an IEPA-supported study (WSP 2269) of 10 other streams in Illinois during which Rhodamine-WT dye was used for measurement of traveltime of peak and leading edge concentrations of a solute cloud and time of passage of the cloud.

Ground-Water Studies. The ISWS and the ISGS are nonregulatory State agencies that have authority to study ground water in Illinois. Frost and Sherrill worked with members of the ISWS to determine adequacy and completeness of available water-level and water-quality networks for ground-water data. Early in 1984, WRD and the IEPA, with assistance from ISWS and ISGS, began a cooperative pilot observation-well network with goals to select wells representative of the major geohydrologic units, describe baseline conditions in each unit, investigate trends in ground-water quality and quantity, and establish a manageable data base for use in assessing ground-water resources. Voelker, with assistance from Oberg and Turner, tabulated the ground-water-quality data collected during 1985–87. Coupe and Warner demonstrated how to use statistical packages associated with the National Water Information System (NWIS) for tabular and graphical representation of ground-water-quality data. Voelker later studied the period 1980–87 and evaluated spatial and aquifer differences in ground-water quality.

Nicholas and Krohelski studied the sand and gravel aquifers in McHenry County. They mapped water levels to determine local flow paths and collected samples to assess water quality.

In the American Bottoms portion of the Mississippi River flood plain near East St. Louis, ground-water levels rose 5–10 feet since the early 1970's, and dewatering of the aquifer by pumping was considered by the Corps-STL as a means to alleviate economic and health concerns caused by high ground-water levels. They supported a study by Voelker to assess the ground-water quality in the aquifer and provide information necessary to evaluate potential methods of disposing of water withdrawn from the aquifer.

Avery and Warner worked with the ISGS to update a map of the bedrock surface and thickness of glacial drift for northern Illinois. They proposed to analyze the compatibility of the ISGS project data base and the USGS Ground-Water Site Inventory data base. Working with scientists from NIU, Martin studied the chlorine isotopic variability of brine samples from Paleozoic sediments and shallow aquifers in the Illinois Basin for purposes of tracing saline-water contamination in freshwater aquifers.

Nicholas assisted Allen M. Shapiro, Northeastern Region Research Hydrologist, in a study to develop models of flow and transport in a fractured dolomite where the heterogeneity within each fracture is treated as a stochastic process. Hydraulic and tracer tests were conducted in a discrete, areally extensive, horizontal fracture in Silurian dolomite in northeastern Illinois. Two methods of estimating the distribution of aperture sizes were evaluated.

During 1991–94, Mills coordinated the District's participation in the MCHI, within which 303 wells in 12 Midwest corn- and soybean-producing States (68 wells in Illinois) were sampled and analyzed for nitrogen fertilizers, herbicides, and herbicide metabolites. At least one herbicide or atrazine metabolite was detected in 24 percent of 579 samples analyzed. Significant seasonal differences were determined for the frequency of herbicide detection.

Sediment Studies. Graf used stage and rainfall data, theoretical stage-discharge relationships, and bottom-material size analyses to evaluate potential for movement of sediment in North Ditch, a small (0.1-mi^2 drainage area) tributary to Lake Michigan at Waukegan. An Administrative Report was provided to USEPA to help assess the potential for resuspension and transport of PCB-contaminated sediment into the lake. Graf later used the analyses of bedload samples collected in the data program during 1979–81 to provide the Corps-STL with usable discharge-bedload rating curves for three streams where sufficient analyses were available. Acceptable relations were observed between measured bedload and bedload computed from channel characteristics for three additional streams. No usable relations were apparent for three streams because grain sizes either were too fine or too coarse to be efficiently sampled with the Helley-Smith sampler.

Lazaro, Fitzgerald, and Frost, also working with the Corps-STL, used 5 years of record at one site to develop transport equations that were then used to estimate long-term suspended-sediment discharges from long-term water-discharge records. In cooperation with IEPA, Frost and Mansue later used a hydrograph shifting method to estimate monthly and annual suspended-sediment loads for 12 streams throughout the State. They concluded that reasonable estimates of annual suspended loads could be made for most sites.

A project was started in 1980 in cooperation with IDOT–DWR to enlarge the data base and analyze sedimentation rates related to land-use changes in the Kankakee River Basin. The project was suspended in 1981 but was reestablished in 1992 and was continuing at the end or the period. In 1994, Terrio prepared a report relating to dendrogeomorphic estimates of sedimentation rates along the river near Momence.

Allen and Gray studied a 2.81-mi^2 agricultural watershed in northern Illinois and determined that of 2,890 tons of suspended sediment transported during a 2-year period, all but 200 tons was transported during one 46.6-hour storm.

Coal Area Hydrology. Environmental concerns related to energy sources began in the late 1970's, continued into the 1980's, and led to various projects related to hydrology of surface-mined lands. USGS and OSM funds for coal-area hydrologic studies were available in Illinois until the mid- to late 1980's. Zuehls led areal hydrologic studies of basins within the Illinois part of the Eastern Region, Interior Coal Province of Illinois, Indiana, and Kentucky. With assistance from G. Ryan, Peart, Fitzgerald, and Peters, 6 of 11 hydrologic-unit areas were studied and reports were prepared on each unit. Toler used data collected for USEPA in the 1970's to relate sulfate and dissolved-solids concentrations in streamflow to the percentage of surface-mined lands in the drainage basins in Illinois (WSP 2078). Voelker made physical and chemical measurements of 107 lakes formed by surface mining in Area 35, one of the 11 hydrologic study units. Brabets studied seven watersheds in three locations in surface-mined lands and documented effects on streamflow, flow-duration curves, and dissolved constituents caused by partial disturbance of the basins by surface mines. Borghese and Klinger made a similar study of one 0.6-mi^2 basin actively mined in Randolph County. Their study expanded on previous studies by including the effects of mining on ground-water levels. Weiss, Galloway, and Ishii went further by developing a means of simulating changes in seepage flux and head caused by ground-water drainage into a surface coal mine.

The MWRDGC began operating a sewage-sludge disposal and surface-mine reclamation project in Fulton County in 1971, and the Illinois District began a cooperative program with them to monitor water quality in streams draining the project area. In 1978, monitoring was extended to measuring ground-water levels and quality and to assessing the hydrologic effects of the project. G.L. Patterson, Fuentes, and Toler studied the hydrologic characteristics of surface-mined land reclaimed by sludge irrigation and Patterson later investigated the hydrologic effects of the storage ponds. Coupe and Macy reviewed all the surface-water and streambed-sediment-quality data to ascertain whether the application of sludge was affecting the surface-water quality.

Nuclear Waste-Site Program. A Fed-funded study at a low-level radioactive waste disposal site at Sheffield began in 1976 as one of various sites being

studied throughout the Nation. Foster led the initial effort from which several additional studies were spawned. The IDNS assisted and USNRC helped fund (OFA) some phases of the project. Collateral projects continued until 1990, but most of the work was completed in the 10-year period, 1977–81. Many publications emanated from the study of the Sheffield site. Before his retirement in 1984, Foster and others completed various publications on the hydrogeology of the site (Foster, Erickson, and Healy) and adjacent area (Foster, Garklavs, and Mackey). Water-Supply Papers resulting from the project discussed evapotranspiration and microclimate (WSP 2327 by Healy, de Vries, and Sturrock), water and tritium movement through the unsaturated zone (WSP 2386 by Mills and Healy), effects of low-level radioactive waste disposal on water chemistry in the unsaturated zone (WSP 2390 by Peters, Striegl, Mills, and Healy), and water movement and water chemistry in the unsaturated zone (WSP 2398 by Mills). Foster was succeeded by Healy, and later by Barbara Ryan, who summarized 10 years of research at the site in WSP 2367, which contains sections on microclimate, evapotranspiration, and tritium release by plants (deVries and Healy), runoff and land modification (Gray), water movement though a trench cover (Healy), water and tritium movement in the unsaturated zone (Mills), gases in the unsaturated zone (Striegl), water and tritium movement in the saturated zone (Healy, Ryan, and Garklavs), and water chemistry (Peters). Ishii, Healy, and Striegl documented a computer code for a numerical solution for the diffusion equation in hydrogeologic systems (WRIR 89–4027). Numerous other USGS reports, journal articles, and presentations resulted from the project at Sheffield. A major challenge near the end of the project was to fill and seal a 6-foot-diameter, horizontal tunnel that had been constructed 400 feet into the hillside beneath the burial pits.

The study of the low-level radioactive waste site at Palos Park began in 1978 and, with collateral projects, continued until 1989. Initially, Olimpio led the Palos Park study and was succeeded by Nicholas. Olimpio studied the geohydrology of the glacial drift at the Palos Forest Preserve as it relates to burial of the waste and the migration of tritium (WSP 2226); Nicholas and Healy expanded coverage to tritium movement in the dolomite and the ground-water/surface-water interaction (WSP 2333).

Regional Aquifer Study. The Northern Midwest Aquifer system underlying parts of Illinois, Indiana, and Wisconsin was selected and funded for study during 1979–82 as part of the Regional Aquifer-System Analysis (RASA) program. Additional funds for report completion were provided in 1981. Sherrill led the Illinois part of the study and provided various maps and hydrologic data to the Regional RASA staff. Sherrill also worked with Adrian Visocky (ISWS) and Keros Cartwright (ISGS) to prepare ISWS/ISGS Cooperative Report 10 (1985), "Geology, Hydrology, and Water Quality of the Cambrian and Ordovician Systems in Northern Illinois." As part of the RASA study, Sherrill and Nicholas worked with the Northeast Region staff to oversee the drilling and testing of the deepest aquifer test well ever constructed in Illinois (a 3,475-foot-deep well in Zion State Park). Much of the information from Illinois is included with information from Indiana and Wisconsin in Professional Paper 405 that was prepared by the Region staff. Collateral to the RASA project, Balding studied the increases in salinity during 1915–84 of municipal wells that were open to aquifers in rocks of Cambrian and Ordovician age in northeastern Illinois.

National Water-Quality Assessment (NAWQA) Program. The UIRB, in parts of Illinois, Indiana, and Wisconsin, was selected in 1986 to be one of seven pilot studies to develop and refine the NAWQA Program. Illinois was the lead District for the UIRB with Mades (1986–87), Blanchard (1988–90) and Schmidt (1991–94) as Project Chiefs. Full implementation of the national program began in 1991. Funding for UIRB peaked in 1991 and was minimal for the period in 1994. In 1994, a NAWQA study of the Lower Illinois River Basin (LIRB) was initiated with Schmidt as Project Chief, succeeded by Groschen. The LIRB extended NAWQA coverage to all of the Illinois River Basin, which terminates at the juncture of the Illinois River with the Mississippi River at Alton.

In 1994, there had been nine abstracts and papers of presentations at professional meetings and eight USGS reports resulting from the NAWQA Project. Mades reported on the project description (1987); Striegl and D.W. Steffeck (USFWS) inventoried and evaluated previous biological investigations (1989); J.S. Zogorski (WRD, South Dakota District), Blanchard, Romak, and Fitzpatrick reported on available wastewater information (1990); Colman and R.F. Sanzolone (Geologic Division) reported on geochemical data for fine-fraction streambed sediment (1991); Fitzpatrick and Colman on manmade, nonagricultural,

volatile organic chemicals (1993); Sullivan and Blanchard on fixed-station network and water-quality data (1994); Sullivan and Terrio on agricultural organic compounds, nutrients, and sediment (1994); and Terrio on relating changes in wastewater-treatment practices to stream-water quality (1994). Blanchard and Schmidt prepared a report analyzing available water-quality data. Reports were near completion by Terrio on nutrients, dissolved oxygen, and fecal-indicator bacteria; by Donna C. Marron (Indiana District) and Blanchard on cross-sectional and depth variation of water-quality constituents; by Fitzpatrick and others on major and trace elements in water, sediment, and biota; and by Schmidt and Blanchard summarizing results of investigations through 1992.

Ruhl led a collateral project during 1988–92 to expand on the biological-data assessment by Striegl and Steffeck. Ruhl's effort was to assemble the available biological data, develop a computerized data base, and describe relations between the chemical and environmental measures of water-quality and biological parameters and evaluate the usefulness to the NAWQA Program. His report (1994) relates fish-community structure to environmental conditions in the Fox, Des Plaines, and Du Page River Basins.

Hazardous-Waste Site Studies. In 1985, the USEPA, Region V, Chicago, requested the Illinois District to provide technical assistance on several hazardous-waste sites on their National Priority (Superfund) List. Funding began in March 1986, and the 1987 program called for designing and conducting aquifer tests in fractured rock and reviewing technical reports submitted to the USEPA by their consultants. Barbara Ryan led the initial effort, and following her departure from the District in 1988, Kay, Mills, and Avery worked on various waste-site studies. Funding for the program increased each year for about 5 years, peaking for the period in 1993. Assistance to USEPA included training for performing aquifer tests, providing technical oversight for fieldwork conducted at some sites, providing technical review on results of work at other sites, and conducting research and providing administrative and(or) USGS reports of results. During the period, WRD assisted USEPA in studies of sites at Byron, Belvidere, Antioch, Rockford, and the southeast Chicago area.

Kay, Olson, and Ryan investigated the hydrogeology and results of aquifer tests at the Superfund site at Byron; Kay, Rauman, and Prinos worked with Douglas Yeskis and William Bolen of USEPA to study the geology, hydrology, and ground-water quality at the site. Avery investigated the interaction of the ground water with the Rock River near Byron, and Kay, Duwelius, and Brown worked with Frederick Micke and Carol Witt-Smith of USEPA to investigate the geohydrology and light-nonaqueous-phase liquids on ground water in northeastern Indiana and the Lake Calumet Area of northeastern Illinois. Kay and Earle studied the site near Antioch, and Kay worked with Pridos and Fred Paillet, Central Region Research Hydrologist, on a site in Rockford. Mills studied the Parson's Casket Hardware and MIG/DeWayne landfill sites in Belvidere and conducted a water-quality and ground-water-flow study of an 80-mi^2 area that encompasses Belvidere.

During 1996–92, Kay led a cooperative project with the Wisconsin Department of Natural Resources to study the transport and fate of volatile organic compounds during landfill-gas migration at a site rear Madison. Unfortunately, the project was terminated when access to the landfill was denied because of possible litigation.

The District began one small project with USFWS in 1993 to provide oversight to remedial investigations and activities at the Crab Orchard National Wildlife Refuge near Marion. Some assistance was provided the USAF in 1994 in reviewing technical documents from Air Mobility Command sites throughout the country. Avery led the work on the USFWS and USAF projects.

Land-Use Information. Most hydrologic investigations during the period used land-use information or mapping procedures to some degree; however; some projects were designed to improve upon available data bases or develop new procedures for using available information. In 1987, the District began a project, led by Sherrill, to compile a data base suitable for evaluating the potential for ground-water contamination of the Great Lakes within the United States part of the Great Lakes Basin. USGS (Fed) and the Department of State, International Joint Commission (OFA), provided funding for the project. Warner succeeded Sherrill in 1988 and joined Earle and Sherrill in compiling a comprehensive bibliography and data base amenable to use with a GIS. Sherrill and Lindsay Swain (Northeastern Region staff) provided information for a report to the Great Lakes Advisory Board proposing a study of contamination potential to the Great Lakes through ground water.

In 1991, led by King, the District began a cooperative study to examine new methods of updating wetland areas and other land-cover features in a six-county Chicago metropolitan area. The approach was to merge Side-Looking Airborne Radar (SLAR) imagery and satellite-based Thematic Mapper (TM) imagery, classify the merged imagery, make the proper conversions, and load to a GIS. At the end of 1994, land-use classification coverage was delivered to all project cooperators, and a journal article was being completed.

Also in 1994, King began a study to use the interrelated technologies of digital raster-based processing, remote sensing/image processing, and GIS in applications to rainfall/runoff models. The effort included creating a high-resolution Digital Elevation Model (DEM) and using the DEM to delineate digital hypsography of small watersheds at a contour interval of 2 feet, and to create a digital land-cover map based on hydrologic mapping units.

INDIANA

By Dennis K. Stewart, including information provided by Charles G. Crawford, Jeffrey D. Martin, Scott E. Morlock, Donald V. Arvin, Bret A. Robinson, Leslie D. Arihood, and Lucy M. Arvin, Indiana District Staff.

INTRODUCTION

In 1979, the Indiana District was located at 1819 North Meridian Street near the center of Indianapolis. The location was not convenient for a large field operation that included a CME 75 auger drill rig, a large fleet of field vehicles, boats, and field equipment. Since there was no secure parking at the office location, field equipment and vehicles were stored at a warehouse in another part of the city. In 1981, the General Services Administration (GSA) finally completed arrangements to move the District Office to 6023 North Guion Road in northwest Indianapolis, a location and facility better suited to District operations. In 1987, GSA required the District to move to 5957 Lakeside Boulevard in northwest Indianapolis along the I–465 beltway. The new space had a similar design to the previous Guion Road location. The quicker access to the I–465 beltway was an improvement for the District's field operations. The office remained at 5957 Lakeside Boulevard location through the end of 1994.

The position of the Area Hydrologist for the Northeastern Region was established at the Indiana District Office in 1991 to coordinate regional studies that included Federal programs in the States of Indiana, Ohio, and Kentucky. Cathy Hill was selected as the Assistant Regional Hydrologist in 1991 and continued until 1993 when she transferred to WRD Headquarters in Reston, Va. The position was abolished in 1993.

Major flooding on Indiana streams occurred in July 1979, February to March 1982, February 1985, May to June 1990, and November 1990 to January 1991. Indiana received Presidential flood disaster declarations in 1979, 1982, 1990, and 1991.

During the 1979–94 period, the District experienced considerable variability in its program funding. The District's program was $3.24 million in 1981, $1.48 million in 1985, $2.56 million in 1986 and increased to $5.35 million by 1994. The most significant reduction in the program between 1981 and 1985 resulted from the reductions in Federal program funds for studies in the coal-mining areas of southwest Indiana, the sharp reduction in funding from the National Park Service following a Northern Indiana Public Service Company (NIPSCO) decision to terminate their plans to build a highly controversial nuclear powerplant adjacent to the Indiana Dunes National Lakeshore, and the reduction in State/Federal cooperative (Coop) funding. New program thrusts in 1991 included a 7-year project in cooperation with the Indiana Department of Highways to study streambed scour at 5,600 bridge sites and the National Water-Quality Accounting Network (NASQAN) study of the White River.

Numbers of personnel varied from 79 in 1979, to 41 in 1987, to 42 in 1990, to 61 at the close of 1994. The District suffered the deaths of William (Al) Skinner in 1989 and David Jacques in 1991.

ORGANIZATION AND PERSONNEL

Office of the District Chief

Dennis Stewart served as District Chief from 1979 to 1991 when he retired. In 1991, Jo Ann Macy was selected as Indiana District Chief, transferring from her previous position as Chief of the De Kalb, Ill., Subdistrict Office. In 1994 Macy accepted an

assignment with the WRD Headquarters and was succeeded in December 1994 by Lindsay Swain, who was previously the Chief of the Appalachian-Piedmont Regional Aquifer-System Analysis (RASA) project. Secretaries to the District Chief included Emma-Lee Beagle (1979–87), and Sonja Sanders (1993–94).

Administrative Services Section

The position of Administrative Officer was filled by Barbara Gallager (1979–80), Sandra Beck (1981), Sharon Kuhnlein (1981–86), and Lucy Arvin (1987–94). Other personnel serving in the Section during this period were Phyllis Bonds, Tonja Clark, Jill Fortner, Irma M. Jeffers, Phyllis Lynch, Deborah Majors, Lauren McKinney, Elizabeth Petty, Candace Remsen, Sonja Sanders, Laura Stokes, Kathy Taskey, and Jamise Zachery.

Hydrologic Surveillance/Data Section

In 1979, the work of this Section included the operation of a large network of surface-water stations and surface-water investigations including flood-insurance studies and the operation of a network of crest-gage partial-record stations on small drainage basins of less than 20 square miles. The data from the partial-record stations was used, along with the data from the existing stream-gaging network, to develop techniques for estimating the magnitudes and frequencies of floods on Indiana streams. The Hydrologic Surveillance Section was renamed the Hydrologic Data Section in 1989, and its principal responsibility was the collection and analysis of water data from the network of surface-water stations, ground-water observation wells, and water-quality and suspended-sediment stations.

The Section Chiefs during the 1979–94 period included William Harkness (1979–84), Dale Glatfelter (1985–89), Ronald Thompson (1989–90), and James Stewart (1989–94). Other permanent personnel who served in the Section during the period are listed in alphabetical order: Joanne Alexander, Donald Arvin, Murray Beasley, Don Beck, Brian Benedict, Kristie Brown, Gerard Butch, Richard Craig, H. Russ Christensen, James Crompton, Jerry Davis, Clyde Deiwert, Tom Eaton, James Fishback, Robert Gold, William Hadley, Lowell (Gene) Hammil, John Hinesley, Paul Hayes, Daniel Hess, Richard Hoggatt, Robert Horner, Jackie Ibsen, Todd Kelly, Charles (Randy) Keeton, Peter Laird, Deborah Majors, Scott Morlock, Graham Nell, Hieu Nguyen, Robert Ondrish, Don Rapp, Josef Schuler, Al Skinner, and Cathrine Woodfield.

Studies Sections

In 1979, the interpretive studies of the District were divided into the Hydrologic Studies Section (ground water) and the Environmental Quality Studies Section (water quality). In 1982, the two Studies Sections were combined into the Hydrologic Studies Section because of a reduction in programs and personnel. In 1989, projects previously housed in the Hydrologic Surveillance Section were transferred to the Hydrologic Studies Section. In 1992, owing to an increase in programs and staff, the Hydrologic Studies Section was split into the Geohydrologic Studies Section and Hydrologic and Environmental Quality Studies Section. Section Chiefs that headed up the Studies Sections are listed chronologically: Steve Ragone (1979–80), Larry Nutter (1979–81), Bill Wilber (1981–82), Konrad Banaszak (1982–88), Charles Crawford (1989–90), David Voelker (1990–94), and Paul Buszka (1993–94).

Other permanent personnel who served in the Sections during the 1979–94 period are listed in alphabetical order: Les Arihood, Don Arvin, Mark Ayers, Zelda Bailey, Randy Bayless, Keith Bobay, Linda Bobo, David Cohen, Paul Doss, Rich Duwelius, Steve Eikenberry, Joe Fenelon, Kathy Fowler, Dan Gillies, Kim Greeman, Mark Hardy, Glen Hodgkins, Mark Hopkins, Mary Hoover, Tom Imbrigiotta, David Jacques, Wayne Lapham, Helen Lindgren, Angel Martin, Donna Marron, Jeffrey Martin, Robert Miller, Victor Mullen, James Peters, Robert Pettijohn, Mike Planert, Danny Renn, Jerry Reussow, Bret Robinson, Robert Shedlock, Cheryl Silcox, Doug Schnoebelen, Barry Smith, Larry Smith, Robert Southwood, Ronald Thompson, John Tyler, David Wangsness, William Warner, Lee Watson, Tim Willoughby, and John Wilson.

National Water-Quality Assessment Program Section

This Section was formed in 1991 to support the White River Basin study as part of the National Water-Quality Assessment (NAWQA) Program. The White River Basin study was one of 20 study units selected for the full implementation of the NAWQA Program

beginning in fiscal year 1991. Charles Crawford was selected as Section Chief and continued in the position through 1994. Other personnel who served in the Section were Nancy Baker, Donna Carter, Barton Faulkner, Joseph Fenelon, Jeffrey Frey, John Goebel, David Jacques, C.G. Laird, Michael Lydy, Jeffrey Martin, Rhett Moore, Patrick Pease, Jeffrey Pigati, and Douglas Schnoebelen.

Publications Unit

In 1979, this Unit edited reports, drafted maps, prepared illustrations, and typed reports. Billy Robinson headed up the Unit from 1979 until 1985 when he retired. From 1995 to 1996, James Peters provided the leadership of the Publications Unit until his transfer in 1986 to Northeastern Region Office in Reston. From 1986 to 1992, the Section Chiefs and their staffs provided editorial review. Patricia Long provided editorial review of reports from 1992 to 1994. Cartographic and illustration support was provided by Mildred La Lond (1979–88), Rudolph (Phil) Contreras (1979–85), Dennis Austin (1981–85), and Mark Huff (1990–94). Reports during 1979 to 1982 were typed by Mary Wilson, Pat Galindo, and Sue Davis.

Computer Unit

Richard Bow served as the District Computer Specialist from 1980 To 1992. Tim McElhone succeeded Bow in 1993. Others who served in this Unit were Candy Canler, Wanda Crews, Scott Daugherty, Tony Denham, Magello Gonzales, and Phyllis Robinson.

GIS Applications Support Unit

This Unit was established in 1992, and Nancy Baker was selected to assist the District technical staff in utilizing GIS applications, primarily in the new White River NAWQA project.

FUNDING AND COOPERATION

Total funding was provided from the Federal/State Cooperative Program, other Federal agencies (OFA), and the Federal Program.

Cooperative Program

The Indiana Department of Natural Resources (IDNR) provided most of the State share of the funding for operation of the network of streamflow stations, suspended-sediment stations, and ground-water observation wells during the 1979–94 period. The IDNR also provided the 50-percent matching funds for a large number of ground-water studies and also shared equally (25 percent) with municipalities to appraise the quantity and quality of the ground-water resources in areas where ground-water development for water supply and irrigation either was increasing or anticipated. Due to reductions in the State budget, IDNR funding from 1984 to 1994 was limited to supporting the hydrologic data network. Cooperative funding was also received from the cities of Indianapolis, Elkhart, Logansport, Carmel, Vincennes, and Fort Wayne and from Kankakee County.

The Indiana Highway Commission, later renamed the Indiana Department of Transportation (INDOT), provided the State matching funds for the 11-year small stream project beginning in 1972 and ending in 1983. The INDOT also entered into a new 7-year cooperative project that began in 1991 to study scour at bridge piers in Indiana. For the 1991–94

Indiana District funds for fiscal years 1979–94

[Funds in thousands of dollars]

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Federal	452	948	960	628	348	203	84	43	113	119	147	160	393	1,067	1,436	1,804
OFA	494	387	603	332	181	196	257	453	262	292	242	324	281	512	822	696
Coop-State	958	847	893	937	664	700	561	1040	1,152	1,154	1,110	1,295	2,077	1,805	2,019	1,897
Federal matching	954	833	785	952	689	514	582	1022	1,109	1,154	1,110	1,068	1,078	996	962	953
TOTAL	2,858	3,015	3,240	2,848	1,882	1,614	1,484	2,558	2,636	2,719	2,609	2,848	3,829	4,380	5,239	5,350

period, INDOT's share was approximately $1.6 million with $0.4 million matched by the USGS.

The Indiana State Board of Health, later renamed the Indiana Department of Environmental Management (IDEM), provided the State share of a number of studies and also supported the installation of Acoustic Velocity Meters in the Gary/East Chicago area where conventional stream gaging is not possible. The City of Indianapolis provided matching funds for a number of water-quality and biological investigations of the White River and its tributaries in and near Indianapolis. In addition, the City of Indianapolis also provided matching funds for several landfill studies in Indianapolis.

Other Federal Agencies

The U.S. Army Corps of Engineers (the Corps) primarily funded the establishment of the large network of Data Collection Platforms (DCP) at stream-gaging stations. The National Park Service provided the funding for a series of investigations and data-collection stations at the Indiana Dunes National Lakeshore aimed at determining the effect of NIPSCO's proposed construction of a nuclear power-plant adjacent to the National Lakeshore. The Department of Housing and Urban Development (HUD) provided funding from 1971 to 1980 for preparing flood-prone area maps for selected streams. The Indiana Department of Environmental Management provided funding for water-quality investigations of the Calumet Region in northwestern Indiana and along the south boundary of Lake Michigan.

Federal Program

Federal funding included two RASA projects: the Cambrian-Ordovician aquifer in northeastern Indiana (1978 to 1982) and the Carbonate Bedrock aquifer in northeastern Indiana (1991–94); the White River Basin NAWQA study (1991–94); and (3) hydrologic data stations for the Hydrologic Bench Mark Network (HBN) and the National Stream-Quality Accounting Network (NASQAN) 1979–94.

HYDROLOGIC DATA PROGRAM

The Indiana District has operated a network of continuous-record stations since 1901. In 1979, the District Office operated 186 continuous-record discharge stations, 9 continuous-record stage stations, 98 partial-record crest-stage gages (CSG), and 13 stations for reservoir or lake stage and content as shown in the table of hydrologic data-collection sites. The number of discharge stations peaked at 195 stations in 1981 and decreased to 167 by the close of 1994. The CSG program declined sharply in 1983 following completion of the 10-year data-collection period that provided peak stage and discharge on small drainages (less than 20 square miles) for the Coop program with the Indiana State Highway Commission. Selected CSG stations at 21–25 sites were operated through 1989 and then discontinued. A program of continuous-record stage stations for 78 public freshwater lakes and reservoirs in northern Indiana began in the 1970's and continued at similar numbers through the period.

The District was progressive in researching and using new technologies in the stream-gaging program during the 1979 to 1994 period. The District started equipping stations with GOES satellite transmitters for data telemetry in 1981, when satellite transmitters were installed at two stations. The number of stations with satellite and telephone telemetry increased every year, and by 1994 more than 100 stations were so equipped. In 1989 the District began replacing mercury manometers with pressure transducers at gages equipped with gas-purge stage-recording stations. Indiana was the first District to completely replace all manometers with pressure transducers.

A summary of the hydrologic data stations operated by the Indiana District from 1979 to 1994 is listed in the table on page 137.

In 1991, the first acoustic velocity meter (AVM) in Indiana was installed at a new discharge station on the Indiana Harbor Canal in East Chicago. By the close of 1994, AVM's were installed at two new stations: Trail Creek at Michigan City Harbor and Burns Ditch at Porter. The existing station on the Grand Calumet River at Gary was retrofitted with an AVM.

The Indiana District began using acoustic Doppler current profilers (ADCP's) to calibrate the Indiana Harbor Canal AVM in 1991. The District borrowed a narrowband ADCP from the USGS California District for the initial AVM calibration. Seeing the potential of ADCP's for making routine discharge measurements on large rivers and during floods, the District purchased a new, state-of-the-art broadband

Hydrologic data-collection sites, 1979–94

Hydrologic stations	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Surface Water																
Discharge	186	185	195	176	174	185	185	189	187	176	176	181	183	175	178	167
Stage only	13	11	13	9	9	3		1	1	4	6	7	7	7	5	6
CSG - Partial record	98	97	95	71	21	24	25	24	23	23	23					
Reservoir stage	13	12	12	9	9	1	1	1	1	1	1	1	1	1	1	1
Lake stage	80	80	80	80	80	80	80	79	79	79	80	80	80	80	80	80
Quality water	65	51	51	26	5	5	5	5	3	3	3	3	3	3	3	2
Suspended sediment																
Daily	6	6	2													
Periodic	57	43	38	21	4	5	5	5	4	3	3	3	1	1	1	1
Ground water																
Water levels	79	79	84	87	84	83	84	94	87	88	91	95	95	94	94	94

ADCP in 1993. The ADCP was quickly integrated into the Indiana Data Program and tripled the number of large-river discharge measurements that could be made in the same timeframe using conventional current-meter measurements from boats and was particularly important during major floods. In 1994, Morlock evaluated ADCP's at 12 selected gaging stations across the United States (WRIR 95–4218) and concluded that ADCP's were a viable method of making discharge measurements at many sites.

Water-Quality Stations

A network of continuous-record water-quality stations had been in place since July 1965 to provide a national bank of water-quality data for broad Federal, State, and local planning and action programs and to provide data for Federal, State, and local management of interstate waters. Major support for the network was from IDNR, the Corps, Ohio River Valley Water Sanitation Commission, and the USGS NASQAN and HBN programs. There were 65 stations in the network in 1979, 51 in 1980 and 1981, 26 in 1982, and 5 or less thereafter (hydrologic data-collection sites table). Measurements of temperature and specific conductance were discontinued starting in 1981 and by September 30, 1982, were not collected at any stations. The remaining water-quality sites from 1983 were NASQAN or HBN stations except for temperature measurements that began in 1984 at one gaging station.

Sediment Stations

The Indiana District maintained a network of sediment stations to provide a bank of sediment data for use in broad Federal and State planning and action programs and to provide data for State and Federal management of intra- and interstate waters. Major support for the program was from IDNR and the Corps. The number of sediment stations was 63 in 1979, 49 in 1980, 40 in 1981, 21 in 1982, and 5 or less thereafter (see hydrologic data-collection sites table). The statewide sediment-station network program with the IDNR was discontinued in January 1982 to allow for the analysis of the collected data. The remaining sediment stations operated through 1990 were for the NASQAN or HBN programs. From 1991 to 1994, suspended-sediment data were collected at the Trail Creek at Michigan City stream-gaging station for the Corps.

Ground-Water Stations

The Indiana District has operated a network of continuous-recording ground-water-level stations since July 1943 to provide a long-term data base on water-level changes due to climate and development. During the 1979–94 period, the number of stations in the network varied from 79 to 95. The largest support for the ground-water network was provided by the IDNR through the Coop program. Many water wells were installed for ground-water investigations, primarily with the District's CME auger drill rig. At the conclusion of the investigations, water-level observa-

tions were continued at selected wells in cooperation with municipalities and(or) the IDNR. Many wells were plugged, removed, or transferred to the municipality for their monitoring activities.

HYDROLOGIC EVENTS

Floods

From May 12 to 17, 1990, a series of thunderstorms produced heavy rainfall across southern Indiana. Up to 10 inches of rain fell from May 15 to 17 in a 5- to 10-mile-wide band that extended from Hazleton in the southwest to Rising Sun in the southeast. These rains caused rapid rises in streams throughout the region. The Lost River near West Baden Springs had the highest stage and discharge recorded since March 1964. Substantial flooding occurred along the White River, and the White River at Petersburg reached the highest stage and discharge since February 1968. Flood damage exceeded $80 million in south-central and southwestern Indiana. The cities of Orleans, French Lick, West Baden Springs, and Prospect were flooded, and the public water supply for Petersburg was rendered unusable when floodwaters severed water-supply lines.

Major flooding also occurred throughout the entire State during late December 1990 and early January 1991. Above-normal rainfall in December in combination with runoff from snowmelt caused rivers to begin rising on December 28. Most small streams peaked on December 29, and larger streams peaked between December 30 and January 2. Floods on the lower Wabash River did not peak until January 7, 1991. Many rivers peaked at the highest stages since 1913. Two people were killed and 33 injured as a result of the flooding, and approximately 4,000 people were evacuated from their homes. More than 1,700 structures were damaged; there was major damage to 565 homes, and 16 mobile homes were completely destroyed. There were major levee breaks and damage to roads, bridges, and municipal water- and wastewater-treatment facilities. Seventy-two of 92 Indiana counties had substantial flood damage estimated at about $100 million.

Droughts

A precipitation deficit and higher than normal temperatures caused a major drought that affected all of Indiana in 1988. By the end of September 1988, statewide precipitation deficits approached 8 inches below normal. Record low water levels were recorded in many monitoring wells. Major reservoirs reached their lowest levels since filling. Low streamflows and high temperatures caused some powerplants to temporarily cease operations because there was inadequate cooling water available. A 90-day ground-water emergency was declared in northwestern Indiana. The drought damaged most major crops in Indiana, with average yields in 1988 as low as 50 percent of 1987 yields. Fowler described the effects of the 1988 drought on ground-water levels, streamflow, and reservoir levels in Indiana

INTERPRETIVE STUDIES

Surface-Water Studies

Flood-insurance studies completed during the 1979–81 period included streams in the Carmel, Greenfield, Greenwood, Ingalls, Jasper, Pendleton, Terre Haute, and Westfield areas. Reports were prepared by Dale Blevins, Bob Miller, and Stephen Wolcott for HUD.

In 1984, Dale Glatfelter completed the analysis of the peak stage and discharge data collected from the 10-year data-collection program on small streams. Glatfelter used the small-stream peak-discharge and stage data along with similar data from the statewide network of stream-gaging stations to prepare the WRIR 84–4134, "Techniques for Estimating Magnitude and Frequency of Floods on Streams in Indiana."

James Stewart, Robert Miller, and Gerard Butch formally analyzed the cost effectiveness of the stream-gaging program in Indiana (OFR 85–4343). The analysis included (1) collecting information concerning data needs and funding sources for each of the 174 discharge stations in the network at the time of the analysis (1983); (2) evaluating alternate methods to produce discharge records (statistical models or flow-routing models), and (3) determining the uncertainty of the rating at individual stations and the optimal travel routes and frequency of visits to stations. Glatfelter and Butch evaluated the Indiana stream-gaging network as it existed in 1989 on the basis of meeting flood-data needs of various government agencies (WRIR 91–4051).

In 1990, Donald Arvin prepared OFR 90–125, "Willie Takes a Field Trip," a coloring book for chil-

dren that featured stream gaging and other USGS activities and was one of the most widely distributed reports in the WRD.

Water-Quality Studies

The Indiana District undertook a wide variety of water-quality studies in the late 1970's through early 1990's. Much of the work focused on the water resources of the Indiana Dunes National Lakeshore, the Grand Calumet River, and the Calumet aquifer in the northwestern part of Indiana. Other work focused on the water resources of the Indianapolis area in central Indiana. Water-quality assessments also were done at several areas throughout the State, and ground-water-quality data collected by various Federal and State agencies in Indiana were compiled and interpreted.

Studies for the National Park Service at the Lakeshore began in the mid-1970's with an assessment of the effects of construction dewatering on water levels and continued with several water-quality studies. Hardy studied seepage from coal fly-ash settling ponds and reported increased concentrations of several trace elements in surface and ground water downgradient from the ponds. An additional study of several streams in the Lakeshore by Hardy identified land and water uses that adversely affected water quality. Cohen and Shedlock noted that sealing the seepage ponds in 1980–81 caused water levels to decline near the ponds, but concentrations of boron, molybdenum, and arsenic in ground water near the ponds remained above background levels. Shedlock, Cohen, Imbrigiotta, and Thompson described water-quality patterns in wetlands and adjacent aquifers, between aquifers, and in various parts of the ground-water flow system.

Cooperative studies with the Indiana Department of Environmental Management, the Indiana State Board of Health, and the U.S. Environmental Protection Agency also assessed water quality in northwest Indiana. A 24-hour water-quality survey was done on the Grand Calumet River in October 1984 to identify nonpermitted sources of effluents. Crawford and Wangsness reported that water quality was much better in the East Branch than in the West Branch and identified four areas where the summed chemical load of effluent differed significantly from the measured instream chemical load. Fenelon and Watson studied water quality in the Calumet aquifer near the Grand Calumet River from 35 wells in five land-use types and concluded that the highest median concentrations of chemicals were from wells in the steel and petrochemical land-use types. Ground water may contribute more than 10 percent of the ammonia, chromium, and cyanide load of the Grand Calumet River. Duwelius, Kay, and Prinos collected samples of ground water from 128 wells near the Calumet Region in June 1993 and reported that the largest concentrations of trace elements and synthetic organic compounds were in wells located in or near areas of industry or waste disposal. Willoughby collected weekly samples of precipitation and estimated an annual loading of major ions and trace elements from precipitation to the Grand Calumet watershed near Gary for the 1-year period beginning June 30, 1992.

The Indianapolis Department of Public Works was the cooperator for several water-quality studies in Indianapolis. Wangsness reported analytical data for four surveys of metals, pesticides, and synthetic organic compounds in water and streambed sediments in streams upstream from Eagle Creek Reservoir. Indianapolis enlarged and upgraded two wastewater-treatment plants in 1983. Studies by Crawford and Wangsness and Crawford, Wangsness, and Martin showed significant improvements in water quality and biological communities in the White River in response to improvements in wastewater treatment. Martin and Craig operated dissolved-oxygen monitors in the White River and Fall Creek in 1986 and 1987 and reported that periods of low oxygen (<4.0 mg/L) typically did not occur during base flow but often occurred during storm runoff. Martin studied water quality upstream and downstream from combined sewer overflows on Fall Creek during the summer of 1987 and reported that water quality downstream from combined sewers was degraded by combined sewers and discharge of filter backwash from water-treatment plants. Bobay reported that leachate from municipal sewage-sludge lagoons had infiltrated to ground water, but the stability of the sludge, neutral pH, and reducing conditions resulted in very low concentrations of metals. Duwelius and Greeman concluded that leachate from two closed landfills had reached shallow ground water but minimally affected deep ground water and that bromide, dissolved solids, and ammonia were useful in delineating the leachate plume at both landfills.

The Indiana Department of Natural Resources and local municipalities were cooperators for several

water-resource assessments in Indiana. Shedlock modeled a plume of saline water at the base of the outwash aquifer near the Vincennes well field. Imbrigiotta and Martin characterized a plume of leachate from a landfill in the outwash aquifer near Elkhart. Wells near the landfill were monitored annually from 1980 to 1989 for bromide and field measurements and Duwelius and Silcox concluded that the leachate plume, as indicated by bromide, had moved to deep parts of the aquifer. Bailey and Imbrigiotta described the water quality of the outwash aquifer near Martinsville; Smith, Hardy, and Crompton described the surface- and ground-water quality of Wildcat Creek Basin near Kokomo; and Fenelon, Bayless, and Watson described the water quality of the St. Joseph, Hilltop, and Nappanee aquifers near South Bend.

The Indiana State Board of Health was the cooperator for a study of the reaeration rate of the Wabash River, and the Indiana Department of Environmental Management was the cooperator for two efforts to compile available ground-water-quality data for Indiana. Crawford measured the reaeration rate of the Wabash River near Lafayette and Terre Haute and concluded that none of 10 commonly used equations predicted rates similar to those measured. Risch compiled analytical data for pesticides in ground water for 521 sites in 81 of 92 Indiana counties and reported that the most frequently detected pesticides were the most commonly used herbicides. Risch and Cohen compiled analytical data for nitrate for 4,448 wells in 88 Indiana counties and reported that 13 percent of the samples exceeded 3 mg/L and 3.4 percent of the samples exceeded 10 mg/L.

Sediment Studies

Crawford and Mansue analyzed data from 7 daily-record and 70 partial-record sediment studies. Data for this investigation were collected between 1952 and 1984. They used the rating-curve method to estimate sediment loads and yields at the partial-record sites. They included in their analysis a statistically based estimate of the uncertainty in the computed sediment loads—the first time this had been done in the USGS. Annual suspended-sediment yields were found to range from 11 to 2,310 tons per square mile. Results of this study were published first as an Open-File Report and subsequently as Water-Supply Paper 2404.

Crawford and Jacques studied suspended-sediment transport in Trail Creek at Michigan City. They estimated the 1981–90 annual average suspended-sediment load to be 6,180 tons with an average yield of 114 tons per square mile. This compared to a median yield of 54 tons per square mile for 14 other streams in northern Indiana studied by Crawford and Mansue. Results of this study were published as a Water-Resources Investigations Report.

Arihood evaluated the performance of the Hydrologic Simulation Program-Fortran (HSPF) for simulating sediment transport in a 2.7-square-mile watershed in southwest Indiana. He found the accuracy of the model to be limited both by the quality of the input data and by the algorithms used in the model to simulate physical processes. He found that simulated sediment concentrations generally had smaller peaks and longer recessions than were seen in the measured data. Results of this study were published as a Water-Resources Investigations Report.

Renn and Arihood investigated sedimentation in Long, Whitewater, and Versailles Lakes—three manmade lakes in Eastern Indiana. They reported that sedimentation had little effect on the storage capacity or surface area of Long and Whitewater Lakes but that there had been significant sedimentation in Versailles Lake. Approximately 36 percent of the storage capacity of Versailles Lake had been lost due to sedimentation between 1956 and 1988 while less than 5 percent had been lost in the other two lakes. Results of this investigation were published in three Water-Resources Investigations Reports.

Fowler and Wilson intensively studied sediment characteristics and transport in Juday Creek in Northern Indiana during 1993–94. Juday Creek has been determined to be one of the few streams in Indiana capable of supporting a reproducing population of brown trout. Studies by researchers at Notre Dame University had shown a decline in benthic invertebrate populations (food supply for the trout), possibly due to increased levels of sedimentation. They found the streambed to consist mostly of sand or larger size particles. Bedload discharge was determined to be the primary mode of sediment transport. Sediment yield during the study was estimated to be 48 tons per square mile. Results of this study were published as a Water-Resources Investigations Report.

Ground-Water Studies

Beginning in 1978, the Indiana District (Shedlock) participated in the RASA study of the Cambrian-Ordovician aquifer that included a small area in the northeastern corner of Indiana. In 1991, the USGS began the new Midwestern Basins and Arches RASA study that encompassed the Devonian and Silurian carbonate aquifers in eastern Indiana and western Ohio. The objective of the RASA was to determine the lateral and vertical hydrologic boundaries, horizontal and vertical distribution of the hydraulic characteristics, and major and minor flow paths in the aquifer. In Indiana, three 6-inch-diameter wells were drilled through the carbonate aquifer near the Kankakee River. The direction of flow and the distribution of transmissivity in the carbonate aquifer were determined by using packer tests and geophysical logs. The results of the study were published in the April 1994 Water Resources Bulletin of the American Water Resources Association (Arihood).

In the 1979–94 period, the Indiana District continued its cooperation with the IDNR to study the ground-water resources of Indiana. Perhaps the most important of these studies involved the interbedded sand and gravel aquifers, the carbonate bedrock aquifer, and the glacial outwash aquifers along the upper White River Basin in Randolph, Delaware, Madison, Tipton, Hamilton, Marion, Johnson, and Morgan Counties. A considerable number of test wells were installed with the District's CME 75 auger drill rig to provide water-level data and mapping of the aquifer in each of the counties. Two- and three-dimensional digital models were constructed and calibrated to measured water levels and streamflow gains/losses to test the conceptual models and to study the potential of the aquifer in terms of yield, drawdown, and streamflow depletion. In Johnson and Morgan Counties, Bailey and Imbrigiotta determined that the outwash aquifer ranged from 0 to 120 feet in saturated thickness over an 88-square-mile segment of the aquifer. Three pumping plans were simulated to determine the reduction in saturated thickness and the reduction of ground-water flow to the White River. The Marion County study by Barry Smith calculated that 97 cubic feet per second could be pumped from seventy-eight 12-inch-diameter, fully penetrating pumping wells in the glacial outwash based on a drawdown limit of 50-percent saturated thickness. Arihood's study of the glacial outwash aquifer in Hamilton and Tipton Counties was based on 1,900 well logs and 125 water-level observations, and determined that 39 million gallons per day could be obtained from the outwash aquifer with a 50-percent reduction in saturated thickness. In the Delaware County study, Arihood and Lapham indicated that the water-level fluctuations are seasonal and have no long-term trends. Based on a water budget when the flow duration in the White River at Muncie was 80 percent, ground-water seepage to streams was 81 cubic feet per second. Recharge to the aquifer was estimated to be 102 cubic feet per second with 80 percent from effective areal recharge of precipitation and 20 percent from ground-water flow across the area boundaries. The ground-water resources study in Randolph County by Lapham and Arihood developed a 5-layer digital model to estimate the potential yield of the aquifer. On the basis of the available withdrawal data, it was estimated that as much as 2.5 million gallons per day can be pumped at some locations with a 50-percent reduction in saturated thickness with about a 10-percent reduction in flow to streams. The Madison County study by Lapham indicated glacial drift covers the entire study area and has four confined sand-and-gravel aquifers interbedded in the drift, a bedrock aquifer, and an unconfined outwash aquifer. The thin and narrow outwash aquifer is an important aquifer because of its proximity to sources of induced recharge. The water budget as simulated by the 5-layer digital model indicates the rate of inflow to the ground-water system in the modeled area is 92.4 cubic feet per second with 78 percent from areal recharge of precipitation and 22 percent from ground-water flow across the boundaries of the study area.

Other projects in cooperation with the IDNR included studies to evaluate the effects of irrigation on the ground- and surface-water resources in Newton and Jasper Counties and in the St. Joseph River Basin in northern Indiana. These studies were prompted by the large increase in the acreage of irrigated agricultural land. In the Newton and Jasper County studies, Marcel Bergeron determined that most of the irrigation was from the bedrock aquifer with a maximum estimated withdrawal during the study period (1976–79) of 34.8 million gallons per day. Various pumping scenarios were used to determine the effect of irrigation pumpage on ground-water levels and streamflow. Because flow in the Kankakee River is usually high during the irrigation season, flow is not significantly reduced in simulating pumping of 10.3 million gallons

per day. The study by Peters and Renn of irrigation in the St. Joseph River Basin using a digital model simulated that for a 16.5-square-mile area of intensive irrigation, the maximum pumping withdrawals from the aquifer resulted in drawdowns of 25 percent of the saturated thickness and ground-water flow to nearby streams was reduced by 40 percent.

The IDNR and the City of Logansport cooperated equally with the USGS in the study of the glacial deposits near Logansport using a 4-layer digital flow model. In WRIR 81–7 Gillies evaluated the ground-water development potential of the glacial deposits underlying a 260-square-mile area near Logansport.

The U.S. Army Corps of Engineers provided funding for a dye-tracing study of the unique Lost River located in the Karst Region with the results published in WRIR 94–4195 "Directions of the ground-water flow and locations of ground-water divides in the Lost River watershed near Orleans" (Bayless, Taylor, and Hopkins).

Water-Use Project

The Water-Use Project, an ongoing program in the Indiana District, experienced large forward strides during the 1979–94 period. These advancements were the product of several events. One of those events was the granting of increased authority to the Indiana Department of Natural Resources (IDNR) in 1985 by the General Assembly. This new authority enabled the IDNR to initiate a registration and data-collection program in which facilities report their monthly water withdrawals on an annual basis. The IDNR maintains those data in a site-specific data base. In addition to utilizing those data for their own water-management needs, the IDNR chose to make the data readily available to other agencies involved in scientific investigations, including the USGS. About this same time the Indiana Department of Environmental Management made available their site-specific wastewater return data. Just as this extensive withdrawal and return data became available to the Indiana District, a powerful aggregate water-use data base was developed for implementation at the District level by the USGS National Water-Use Information Program.

Beyond the District's traditional participation in the 5-year national compilations of data for the "Estimated Use of Water in the United States," the availability of high-quality water-use data, a flexible aggregate water-use data base, and close communication between the IDNR and the Indiana District resulted a series of successful cooperative investigations within the Water-Use Program. The results of these cooperative investigations were documented in a number of reports, some published by the IDNR and some published by the USGS. In addition, the improved availability of water-use data contributed beneficially to water investigations carried out in the St. Joseph River Basin, Newton and Jasper Counties, and several other local and regional areas.

Some of the cooperative studies between the IDNR and the Indiana District focused on analyses of the withdrawal data reported to the IDNR by significant water-withdrawal facilities. Results of one such study indicated that, over time, public water-supply facilities in the State have increased their reliance on ground-water withdrawals.

Other studies involved the collection and analysis of field data. For example, one study was a cooperative effort between the IDNR, the Indiana District, and the USGS Hydrologic Instrumentation Facility located at the Stennis Space Center near Bay Saint Louis, La. As part of that study, noninvasive pipe-flow measurements were made using transit-time, time-of-flight, and reflective-Doppler technologies. The results of that study compared the success of the various instruments in measuring pipe flow, while providing facility operators the ability to report their withdrawals with increased accuracy.

Coal Area Hydrology

Growing awareness of the environmental impacts of surface coal mining in the 1970's led to several projects in the District. Eikenberry and Bobo studied hydrologic and water-quality changes in reclaimed cast overburden in a large mine in west-central Indiana. This study, which was funded by the U.S. Environmental Protection Agency and the Indiana Department of Natural Resources, collected hydrologic and water-quality data from 41 wells and 24 stream sites. Linda Bobo catalogued approximately 1,000 coal-mine lakes in nonactive mine areas. The resulting gazetteer, which was published as a Water-Resources Investigations Report, provided information about the shape, area, and location of the lakes. Specific conductance and pH measurements were provided for 287 of the lakes.

Passage of Public Law 95–87, the Surface Mining Control and Reclamation Act of 1977

(SMCRA), greatly expanded coal-area hydrology programs in the District. Among other things, this Act required an appropriate Federal or State agency to provide hydrologic information necessary to assess probable hydrologic consequences of proposed mining. Wangsness coordinated preparation of three coal-area hydrology reports published as Water Resources Investigations Reports that summarized historical information in partial fulfillment of this requirement for Indiana. These were among 57 national coal-area hydrology reports prepared by the USGS. Martin and Crawford summarized historical streamflow and water-quality data at 21 Indiana State Board of Health and 16 USGS monitoring stations. This study was published as a Water-Supply Paper.

In addition to the analysis of historical data, funds provided by the SMCRA supported collection of substantial amounts of new data published in several Open-File and Water-Resources Investigations Reports. These data were intended to supplement the relatively limited amount of historical data in the coal-mining area of Indiana. The spatial distribution of historical data in the area at the time in particular was limited. Renn, Ragone, and Wilber reported on a reconnaissance sampling of 293 sites (field measurements only) and synoptic sampling of 84 sites (field parameters and water chemistry) in 1979. Renn reported water-chemistry data collected at 85 sites in 1979 and 1980. Wilber and Boje reported on a reconnaissance study of streambed chemistry collected from 69 sites in 1979 and 1980. Wangsness reported water-chemistry and stream-biota data collected from 84 and 16 sites, respectively.

The SMCRA required that permit applications for mining contain a description of the hydrologic characteristics of the mining site and adjacent area and an assessment of the probable effects of the mining on surface and ground water. Office of Surface Mining regulations provided little guidance or insight on how these impact assessments were to be prepared or how probable hydrologic consequences should be determined. To help fill this void, Zogorski, Martin, and others prepared an Open-File Report containing a hydrologic evaluation of a hypothetical mining site in Spencer County. This study compiled and interpreted available geologic and hydrologic information, collected new data as necessary, and used this information to assess hydrologic impacts as required by SMCRA. Bobay used a one-dimensional, steady-state stream, dissolved-oxygen model and the aqueous geochemistry model PHREEQE to theoretically predict the cumulative effects of iron and manganese oxidation in streams receiving mine drainage. This study was published as a Water-Resources Investigations Report.

Streambed Scour at Bridges

Streambed scour in the vicinity of bridges is an ongoing concern and can pose a real risk to public safety. Over the years, there have been numerous cases of catastrophic bridge failure when floodwaters have undermined piers and abutments. To minimize this risk to public safety, in 1991 the Indiana District entered into a 7-year cooperative project with the Indiana Department of Transportation to investigate bridge scour in Indiana. The objective of this project was to collect scour-assessment data at nearly 5,600 bridges in Indiana and to identify those bridges that were likely to develop scour-related problems in the future.

During the period of 1991 to 1994, scour-assessment data were collected at more than 4,900 bridges in Indiana. These data were entered into a scour-assessment data base and were evaluated in terms of existing and potential scour problems. In 1993 a paper was presented at the Hydraulics Conference of the American Society of Civil Engineers that outlined the field methods developed to efficiently collect scour-assessment data at a large number of bridges. In 1994 a report was prepared to present an observed-streambed-scour index for selected bridges in southwestern Indiana.

National Water-Quality Assessment (NAWQA) Program

The White River Basin (WHIT) study was one of 20 study units selected for the full implementation of the NAWQA Program in fiscal year 1991. Charles Crawford was selected as Study Unit Chief. The first 2 years of the project were devoted to project planning and recruitment of staff. Eight full-time staff were recruited to work on the project, including an aquatic biologist (Lydy), a GIS specialist (Baker), an organic chemist (Carter), a surface-water-quality specialist (Martin), a ground-water-quality specialist (Schnoebelen), a hydrologist (Jacques), and two hydrologic technicians (Goebel and Laird). Because of a lack of personnel available within the District to work on the project, all but Laird and Martin were recruited from outside the District. Three staff held Ph.D. degrees

(Baker, Carter, and Lydy), adding considerably to District technical expertise. After the sudden and untimely death of David Jacques in 1991, two additional hydrologists were added to the project (Frey and Moore). Fenelon replaced Schnoebelen as groundwater specialist in 1994. During the first 4 years of the project several other District staff assisted with various aspects of the project, including Bayless, Hodgkins, Renn, and Watson as well as several staff of the Kentucky District (Harry Hitchcock and Doug Zettwoch).

The WHIT study unit was selected as one of only four 1991 study units to participate in prototype sampling of surface water in 1992. The purpose of this effort was to evaluate sampling frequencies to be implemented within the NAWQA Program and to test and refine sampling protocols. Samples were collected as often of three times per week at two small streams and from the White River near the mouth as part of this effort. Regular high-intensity phase sampling began at these three and eight other surface-water sites in fiscal year 1993 and were continuing in 1994.

Drilling of more than 100 water wells in four monitoring networks was begun in 1993. The WHIT study unit was one of only a few 1991 NAWQA study units that installed all wells sampled. WHIT staff also designed and implemented a study investigating the transport of atrazine in the unsaturated zone in central Indiana till soils. This study, which was unique among 1991 NAWQA study units, was used as a guide for further unsaturated-zone studies included in Cycle II of the NAWQA Program, which began in 2001.

Most of the first 4 years of the project was devoted to designing and implementing the data-collection program, so few publications were prepared during this time. A brief description of the project was prepared by Crawford and Jacques in 1991. Martin and Crawford presented papers describing historical nutrient and pesticide data at an American Water Resources Association symposium on the National Water-Quality Assessment Program in 1994.

KENTUCKY

By Alfred L. Knight and reviewed by Donald S. Mull

ORGANIZATION AND PERSONNEL

In 1979, the Kentucky District was organized into four Sections, two Units, three Subdistricts (Louisville, Paducah and Williamsburg), and one Field Headquarters (Prestonsburg) and was staffed by 47 permanent employees. Organizational changes made between 1979 and 1994 resulted in abolishing the Louisville Subdistrict, converting Williamsburg and Paducah into Field Headquarters, and creating three Sections, seven Units, and three Field Headquarters. The number of permanent employees reached 57 in 1980; however, a reduction in the coal and oil-shale hydrology program caused a reduction of personnel. In 1981, permanent employees decreased to 40, then to 34 in 1984. As new cooperative projects started and the National Water-Quality Assessment Program (NAWQA) pilot project was ongoing, staff were added and permanent employees reached 49 in 1992. Following the completion of the NAWQA project, permanent staff dropped to 45 in 1994. In 1991, Headquarters reorganization moved the Kentucky District from the Southeastern Region to the Northeastern Region.

District Headquarters, Louisville

Office of the District Chief

In 1979, the District Office was in the Federal Building at 600 Federal Place and the Louisville Subdistrict was in the Post Office at 601 West Broadway. In 1986, the District Office relocated to 2301 Bradley Avenue, an old renovated school building provided by the University of Louisville through a Joint Funding Agreement. In addition to the move, a minicomputer was introduced and terminals were made available for many to use. Between 1979 and 1994, many changes were made in the computer systems and effective use of the computer in all phases of District operations.

Philip A. Emery was District Chief from 1979 to 1981 when he transferred to Alaska. Alfred L. Knight, who transferred from Miami, Fla., replaced Emery in 1981. Assistant District Chiefs were John A. McCabe (1979), Ferdinand Quinones-Marquez (1980–81), Robert J. Faust (1980–86), James M. Bettandorff (1982–90), Lloyd H. Woosley, Jr. (1987–92), Harry C. Rollins (1991–94), and Thomas D. Mesko (1993–94).

In 1991, Bonnie J. Stich became the first District Secretary. In 1992, Stich accepted a position as Editorial Assistant and Linda S. Maglothin succeeded her.

Administrative Services Section

Robert D. Hudson was Administrative Officer in 1979. When Hudson transferred to the Southeastern Region Office (1979), John A. McCabe temporarily assumed the responsibilities of Administrative Officer. In 1980, Mary C. Rhodes succeeded Hudson. Rhodes resigned in 1983 and was succeeded by Regina C. Haynes who transferred from the National Water Quality Laboratory in Atlanta, Georgia.

Others serving in the Administrative Services Section were Maxine T. Catlett, Wenda M. Linnemann, Jenny L. Ramsey, Brock P. Henderson, Marguerite M. Cornish, Leroy Marburger, Patti L. Sturm, Debra K. Skees, Elizabeth A. Aboud, Roszelle H. Moore, Ann S. Phillips, Linda K. Vertrees, Julie M. Hicks, Cheryl B. Stuppy, Edie M.Wolfe (Crone), and Pamela K. Cooper.

Hydrologic Surveillance (Data) Section

This Section was organized into Units and was responsible for a Sediment Laboratory, Computer Services, and Field Headquarters. Section Chiefs were Ferdinand Quinones-Marquez, James M. Bettandorff, and Harry C. Rollins. Section members were Russell F. Flint, John F. Santos, John N. Sullavan, John S. Zogorski, William H. Jackson, Douglas V. Whitesides, James L. Myrick, Florence L. Witherspoon, David E. Bower, Charles E. Schoppenhorst, David W. Leist, Steven D. Weedman, Harry A. Moody, Clyde J. Sholar, Saundra J. Couts, Patricia G. Casey, Kevin D. Metzker, Ronald D. Evaldi, Kevin J. Ruhl, Thomas W. Kollar, Billy L. Raney, Dennis L. McClain, Gregory K. McCombs, Stephen D. Farrington, Sharon A. Toms, Timothy D. Liebermann, Matthew S. Graves, Michael S. Griffin, Douglas D. Zettwoch, Brian L. Moore, Eric J. Humbert, Rene Garcia, Robert W. Forbes, Robert G. Goettel, Paula L. Griffin (Ottersbach, Faith), Gary R. Martin, Bridgett E. Lyons, Harry A. Hitchcock, Paul J. Bruenderman, Donald W. Eichert, Jonathan H. Whitesides, Ralph E. Puckett, Rebecca J. Burns, Charles H. Allen, David P. Allgeier, Aimee C. Haliday, Yolanda E. Pinkelton, and Loren G. Kloft.

Hydrologic Investigations (Studies) Section

This section was primarily responsible for developing, planning, implementing, and publishing the results from investigations of ground-water and surface-water hydrology and quality, the management of spatial data, and publications processing.

Section Chiefs were John A. McCabe, Robert J. Faust, Lloyd H. Woosley, Jr., and Thomas D. Mesko. Section members were Robert W. Davis, Robert J. Faust, T. William Lambert, Harold H. Zehner, Joel E. Dysart, Kenneth E. Stevens, Douglas D. Zettwoch, Curtis H. Hannum, Charles E. Schoppenhorst, Donald S. Mull, Elizabeth A. Aboud, Echo I. Elliott, Bobbie F. Quinn, James L. Kiesler, Mona J. Brawner, Rebecca L. Violette, David E. Bower, David W. Leist, Mark A. Lyverse, Arthur J. Whallon, James L. Smoot, Anne F. Choquette, Kevin D. White, James K. Jackson, Kirk D. Fauver, Ronald D. Evaldi, Thomas W. Kollar, Michael D. Unthank, Elizabeth A. Flanary, Jeffery J. Starn, Karen S. Wilson, Albert G. Alexander, David S. Mueller, Stephen D. Porter, Charles J. Taylor, James M. Parnell, Patricia A. Grace, Martin F. Rose, Ben F. Marquess, Luann B. May, Bonnie J. Stich, Elizabeth A. Shreve, Kim H. Haag, Robert W. Forbes, Robert G. Goettel, Jane M. Poole, Angela M. Machniak, John R. Moorman, Hugh L. Nelson, Lynn G. Jarrett, and Susan C. Lambert.

Subdistrict/Field Headquarters

As the period began, the Louisville, Paducah, and Williamsburg Subdistricts and the Prestonsburg Field Headquarters were responsible for hydrologic data collection in Kentucky. In addition, the Paducah and Williamsburg offices were responsible for specific investigative studies. Following organizational changes between 1984 and 1986, the Louisville Subdistrict was closed, Paducah and Williamsburg were made Field Headquarters, and data operations were distributed among the District Office and the Field Headquarters.

Louisville Subdistrict

In 1979, the Louisville Subdistrict was in the U.S. Post Office at 601 West Broadway. The District Office relocated to 2301 Bradley Avenue in 1986 and the Subdistrict was closed. Personnel and operations were reassigned to the Hydrologist-in-Charge of the Hydrologic Surveillance Section (James M. Bettandorff). Timothy W. Hale served as Subdistrict Chief in1979–80. He was succeeded by Norwood B. Melcher (1980–86). Members of the Subdistrict were

David W. Leist, Thomas W. Kollar, Billy L. Raney, Welby L. Stayton, Dennis L. McCain, Gordon E. Staab, James M. Haragan, Mark S. Hillerich, Mark A. Lyverse, Steuart P. Pearce, Rick L. Exler, Gregory K. McCombs, Sharon A. Toms, Kevin J. Ruhl, Clyde Sholar, Steven D. Weedman, Kevin D. Metzker, and Florence L. Witherspoon.

Paducah Subdistrict/Field Headquarters

The Paducah office, located at 501 Broadway, was a Subdistrict from 1979 until 1985 when it was designated as a Field Headquarters. Wilson G. Bonham was Subdistrict Chief until his retirement in 1984. John N. Sullavan transferred from the Louisville office and served as Subdistrict Chief from 1984 until he retired in 1985. In 1985 the Paducah office was designated as a Field Headquarters and Jack D. Doyle was Technician-in-Charge from 1986 to 1989. Alan C. Brown was Technician-in-Charge from 1989 to 1994. Other Paducah staff included Raymond O. Plebuch, Bob L. Miles, Gale L. Hubbard, Saundra A. Bradley, Kenneth R. Scott, Robert G. Locke, Fred M. Wreck, Mark A. Lyverse, Roy S. Darnell, Kenneth C. Galyean, Joyce M. Kinsey, Michael D. Eidson, Leah M. Dumortier, and James D. Filbeck.

Williamsburg Subdistrict/Field Headquarters

The Williamsburg office, located at 103 S. Second Street, was a Subdistrict in 1979 and Chester H. Minehan was Hydrologist-in-Charge. In 1980, Minehan retired and Franklin D. King transferred from Alabama as Technician-in-Charge. The office was moved to the Jackson Mall in 1983; in 1984, the Williamsburg Subdistrict was designated as a Field Headquarters. Frank D. King retired in 1988, and F. Dave Byrd transferred from Alabama to be Supervisory Hydrologic Technician.

Other Williamsburg staff included Vernon T. Bird, Clifford R. Moses, Jerry D. Bird, Paul J. Lyden, Anthony K. Dirrim, Wilda J. Carr, Keith D. Richardson, Stephen B. Pickard, and Lisa R. Peace.

Prestonsburg Field Headquarters

At the beginning of the period, the Prestonsburg Field Headquarters was located at Route 1107 in Van Lear, and Carl W. Faulkenburg was Technician-in-Charge until his transfer to West Virginia in 1980. Other staff members were Henery T. Hammond, Zeke Hensley, and Timothy G. Francis. By 1984, the Prestonsburg office was primarily a one-person operation (Zeke Hensley) housed in a modular office on U.S. Army Corps of Engineers property in Van Lear. From 1980 to 1985 the Prestonsburg office was supervised by the Louisville Subdistrict and by the Hydrologic Surveillance and Data Section from 1986 to 1994. In 1994 the office was closed, and Hensley transferred to Louisville.

Funding and Cooperation

Between 1979 and 1984, the Kentucky District was heavily involved in the national coal hydrology program. During this period, large hydrologic-data-collection programs, small-basin-modeling research projects, and several coal-area projects were in progress. At the peak of the program in 1981, Kentucky's budget was about 48 percent Federal funds. From 1981 to 1984 substantial decreases were made in the coal hydrology program, and in 1985 Federal funds made up only 18 percent of the District's budget and 8 percent in 1994. As funding for the coal and oil-shale hydrology programs decreased, the District struggled to develop cooperators and obtain funding. In order to keep the District financially viable, many employees accepted details to other Districts. One employee in particular (Zettwoch) spent much time traveling with the District's drill rig, assisting other Districts.

Kentucky District funds for fiscal years 1979–94

[Source: District program documents; Coop, Cooperative program; OFA, other Federal agencies; Fed, Federal program]

FUNDS	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	1,070	1,143	1,133	1,181	1,304	1,114	1,365	1,240	1,260	1,388	1,355	1,448	1,745	1,997	2,038	1.856
OFA	365	436	366	574	270	505	659	812	589	792	839	836	1,172	783	926	996
Fed	809	1,250	1,385	789	668	490	435	640	754	986	911	830	784	543	413	256
TOTAL	2,244	2,829	2,884	2,544	2,242	2,109	2,459	2,692	2,603	3,166	3,105	3,114	3,701	3,323	3,377	3,108

Prior to 1981, the Kentucky Geological Survey (KGS) was the major cooperating agency, contributing about 85 percent of the cooperative funds. The KGS reduced funding during the period, and by 1994 the KGS provided only about 15 percent of the cooperative funding. By 1984 the KGS had discontinued support for ground-water data collection, and by 1993 support for surface-water data collection had also been essentially discontinued. The Kentucky Natural Resources and Environmental Protection Cabinet began supporting the data-collection programs in1985. In addition, many county and city cooperators funded data collection at the local level. During the period, the number of cooperators almost tripled.

As indicated by the funding table, the Federal-State Cooperative program doubled and the other Federal agency (OFA) program almost tripled during the period.

Principal Programs

Hydrologic-Data Collection

During the mid-1980's, the data-collection program accounted for 57 percent to 69 percent of the District's program. As the coal and oil-shale hydrology programs decreased, data-collection sites were terminated and cooperators began evaluating their needs to maintain long-term stations. By 1991, the data-collection program was about 36 percent of the District program, but by 1994 the data-collection program increased to about 53 percent.

Water year 1988 was a year of hydrologic extremes. In May, streamflows in the Bluegrass Region were running at 20 percent of normal, and by June the lower Ohio River had been closed to barge traffic several times. Monthly streamflow amounts on other streams throughout the State reached record lows for June with streamflows of less than 15 percent of normal. A statewide water shortage watch was declared by the Governor on June 17; later, on July 18, a statewide water emergency was declared. At the other extreme, high streamflows occurred when heavy rains fell over much of the State, starting on February 13 and continuing through February 16, 1989. The heaviest rains, more than 10 inches, occurred in the west-central part of the State. Lexington and Richmond, in the central part of the State, both reported 7.1 inches and Frankfort, the State capital, reported 6.4 inches over the 4-day period. Property damage was estimated at from $22 to $40 million at Frankfort and $1.1 million at Lebanon Junction. At least three deaths were attributed to the flooding. Flood peaks for the Kentucky River at Lock 2 and Rolling Fork at Lebanon Junction were slightly greater than a 100-year recurrence interval. At the request of the Federal Emergency Management Agency (FEMA), Bettandorff represented the USGS as a member of a Federal interagency flood-assessment team. Reports from the assessment team resulted in 61 of the 120 Kentucky counties qualifying for emergency disaster relief.

Streamflow Stations

In 1979, the District was maintaining approximately 112 continuous-record stations. The number of stations peaked to 117 in 1981 but dropped to 99 in 1984 due to a change in funding from the U.S. Army Corps of Engineers. By 1985, the number of continuous-record stations reached 103 and remained fairly stable until 1993 when the number dropped to 98. By 1989, 61 sites were equipped with data-collection platforms. In 1979, the District operated 124 crest-stage gages. The number declined yearly until the last crest-stage gage was discontinued in 1990. Streamflow data were analyzed and reports prepared by Quinones, Kiesler, and Macy (flow duration); Sullavan (low-flow characteristics); Melcher and Ruhl (streamflow and basin characteristics); Choquette (regionalization of peak discharges); Martin and Ruhl (regionalization of harmonic-mean streamflows); and Ruhl (effectiveness of the streamflow network).

Water-Quality Stations

Chemical water-quality data were collected at 225 coal-hydrology sites in 1979, 232 sites in 1980, and 227 sites in 1981. In 1979, water-quality data were published for 39 stations. In 1980, the District was operating 12 National Stream-Quality Accounting Network sites, and water-quality data were published for 10 monitor sites. Between 1981 and 1987, water-quality sites ranged from 16 to 26. As the NAWQA Program began and sampling started for the Kentucky River pilot study, water-quality sites peaked at approximately 50 in 1988–89 and decreased to 36 sites in 1994.

Ground-Water Observation Wells

From 1979 to 1983, the statewide network consisted of 70 to 75 recording wells and 85 to 117 partial-record sites. This network was maintained primarily through a cooperative agreement with the KGS for direct credit. In 1984, the KGS discontinued their support for the ground-water stations, and the statewide network declined annually until it consisted of 13 recording wells and 84 partial sites in 1994. Following the reduction in support by the KGS, most of the ground-water network was supported by local cooperators such as the cities of Louisville and Elizabethtown. Whitesides, Faust, and Zettwoch used the data to describe problems of rising ground-water levels in the Louisville urban area.

Water-Use Data

Throughout the duration of the period, water-use information was compiled through a cooperative program between the USGS and the Kentucky Natural Resources and Environmental Protection Cabinet (KNREPC). The water-use program was unique within the USGS because most of the data were collected by sources other than the USGS. The KNREPC provided this information through a direct-services agreement. Mull served as Project Chief of the Kentucky Water-Use Program from 1979 to 1983 and Sholar served from 1984 to 1994.

Fluvial-Sediment Stations

In 1980, sediment data were collected at 49 sites. By 1986, the number of sites had decreased to 23, and in 1994 data were being collected at 11 sites. Prior to 1980, Kentucky's suspended-sediment samples were analyzed by the Ohio District in Columbus, Ohio. The Kentucky District Sediment Laboratory began operations in the basement of the Federal Building in 1980 during the Coal Hydrology Program. The District Sediment Specialist (Flint) started the laboratory and served as the first Laboratory Chief. Sholar served as Laboratory Chief from 1981 until August 1994. During this period the laboratory was expanded to serve States outside of the Kentucky District. In August 1994, Shreve was assigned as Laboratory Chief. The laboratory was analyzing samples for four States by the end of 1994.

Interpretive Studies

National Water Quality Assessment Program (NAWQA) Pilot Project

In 1983, a series of planning studies and special projects for the Kentucky River Basin were initiated in cooperation with the Kentucky Geological Survey. In 1986, the Kentucky River Basin was selected as one of seven pilot water-quality studies as part of the USGS National Water-Quality Assessment Program. This project accounted for an increase in the District's budget and opportunities for District personnel. Smoot, White, Haag, Evaldi, and Porter provided team leadership.

Karstic Aquifer Studies

Karstic aquifers occur throughout much of Kentucky and are unique, important ground-water resources. These aquifers are subject to rapid entrainment and transport of contaminants. Ground-water problems were especially noticeable in Bowling Green, Elizabethtown, and the Mammoth Cave National Park. Whallon coauthored a fact sheet on hydrologic hazards in karst terrain, and Mull and Lyverse reported on the karst hydrology of the Elizabethtown area. Mull, Smoot, and Liebermann developed dye-tracing techniques used to determine ground-water flow in carbonate aquifers. Mull continued to develop the techniques and completed studies at a Superfund waste-disposal site and a research farm at Kentucky State University and coauthored a technique manual for the USEPA with Liebermann, Smoot, and Woosley.

Ground-Water Studies in Louisville

During World War II, overdevelopment of ground water in the Louisville area resulted in a substantial lowering of the water table. As withdrawals were reduced after the war, water levels recovered and appeared to stabilize around 1981. In 1984, more interest in the use of ground water for heating and cooling and new permitting requirements illustrated the need for a better understanding of the ground-water system. Ground-water-level conditions were reported by Faust and Lyverse in 1987 and by Faust and Lyons in 1989. A compilation of selected references on ground-water resources and geohydrology of the Louisville area (1944–93) was published by Starn

and Mull in 1994. A two-dimensional finite-element ground-water-flow model was developed by Lyverse, Starn, and Unthank.

Maxey Flats

In 1979–80, Zehner completed studies providing information defining the geology, flow systems, quality of water, and inorganic and organic character of leachates at Maxey Flats, a low-level nuclear-waste site in Kentucky. As State officials developed closure plans for the site, the Kentucky District was requested to serve on advisory committees and to conduct other studies to assist the State in protecting the water resources adjacent to the site. Knight, Zehner, and Lyverse served on several committees. Lyverse continued investigative studies at the site after Zehner transferred in 1980.

Geographic Information System Technology

In 1988, Liebermann began working with geographic information system (GIS) technology to develop a hydrology-related data base for Kentucky. This technology proved to be a valuable tool in water-resources management and investigations analyses, and demonstration projects were initiated with the City of Elizabethtown and the University of Louisville. In 1992, a Spatial Data Analysis Unit was added to the District organization with Forbes as unit leader. During the period, District personnel supported other Districts with GIS projects such as the F.E. Warren Air Force Base Installation Restoration Program (IRP) in Wyoming and the Survey's GIS program by providing course instruction at both the University of Louisville and at the USGS National Training Center in Lakewood, Colo.

Urban Hydrology

As more and more development occurred in Jefferson County, diverse hydrologic data were needed to evaluate changes in land- and water-management practices. Extensive data-collection programs were initiated with the Louisville and Jefferson County Metropolitan Sewer District, and several publications by Evaldi, Moore, and Burns described stormwater data, chemical quality of bottom sediments, water quality, yields of selected constituents, and techniques for estimating the quantity and quality of storm runoff.

Other Activities

During the period, the Kentucky District supported several national programs such as the Federal Highway Administration National Bridge Scour Program. Although the core program personnel were associated with the Office of Surface Water, the District provided human resources and other types of support on an immediate basis. Major floods were studied, and research conducted by Mueller was presented at conferences and in journal articles. Others assisting with the program were Hitchcock and Hubbard.

Kentucky personnel participated on Ph.D. review committees for the University of Louisville and several taught courses at the university. Those teaching classes were Starn, White, Haag, Lyverse, Forbes, Ruhl, and Smoot.

MAINE

By Gordon R. Keezer and Derrill J. Cowing

INTRODUCTION

During the 1979–94 period, the Maine Office remained part of the New England District and then the Northeast Program Area. From 1979 to 1981, the office was designated as the "Maine Subdistrict" and from 1981 until 1991, it was renamed as the "Maine State Office," both time periods as part of the New England District. In 1991 with the reorganization of the WRD into program areas, Maine became a District once again as part of the New England Program Area. The office remained at the same location, 26 Ganneston Drive in Augusta, for the period.

ORGANIZATION, MANAGEMENT, AND PERSONNEL

In 1979, Jeff Armbruster was the Subdistrict Chief and also served as the Chief of the Hydrologic Studies Section. Lennie Frost was Chief of the Hydrologic Data Section and Pat Clark provided administrative and fiscal support to the office. In 1980, Jeff transferred to the Georgia District, and Lennie transferred to the Illinois District. John Briggs was detailed in from the New England District Office to serve as Subdistrict Chief until Derrill Cowing was selected as the new Subdistrict Chief and transferred in from the

Alaska District in September 1981. Derrill served as the Subdistrict Chief, Office Chief, or District Chief from 1981 through the rest of the period covered by this history. Richard (Red) Morrill was selected to serve as the Data Section Chief to replace Lennie Frost.

In 1981, Tom Maloney transferred in from the Illinois District to become the Chief of the Hydrologic Studies Section. In 1983, after Pat Clark transferred to the Georgia District, Carol Atkinson was hired as the Administrative Operations Assistant for the office and served in that capacity throughout the period. 1984 was a year of significant change—Dick Haskell, a long-time hydrologic technician in the Hydrologic Data Section, died unexpectedly. Because of Dick's key role in processing surface-water records for the office, it took several years to fully recover from the loss of his institutional knowledge. In addition, in 1984, Bill Bartlett transferred in from the Ohio District to become the Chief of the Hydrologic Data Section, when Red Morrill was assigned full-time to the FEMA-Flood Insurance Studies Project Chief position.

In 1985, Tom Maloney was assigned responsibilities as the Office Water-Quality Specialist, and Rick Fontaine was designated as the Surface-Water Specialist. In 1986 Rick also was selected as the Surface-Water Specialist for the entire New England District, working out of the Augusta Office. In 1988, Tom Maloney transferred to the USGS National Water Quality Laboratory in Lakewood, Colorado, and Cowing assumed additional responsibilities as the Chief of the Hydrologic Studies Section.

In 1991, Rick Fontaine transferred to the Hawaii District, and Bill Bartlett was selected to become the Surface-Water Specialist for the New England Program Area, again working out of the Augusta Office. Joe Nielsen was selected as the Chief of the Hydrologic Data Section to replace Bill.

During the period covered by this history, Gloria Morrill served as a Cartographic Technician and was responsible for assisting in the preparation and publication of nearly all reports produced from 1980 through the period. In addition, Hydrologic Technicians Wayne Higgins and Gordon Keezer made important contributions. Wayne helped develop and operate one of the first real-time river water-quality monitoring programs in the country and worked at the regional and national levels to help implement these technologies. Gordon Keezer was instrumental in his early work to push the real-time satellite telemetry capabilities, which are now standard. In addition, Gordon was known for his abilities to test (and sometimes destroy) older cableway systems throughout New England and New York and then negotiate to rebuild them to the new more conservative design specifications.

Maine Subdistrict/Office/District Personnel during the period 1979–94 are show in the table below.

Adamik, James T.	1981–86	Morgan, Mary	1980–84
Armbruster, Jeff	1979–80	Morrill, Gloria	1980–94
Brassy, Kristen	1985–92	Morrill, Richard	1979–88
Clark, Patricia	1979–82	Morrissey, Daniel	1980–86
Cloutier, Andrew	1985–94	Nichols, William H.	1979–94
Cowing, Derrill	1981–94	Nielsen, Martha	1993–94
Dudley, Carol	1983–94	Olson, Scott	1987–94
Fontaine, Richard	1979–91	Parker, Gene	1979–84
Front, Leonard	1979–80	Petersen, Joel	1987–94
Haskell, Richard	1979–84	Prescott, Glenn	1979–83
Higgins, Wayne	1979–94	Rogers, Marilyn	1979–83
Hodgins, Glenn	1988–90, 1994	Steiger, Judy	1988–91
Johnson, Carole D.	1983–88	Smath, Joe	1983–86
Keezer, Gordon	1979–94	Stewart, Greg	1990–94
Lippert, Robert	1979–94	Tepper, Dorothy	1980–87
Maloney, Thomas	1979–80	White, Blaine	1979–80

PRINCIPAL PROGRAMS

Federal-State Cooperative Programs

During this period, the Maine Geological Survey (MGS), Maine Department of Environmental Protection (MDEP), Maine Department of Transportation (MDOT), and University of Maine (UM) were major partners in funding and conducting investigations of water-resources issues in the State of Maine. The MGS was the principal State cooperator for funding the statewide streamflow and ground-water-level monitoring networks. In addition, MGS cooperated in the conduct of numerous geohydrologic studies. The most notable of these studies was the Significant Sand and Gravel Aquifer Mapping Program, which ran from 1982 through 1994. The MDEP was a very proactive partner and cooperated in a wide range of important hydrologic and water-quality studies during the period. Notable examples are time-of-travel Studies for the state's major rivers, several investigations of nutrient nonpoint source contamination of specific lakes and ponds, development of precipitation-runoff models to support the environmental review process of the proposed Bald Mountain Cooper Mine Project, and continuous real-time monitoring of dissolved oxygen, specific conductance, water temperature, and pH at critical locations on the lower reaches of Maine's major rivers. The MDOT became a very important cooperator during the latter part of this period. When the State's budget problems became chronic in the late 1980's, MDOT stepped forward and helped fund stream gages in the statewide network that were identified as critical for continued operation for long-term analyses of regional hydrology. In addition, MDOT helped initiate and fund studies of flood-frequency characteristics of Maine rivers and water-quality characteristics and effects of highway runoff. In 1988, the Water Resources Institute at the University of Maine at Orono and the Maine Office worked together to site, build, and operate a set of stream gages as part of an effort to establish a small-watershed paired-basin research area in Maine. This effort was successful and resulted in the long-term hydrologic research site on Bear Brook in southeastern Maine. This site continues to attract many research scientists and projects of regional, national, and international significance.

Programs in Support of Other Federal Agencies (OFA)

During this period, the Environmental Protection Agency (USEPA), Federal Energy Regulatory Commission (FERC), Federal Emergency Management Agency (FEMA), and International Joint Commission (IJC) were important Federal program partners with the Maine Office. The USEPA funded detailed geohydrologic studies of several ground-water contamination sites as part of the USEPA Region 1 Superfund Program. Notable among these was the Loring Air Force Base site in Aroostook County and the Saco Landfill site in southwestern Maine. The FERC program had two components. The first was funding the operation of designated stream gages and water-quality monitoring stations operated by the USGS in support of FERC license requirements for hydroelectric projects. In addition, the relicensing of older hydroelectric projects and the submission of proposals for the licensing of new or altered hydroelectric facilities mushroomed during this period. This caused a large increase in the number and complexity of technical reviews to be completed for FERC by the Maine Office. Throughout the period covered by this history, the Maine Office had a strong working relation with FEMA Region 1 in the Flood Insurance Studies Program. These studies covered dozens of communities and water bodies in Maine. Studies ranged from approximate level "Limited Detailed Studies" to "Detailed Studies" involving sophisticated mapping and hydrologic modeling. The results of these studies were used by FEMA for constructing National Flood Insurance Program rate maps for these communities. The IJC supported streamflow and water-quality monitoring programs on the Saint John and St. Croix Rivers, which form portions of the international border between Maine and Quebec and New Brunswick, Canada. In addition, the IJC program funded USGS participation in IJC-sponsored technical annual meetings with other Federal and State/Provincial officials in the United States and Canada. These international meetings were important in promoting coordination of programs, technical interchange, and cordial relations among technical and managerial personnel across the border.

USGS Federal Programs

Primary Federal Programs funds during this period were derived from annual Headquarters finan-

cial support for the Collection of Basic Records (CBR) program, special allocations to help document extraordinary hydrologic events, and funding for special Headquarters-managed programs. The CBR program funding for key Federal network surface-water, ground-water, and water-quality stations steadily diminished during the period. This happened during the same time that severe budget problems were impacting many of our cooperators. As a result, the USGS network of hydrologic data-collection sites in Maine dropped significantly. The number of full-time streamgages dropped from more than 70 to only 47 in 1993. The number of water-quality monitoring sites dropped from 19 to a low of 10 in the late 1980's. In the early 1980's, Federal funds were provided by the Office of Surface Water for completing the prototype analyses and report for presenting new methodology for performing cost-effective evaluations of stream-gaging networks. These results were published in 1984 as Water Supply Paper 2244 authored by Richard Fontaine, Marshall Moss, Joseph Smath, and Wilbert Thomas. The Office of Surface Water also provided financial support to help document the floods of April 1987 in central and southern Maine. Water-Supply Paper 2424 "Flood of April 1987 in Maine" was authored by Richard Fontaine and Joseph Nielsen. During this period, Federal funds also were provided to help in the preparation of a series of National Water Summary Reports. These National Water Summaries included sections covering Maine water issues, Maine surface-water resources, Maine ground-water resources, Maine floods and droughts, Maine water supply and use, and Maine ground-water quality.

Funding for Maine is shown in the funding table below.

Other Notable Activities and Events

Two major floods occurred during this period—one in April 1987 and the second in April 1991. The April 1987 flood in central and southeastern Maine was caused by heavy rains and rapid melting of the early spring snowpack. Record peaks were recorded at 13 stream gaging stations. Several peaks were the highest known since the area was settled more than 200 years ago. Fourteen of 16 counties were declared State and Federal disaster areas. As a result of the flood, the Maine River Flow Advisory Committee re-established the Maine statewide snow survey program, which had been terminated in the mid-1970's.

The flood and major ice jams of April 1991 in northern Maine were caused by snowmelt and ice breakup resulting from warm weather and rainfall in the St. John River Basin. Two bridges and two stream-gaging stations were lost.

Maine District funds for fiscal years 1979–94
[Note: Funding for 1984 and 1986 are only approximate]

Fiscal year	Federal	OFA	State	Federal matching	Total
1979	$85,600	$155,200	$267,800	$251,700	$760,300
1980	$113,900	$108,700	$338,200	$315,300	$876,100
1981	$157,700	$94,300	$399,200	$384,000	$1,034,200
1982	$101,800	$83,200	$382,600	$374,200	$941,800
1983	$127,400	$96,200	$283,800	$274,200	$781,600
1984	$95,300	$65,400	$352,500	$287,400	$800,600
1985	$130,100	$445,000	$274,500	$277,000	$1,124,600
1986	$86,400	$267,800	$253,000	$238,000	$845,200
1987	$200,800	$264,000	$334,400	$242,500	$1,041,700
1988	$131,800	$311,100	$322,500	$285,700	$1,051,100
1989	$87,800	$115,800	$367,800	$293,200	$964,600
1990	$94,200	$280,000	$413,200	$276,000	$1,063,400
1991	$150,100	$289,700	$276,300	$237,800	$953,900
1992	$107,800	$302,000	$332,400	$299,300	$1,041,500
1993	$115,600	$524,500	$329,700	$308,200	$1,278,000
1994	$88,000	$430,700	$322,200	$307,000	$1,147,900

In 1984, the Governor of Maine established the Maine River Flow Advisory Committee (RFAC). Members were drawn from Federal and State agencies, as well as electric utilities and pulp and paper companies. All members had direct responsibilities for monitoring or managing surface-water runoff conditions in the State. The RFAC met each March to share information on snowpack conditions, headwater reservoir storage levels, river flow and ice-cover conditions, and the outlook for spring meteorological conditions. Press releases were issued to help raise public awareness of the annual potential for damaging spring floods and ice jams. After significant events, a second meeting was held as a post-mortem to discuss ways to improve communications and operations during subsequent events. This committee was co-chaired by the Maine Geological Survey and the USGS. The members and function of this committee remain an important support group for the USGS programs in Maine.

Also during this period, the USGS developed a close working relation with the Maine Emergency Management Agency. As a result, the USGS is now a participant in the operations of the State Emergency Operations Center (EOC) during significant hydrologic events. This allows information from the USGS Office to flow rapidly to the EOC for dissemination to other agencies and the EOC provides assistance to the USGS in accomplishing field work by helping provide access to the flood damage regions.

Epilogue

During the period 1979 through 1994, the Maine Office saw considerable change in the technical skills of staff and tremendous advancements in the technology to accomplish the mission of studying and reporting on the water resources of the State of Maine. Routine monitoring and reporting of surface-water runoff, statewide ground-water levels, fixed-station water-quality monitoring, and mapping of favorable ground-water areas developed into sophisticated real-time hydrologic information networks with the products available to the public on the internet, site-specific quantitative studies of ground-water flow and quality, Super Fund investigations of hazardous waste sites, and detailed hydraulic modeling and hydrologic studies of flood-prone areas for the FEMA-National Flood Insurance Mapping Program. The advancements in basic computer technology, borehole geophysical techniques, surface-geophysics applications, GPS technology, GIS, and new digital modeling software changed nearly all the day-to-day operations of the office.

MARYLAND–DELAWARE–DISTRICT OF COLUMBIA

By Herbert J. Freiberger

INTRODUCTION

During the period 1979–94, the Maryland–Delaware–District of Columbia District (MD-DE-DC) of the U.S. Geological Survey (USGS) Water Resources Division (WRD) was anything but status quo. There were many changes in personnel, programs, finances, cooperators and management structures. Following are several highlights:

- Four District Chiefs served MD-DE-DC during the period.
- The District budget climbed steadily from about $2,100,000 in 1979 to about $7,500,000 in 1994.
- Successful financial closeouts marked the entire period. The only real strains occurred during fiscal years 1982–85 when substantial Federal dollars for coal hydrology studies came to a close.
- The number of personnel grew from 48 in 1979 to 80 in 1994.
- The Maryland Geological Survey (MGS) and the Delaware Geological Survey (DGS) remained the major and closest cooperators. However, many new cooperators joined the program during the period, notably the U.S. Army at Aberdeen Proving Ground in Maryland and the Maryland Department of Health and Mental Hygiene (now the Maryland Department of the Environment).
- The District technical program took on a new flavor from one of mostly surface- and ground-water assessments. Projects associated with the quality of runoff into the Chesapeake Bay and assessing the degree of ground-water contamination at military hazardous waste sites were added.
- The Delmarva Peninsula in the MD-DE-DC was chosen in 1986 as one of seven pilot sites for a major USGS initiative, the National Water-Quality Assessment Program (NAWQA). The

study brought much exciting water-quality information to the District as well as much positive national recognition.

- In 1982, as part of a management pilot effort, the MD-DE-DC and the Virginia Districts were merged into one District, the Mid-Atlantic District, under the supervision of one District Chief.
- In 1991, the Mid-Atlantic District was demerged back to MD-DE-DC and Virginia Districts as part of a national District management change to a 16-program-area concept. The MD-DE-DC, Virginia, and West Virginia Districts, each with its own District Chief, became parts of the Mid-Atlantic Area under the direct supervision of an Area Assistant Regional Hydrologist.

The period was marked by change. For MD-DE-DC, most of it was good.

ORGANIZATION AND MANAGEMENT

MD-DE-DC had four offices during the period. The District office was located in the Maryland Executive Park at 8600 LaSalle Road in Towson, Md., for the entire period. The Delaware Subdistrict Office was 3in the Federal Building at 300 South New Street in Dover for the entire period. The Annapolis Field Headquarters was in the Maryland Department of Natural Resources in the Tawes State Office Building at 580 Taylor Avenue in Annapolis for the entire period. The Cumberland Field Headquarters was located in the Allegheny County Government Building on Pershing Street in Cumberland, Md., until 1989 when the office was moved to the Braddock Square Mall in LaValle, Md., about 5 miles west of Cumberland.

Office of the District Chief – Walter White served as the second District Chief of MD-DE-DC from 1966 until early 1980 when he retired. He was replaced in 1980 by Herbert J. Freiberger who transferred from the staff of the Regional Hydrologist, Northeastern Region, Reston, Va. In 1991, Freiberger became the Area Assistant Regional Hydrologist for the newly created Mid-Atlantic Area. He was replaced by David Grason from within the District. In 1993, Grason was chosen to become the Associate Regional Hydrologist, Northeastern Region in Reston. He was replaced by James G. Peters who transferred from the staff of the Regional Hydrologist, Northeastern Region, in Reston. Peters was the District Chief in 1994, the ending year of this period of history. Eva J. Cockey served as Secretary to the District Chief from 1981 until her retirement in 1992. Kenneth R. Taylor served as Assistant District Chief from 1979 to 1986 when he retired. The position was not filled after his retirement. Robert W. James, Jr., served as the Chief of the Hydrologic Data Section for the entire period.

Laurence J. McGreevy served as Chief of the Hydrologic Studies Section from 1979 to 1984 when he became Chief of the District Reports Processing Unit. He was replaced by James M. Gerhart, who transferred from Harrisburg, Pa. Gerhart served in that position until 1991 when he became Project Chief of the Potomac River NAWQA study. He was replaced by Gary N. Paulachok who served in the position until the end of the period.

A large infusion of funding and projects from the U.S. Army at Aberdeen Proving Ground necessitated the establishment of a separate Hazardous Waste Hydrology Section in 1988. Barbara J. Ryan was the first Chief of this Section, serving just 1 year until 1989 when she transferred to the Department of Interior in Washington, D.C., as a WRD liaison to the Secretary of the Interior's office. Wayne H. Sonntag transferred from Miami, Fla., to take over as Chief of the Section and served in that capacity until the end of the period.

MD-DE-DC established a Water Quality Support Section in 1979. David Grason, who transferred from Illinois, was the first and only Chief of the Section, which was later merged into other large water-quality projects around 1986.

The District undertook two major NAWQA studies during the period. Robert J. Shedlock transferred from Indiana in 1986 to head up the Delmarva NAWQA project. James M. Gerhart headed up the Potomac NAWQA study, which started in 1991 and was still active when the period ended in 1994.

The District had a small Subdistrict Office in Dover, Del., consisting of about 8 to 10 employees depending on the amount of program in any given year. Phillip Pfannebecker was the Subdistrict Chief in the beginning of 1979 until he retired. Arthur L. Hodges, Jr., was the Subdistrict Chief from late 1979 until 1987 when he retired. Gary N. Paulachok transferred to Dover from New Jersey in 1987 after completing a large offshore drilling project near Atlantic City, N.J., to assume the role of Delaware Subdistrict Chief. Paulachok transferred to Towson in 1991 as the Hydrologic Studies Chief but still super-

vised the Delaware interpretive program through the end of the period.

The Cumberland Field Office (later LaVale) was responsible for the operation and analysis of streamflow records in western Maryland. Other activities included operation of three water-quality monitors on the Potomac River for the Baltimore Corps of Engineers and project data-collection support, most notably the Mettiki mine project and the Potomac NAWQA study. Bernard F. Strain was the Hydrologic Technician-in-Charge for the entire period. Also serving in that office were James E. Auvil, Steven N. Hiortdahl, Jeffrey L. Griffith, and James R. Jeffries.

The Annapolis Field Office consisted of Frederick K. Mack, Stephen E. Curtin, and Judith C. Wheeler. Mack, who provided support to the USGS/MGS projects, retired from USGS in 1980 and was immediately employed by the MGS to do the same work in the same location. Curtin collected and analyzed records for the southern Maryland groundwater network and operated the District's borehole geophysical logger. Wheeler was Project Chief for the Maryland and Delaware water-use projects.

Donald A. Turney was the Administrative Officer at the beginning of the period until he transferred to Florida at the end of 1979. Yvonne Von Steen became the Administrative Officer in early 1980. She remained in charge of the Section until 1994 when she retired. H. Theresa Rose, who was a member of the Section, became Administrative Officer in late 1994. Other members of the Administrative Section were J. Elizabeth Smith, Mildred K. Wojcik, Carol T. (Shultz) Taylor, Mary Dee Mayfield, Shirley A. Hartsoe, Shirley Cox, Laurel E. Winand, Gloria I. Lopez, Mary Ann Blough, Yvette M. Zakes, Linda D. Warden, Jane P. Guy, and Emmalou Helinsky. In addition, part-time administrative and clerical support was supplied by Jill R. Rush, Marjorie S. Martin, and Patricia R. Lucas of the Delaware Subdistrict Office.

The beginning of the period, 1979, also coincided with the beginnings of computer automation in District operations nationwide. The MD-DE-DC started with one remote terminal. The system was installed and shepherded by interested scientists, notably, Thomas J. Trombley and William B. Fleck, who did this in addition to their projects. In 1984, as MD-DE-DC moved on to a series of minicomputers and eventually to the point of terminals on every desk, Nelson E. Williams was hired as the Site Administrator and Chief of the Computer Applications Unit. Williams was given the freedom to design the District computer system and did so aggressively. As a result, the District quickly came up the curve in the computer generation. Williams transferred to North Carolina in 1990. Frank P. Holtschneider, from within the Unit, became Chief in 1991 and served until the end of the period. Others who served in the Computer Unit were Cheryl Williams, David S. Devereux, Thomas M. Pickett, David A. Dehanas, Gregg F. Countryman, Vyacheslav "Slava" Shubinsky, Paul E. Exter, Lillian B. Maclin, Vanessa Smith, and Judith L. Tegler.

During the first several years of the period until 1984, technical reports processing was done informally by the authors, the studies section chiefs, an editorial assistant (Sheryl J. Protani), a cartographic technician (Mary R. Halberstadt), and later another cartographic technician (Gloria Jean Hyatt). This process worked fine until the growing District produced more reports than an informal group could handle. In 1984, Laurence J. McGreevy became the first District Reports Specialist. He instilled a more formal process to keep track of reports, to prioritize the work, and to approve them for forwarding for further review and approval at Regional and Headquarters levels. In 1982, the Mid-Atlantic District was formed, and reports processing was one of the functions that was consolidated. In effect, the District reports processing unit did all the reports work for Maryland, Virginia, and Delaware. McGreevy retired in 1987 and was replaced by Linda S. Weiss, who transferred from the U.S. Army Corps of Engineers in Washington, D.C., in 1988. As the Mid-Atlantic District continued to grow, more reports were generated and the size of the Publications Section needed to be enlarged. By the end of the period, the Section had added Donna R. (Lowry) Knight, John W. Brakebill, Judith A. McFarland, Amy J. Chen, Sharon A. Rafferty, Dorothy C. Grasso, Valerie A. (Morris) Gaine, Timothy M. Auer, Willie R. Caughron and Kimberlee A. Bouder. The District had a good track record of producing quality reports on time.

In 1991 the Mid-Atlantic Program Area was established, and the West Virginia District report production was added to the MD-DE-DC Publications Section. In 1994, Weiss transferred to Nebraska to become District Chief. She was replaced by Eugene C. Hayes who had just completed a foreign assignment. He remained Chief of the Section through the end of the period.

Funding and Cooperation

Total funding for MD-DE-DC more than tripled during the period (see funding table). Program growth was nearly constant during the period and kept pace with inflation. Even though overall funding grew steadily, the makeup of the funding with regard to Federal-State Cooperative (Coop) Program, other Federal agency (OFA) programs, and Federal program (Fed) was much different in 1994 than in 1979. Although the Coop program grew almost every year, it represented 72 percent of the total dollars in 1979 but represented just 43 percent in 1994. Large increases in OFA and Fed programs kept the District solvent. OFA programs represented 18 percent of total funding in 1979 and 30 percent in 1994. Likewise, the Fed programs increased from 10 percent of the total funding in 1979 to 27 percent in 1994. During the course of the period, Federal matching funds gradually did not keep up with the offerings of the various cooperators. In MD-DE-DC in 1979 only 2 percent ($15,000) of cooperator offerings went unmatched. By 1994 that figure increased to 45 percent or $929,000 unmatched. Many cooperators were willing to put in unmatched money for USGS data and products.

In Maryland, the primary cooperator in tenure (and in funding early in the period) was the Maryland Geological Survey, which was part of the Department of Natural Resources. Other major cooperators during the period were Charles, Frederick, Harford, Queen Annes, Washington, Anne Arundel, Cecil, Kent, Howard, and Baltimore Counties. The Maryland Water Resources Administration contributed to the water-use program and stream gages. The Interstate Commission on the Potomac River Basin contributed for stream gages and time-of-travel studies in the basin. The Maryland State Highway Administration funded stream gages, flood-frequency studies, and a bridge scour project. The Maryland Department of Health and Mental Hygiene began to fund work associated with the Chesapeake Bay early in the period. Most notable were a long-term nonpoint-source study and water-quality sampling on major Chesapeake Bay tributaries. The town of Ocean City contributed for a chloride network and a ground-water flow model. The City of Baltimore contributed towards a Baltimore Urban Hydrology study in the early part of the period. Many cities and towns contributed to the surface- and ground-water data programs with all their funding going through the Maryland Geological Survey. The U.S. Army at Aberdeen Proving Ground began efforts to assess its ground-water contamination problems in 1984 and contributed nearly $1,000,000 to the OFA program each year for the rest of the period. Bolling and Andrews Air Force Bases in the Washington, D.C., area joined the District program during 1987 to 1991. The U.S. Army Corps of Engineers, Baltimore District, contributed funding for stream gages and water-quality monitors, mostly associated with reservoir management. The U.S. Environmental Protection Agency contributed to the program for work in the Chesapeake Bay program and for consultation and work on Superfund sites.

In Delaware, the major cooperator was the Delaware Geological Survey (DGS). All funding in Delaware that came from State or local sources earmarked for the Coop program was legislatively mandated to go through the DGS. The Delaware Department of Natural Resources and Environmental Control contributed to the stream-gaging program as well as ground-water and water-quality work. The Delaware Department of Transportation funded a flood-frequency study and part of a tri-State bridge-scour study with Maryland and Virginia. The Water Resources Agency for New Castle County also cooperated on stream gaging and other problem-oriented studies. The U.S. Army Corps of Engineers, Philadelphia District, supported several stream gages and tide gages in the

Maryland-Delaware–District of Columbia District funds, fiscal years 1979–94

(Funds, in thousands of dollars)

Fund source	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	1,524	1,658	1,752	1,906	1,749	2,033	2,338	2,286	2,479	2,632	2,677	2,929	3,341	3,051	3,267	3,209
OFA	375	558	536	319	128	209	337	858	1,212	2,102	2,231	1,672	1,647	1,734	1,940	2,228
Fed	223	417	490	586	390	315	191	534	786	1,015	1,013	1,170	1,608	2,024	1,823	2,088
Total	2,122	2,633	2,778	2,811	2,267	2,557	2,866	3,678	4,477	5,749	5.921	5,771	6,596	6,809	7,030	7,525

Delaware drainage. In 1994, Dover Air Force Base began funding for a major ground-water contamination study of the base.

The program with the District of Columbia was extremely small, one gaging station on Rock Creek. It was funded by the D.C. Department of Consumer and Regulatory Affairs. The U.S. Army Corps of Engineers, Baltimore District, helped fund the Potomac River at Wisconsin Avenue tide gage.

Principal Programs

The MD-DE-DC District was well balanced in amounts of Coop program funding, OFA funding, and Fed program funding. In the early part of the period, data programs and interpretive programs were about equal but by 1994, the data program was about 30 percent of the program and investigative studies accounted for 70 percent. Both increased during the period, but the investigative increase was much more substantial. In the early part of the period the balance of technical disciplines was slanted towards surface- and ground-water data collection and investigations. At the end of the period, water quality had become a major component of the MD-DE-DC technical program.

Hydrologic Data Collection

The Hydrologic Data Section was responsible for the collection, processing, and dissemination of data for the entire stream-gaging program, the ground-water network, some water-quality data, and the sediment network. These data were published annually in the District's Water-Resources Data Report.

Streamflow Stations—During the period, the District operated an average of 95 streamflow stations (78 in Maryland, 15 in Delaware, and 2 in the District of Columbia). In Maryland, the number of stations hovered around 80 for the entire period, but the makeup of the network changed due to periodic funding shortfalls. Decisions had to be made yearly on what stations to discontinue, which eroded the strength and hydrologic viability of the network. At the same time the Maryland Water Resources Administration instituted a more stringent water-diversion permit process that required water users to pay for stream gages if they were to divert water. Two examples included diverting water for a fish hatchery and another for making artificial snow for a ski area. While these water-management stations were funded on an unmatched basis and provided funding for personnel in the Hydrologic Data Section, they did not add to a hydrologic network that could be used for calculating flood-frequency or low-flow characteristics because they were regulated streams. While the number of stations in Maryland remained almost constant, the hydrologic viability of the network was compromised with the biggest holes being in the Piedmont, southern Maryland, and the lower Eastern Shore. Maryland did not operate any crest-stage gages or low-flow sites during the period. The Delaware network remained relatively constant at 12 to 16 gages for the entire period.

The workload of the streamflow program was handled from three offices. The Delaware office collected and computed all the records from Delaware and the Maryland Eastern Shore (about 22 stations). The District Office in Towson collected and computed the records for all of Maryland's western shore east of about Hagerstown (about 50 stations). The Cumberland (LaVale) Subdistrict Office collected and computed all of western Maryland (about 23 stations) data.

There were two significant floods during the period. In November 1985, heavy rainfall, as much as 20 inches, in an area that created the headwaters of the Potomac Basin and the Roanoke Basin sent rivers to record levels in West Virginia, Virginia, and Maryland. The U.S. Army Corps of Engineers closed the gates at the Bloomington Reservoir on the North Fork Potomac River, and the elevation in the lake increased 86 feet in one day. Still a downstream station at Paw Paw had a stage that approached the 1936 records. The flood on the Potomac dissipated as the water came downstream where rainfall was less. Ironically, during the storm all the data chiefs in the Northeastern Region were at a meeting in Bay St. Louis, Miss., so the three Districts had to weather the storm without them.

In July 1989, a flash flood occurred in northern New Castle County, Del., sending about eight streams in this highly urbanized area to peak-flow levels. Personnel in the Delaware and Maryland offices covered the storm very well, and many valuable high-water measurements were obtained.

In the mid-1980's the District began to install data-collection platforms (DCP's) on stream-gaging stations that would send signals to a satellite which would then transmit the stages back to a receiver, essentially providing real-time data. The biggest data

users were the Corps of Engineers, to operate their reservoirs, and the National Weather Service, to forecast floods. By the end of the period (1994), the District had about 20 gages equipped with DCP's.

Maryland personnel who worked in the surface-water part of the Data Section were Robert W. James, Jr., Myron N. Lys, Bernard M. Helinsky, Denis F. Gillen, John F. Hornlein, Lillian B. Maclin, James J. Manning, Joseph L. Fink, Edward M. Sadecki, James R. Dine, Mary E. Walters, Thomas Herrett, Steven N. Hiortdahl, George L. Zynjuk, Robert J. Sexton, Robert H. Pentz, Shaun M. Wicklein, Edward J. Doheny, Richard W. Saffer, and Jonathan J. Dillow.

Delaware personnel were Robert H. Simmons, Wayne A. George, George Phillips, Marjorie S. Martin, Frank A. Danner, Susan Westover, Thomas Hodukavich, Anthony J. Tallman, Deborah A. (Roy) Bringman, and Michael J. Cole.

Ground-Water Stations—The MD-DE-DC District essentially operated two ground-water-level monitoring networks. One was a statewide network that averaged about 175 wells during the period. This network covered the water-table aquifer statewide and the deeper aquifers of the Northern Atlantic Coastal Plain. The heaviest source of ground-water pumpage in the State is from the coastal plain, and thus the highest number of monitoring wells were concentrated there. Many monitoring wells were the direct result of interpretive projects that had a drilling component. Most wells that were drilled for a project automatically became part of the network but usually with no additional operating funds. So, in the late 1980's James M. Gerhart conducted an informal network analysis on the ground-water monitoring network by using then a state-of-the art Geographic Information System (GIS). The results not only showed a lack of wells in western Maryland but also a multiplicity of wells in the coastal plain. Some wells were eliminated with no loss of credibility to the network. The ground-water network was operated cooperatively with the MGS. Delaware only had only a few wells as the DGS operated its own small network.

The second ground-water network was the southern Maryland network. The network was done cooperatively with the Maryland Power Plant siting program and MGS throughout the period. The purpose of the network was to monitor the effects of pumpage on major deep aquifer systems (primarily the Patapsco Formation) by three powerplants (Calvert Cliffs, Chalk Point, and Morgantown) in southern Maryland. The program was critical as several southern Maryland communities, namely Waldorf and St. Charles, were experiencing large population increases with questionable water-supply sources. Primary personnel on this network were Frederick K. Mack, Stephen E. Curtin, and Roger J. Starsoneck. The network consisted of about 305 wells. Products were potentiometric surface maps of the areas each year. All ground-water records from both networks and interpretive projects were published in the annual data report.

The District operated a borehole geophysical logger with all capabilities just short of neutron probes. The logger stayed busy a good part of the time on projects and also on wells drilled by other entities, commercial or State. Daniel J. Phelan, Stephen E. Curtin, and Roger J. Starsoneck all operated the logger during the period.

The primary point person for the ground-water network for the period was Michael J. Smigaj. Others were Edward G. Otten, John T. Hilleary, Arthur L. Hodges, Roger J. Starsoneck, Tracey M. Curley, Ray G. Davis, Dan D. Edwards, and Mark R. Danner.

Water-Quality Records—MD-DE-DC operated a small network of water-quality sites until 1980 when they were discontinued. Analyses of these samples were for inorganic constituents.

From about 1978 to 1981, the MD-DE-DC and Virginia Districts operated water-quality stations at Susquehanna River at Conowingo Dam, Choptank River at Greensboro, Md., and James River at Cartersville, Va. The Potomac River at Chain Bridge in the District of Columbia was handled by a Virginia Polytechnical University laboratory in northern Virginia. The work was funded by the U.S. Environmental Protection Agency (USEPA) Chesapeake Bay Program, and its purpose was to determine the quality of runoff from the watershed. Sampling at the above four rivers would provide water-quality information for about 85 percent of the Chesapeake drainage. The USEPA used the information to help develop courses of action on how to clean up the bay. Analyses were done for nutrients, inorganic constituents, pesticides, and suspended sediment. These four constituents were found to occur at higher than acceptable levels at most sites. All the stations were reestablished in about 1982, and others were added and will be discussed in a later section. The people most associated with this network were David Grason, Linda (Darrell) Zynjuk, David J. Lang, and George W. Noah.

The Cumberland (LaVale) Field Office operated three flow-through water-quality monitors for the Baltimore Corp of Engineers on the North Branch Potomac River in western Maryland. One was above the new Bloomington Reservoir, one just downstream from the reservoir, and another about 10 miles farther downstream. The measured parameters were dissolved oxygen, pH, specific conductance, and temperature. The Corps was required to provide water downstream from the reservoir with quality at least as good as the natural water coming into the reservoir. In many cases, the water coming out of the reservoir was of better quality because much of the effects from acidic mine drainage had been removed while the water remained in the reservoir. The monitors remained in operation for the entire period, but record computation was discontinued in the late 1980's due to funding constraints. The monitors were operated by Steven N. Hiortdahl, Jeffrey L. Griffith, John R. Sobashinski, and Bernard F. Strain.

For several years, the Delaware office operated a small biological network on rivers in northern Delaware that entered the State from Chester County, Pa., and was part of a program funded by Chester County and the Pennsylvania District. The constituent of interest was periphyton, and it was analyzed to estimate the biological health of the streams. The collector of the data that were sent to the Pennsylvania District was Wayne A. George. The program was discontinued in the early 1980's.

During the entire period, the District operated five National Stream-Quality Accounting Network (NASQAN) stations as part of a national effort to collect similar water-quality information from about 535 rivers. This work was handled by George W. Noah, Brenda L. Feit, and David P. Brower.

Sediment Network—In 1979, MD-DE-DC operated five continuous suspended-sediment stations. They were Brandywine Creek at Wilmington, North Branch Potomac River at Cumberland, Conococheague Creek at Fairview, Potomac River at Point of Rocks, and Monocacy River at Frederick. All were Fed funded, and all required local observers to collect daily samples. The station with the most sediment per square mile was the Monocacy River. Heavy costs to operate these stations and dwindling funds from Headquarters forced the District to shut down all five stations one by one, and the program was gone by 1990. Those responsible for operation and analyses of the stations were Robert W. James, John R. Sobashinski, Linda (Darrell) Zynjuk, and Bernard M. Helinsky.

Water-Use Records—Water-use data were assembled statewide in Maryland in cooperation with the MGS and DNR's Water Permit Section and in Delaware in cooperation with DGS and DNREC. Water-use data for the District of Columbia were minimal and were included in the Maryland figures. Data were collected since 1980 in various categories including public supply, domestic supply, industry, irrigation, mining, commercial supply, and supplies for hydroelectric and thermoelectric facilities. The information was put into State water-use data bases and aggregated nationally every 5 years. Summaries of water-use data were published approximately every 2 years. Judith C. Wheeler was the Project Chief for both States during the entire period.

INTERPRETIVE HYDROLOGIC STUDIES

Maryland Geological Survey Program

In the early part of the period, MGS was by far the largest cooperator for the Maryland data program and the interpretive program. Near the end of the period, the interpretive program declined as MGS chose to do more of that work with their own people. During the early part of the period MGS had limited space in their offices at Johns Hopkins University, and the USGS housed three MGS hydrogeologists in the Towson space. They were Jon Achmad, David Drummond, and Mark Duigon. Each of them was either a project chief or project member on a USGS/MGS cooperatively funded project. The three hydrogeologists were considered direct services, meaning that MGS offered up the value of their services and USGS matched those salaries with cash. USGS provided the space and also supervised the three MGS employees. That positive situation was in place until about 1987 when MGS moved into its own newly refurbished building on St. Paul Street in downtown Baltimore and relocated their three employees there. The three still remained project leaders on Coop projects, but it became more difficult to monitor progress and timeliness on projects (a USGS mandate) because of the distance factor. By the end of the period, the number of Coop projects was less than one-half of what was done with MGS 15 years earlier. The two agencies still remained close, but the joint program was not as large.

Maryland is one of the smallest States in areal extent at about 10,000 square miles and 23 counties. Long before the period began, MGS and USGS embarked on a program of doing 3- and 4-year county studies. The main objective of these studies was to systematically upgrade the base of hydrologic information in all 23 counties in the State over a period of several decades. The funding split for these studies was typically 25 percent county, 25 percent MGS, and 50 percent USGS. Technically, the studies included surface-water, ground-water, and water-quality components. The surface-water component included new stream gages at locations that were ill defined for flow and also low-flow networks for computing low-flow statistics. The ground-water component included extensive well inventories and new observation wells in areas that were not well defined; in many studies, new wells were drilled. The water-quality component usually was a network of wells and streams where samples to be analyzed for inorganic chemicals were collected. If funding was sufficient, pesticide samples would be collected once during the life of the project. In some cases, small watersheds were studied in more detail to attempt to better understand local hydrologic problems; late in the period, modeling became an integral part of the projects. The final products of the investigations were technical reports that were published in the MGS report series. During the period, investigations were completed in Anne Arundel, Cecil, Charles, Frederick, Harford, Howard, Kent, Queen Anne's, Somerset, and Washington Counties. USGS personnel who worked in the MGS interpretive program during the period were Laurence J. McGreevy, Kenneth R. Taylor, Edmund G. Otton, David H. Carpenter, Larry J. Nutter, James M. Weigle, James F. Williams, Michael J. Smigaj, John T. Hilleary, Richard E. Willey, Leon J. Bachman, Francis H. Chapelle, James R. Dine, John M. Wilson, Tracey M. Curley, Roger J. Starsoneck, James M. Gerhart, Ray G. Davis, George L. Zynjuk, Dan D. Edwards, James C. Adamski, Mark R. Danner, Vicki E. DeFries, Michael E. Wieczorek, Kurt C. Hinaman, Patricia L. Wilbanks, Joel E. Dysart, William H. Werkheiser, Martha A. Hayes, and Frederick K. Mack.

In about 1990, the Department of Natural Resources took a stronger stance in prioritizing the work of MGS and, in effect, the Coop program. The priorities for the MGS program changed from the county study concept to particular areas of concern such as saltwater intrusion and water-supply problems. Specifically, work was diverted to study saltwater intrusion in the Ocean City and Anne Arundel County areas in Maryland, both growing areas whose water supply depended on ground water that already was being stressed by invasion of saltwater due to deeper cones of depression in the aquifers from continually heavy pumpage. Ground-water modeling studies were initiated in both Ocean City and Anne Arundel Counties that involved both quantitative and solute transport modeling. The modeling in Ocean City was done by Jon Achmad (MGS), and the Anne Arundel project was headed by William B. Fleck. For the Anne Arundel project, Barry S. Smith, a Virginia District employee, produced a ground-water solute transport model that was linked with Fleck's quantitative ground-water flow model.

Delaware Geological Survey Program

The DGS' main interest in the Coop program was to maintain a viable stream-gaging program, which was where most of their resources were directed. Each year during the period, DGS contributed about $40,000 toward an interpretive project. MD-DE-DC matched that amount to make the project about $80,000. In 1979, that amount supported a project chief almost full time, but by 1994 inflation set in so that the project could only support a person for about 6 months; thus, the program only generated one-half the technical information. In the years before 1979, DGS interests were mainly in characterization of aquifer systems such as the Potomac, Cheswold, and Piney Point aquifers. In 1979–80, Arthur Hodges completed a ground-water modeling study of the Manokin aquifer. That was one of the last quantitative ground-water studies done in the DGS-USGS Coop program. DGS became somewhat disillusioned with ground-water-flow models as USGS could not always readily reconstruct them for use in later years. Also, DGS wanted to redirect the program to study water quality in the water table aquifer. Starting in 1980 and continuing through the end of the period, the program was directed to determining the effects of agriculture and septic systems on the quality of water in the surficial aquifer system. Judith M. Denver was the Project Chief on all of these projects, which produced a significant number of reports on water quality in agricultural areas. In 1986, the Delmarva NAWQA study began, and combining efforts with the DGS-USGS Coop studies benefited both projects. Others who partici-

pated in the DGS-USGS Coop program were Wayne A. George, William H. Werkheiser, George A. Phillips, Susan Westover, Daniel J. Phelan and Deborah (Roy) Bringman.

Regional Studies

Chesapeake Bay

The USEPA Regional Office in Philadelphia began an effort in 1981 to develop a Chesapeake Bay Program. The program headquarters was located in Annapolis, Md. The purpose of the program was to bring together those parties that may have some influence on helping to mitigate the rapidly declining water quality of the bay. The major participants were the USEPA, who took the lead, the States of Pennsylvania, Maryland, and Virginia (New York, West Virginia, and Delaware chose not to participate), the District of Columbia, a number of Federal agencies, academia, and a host of local agencies and interested parties. The program contained an executive committee that consisted of the administrator of the USEPA, the governors of Pennsylvania, Maryland, and Virginia, the mayor of the District of Columbia, and the chairperson of the Chesapeake Bay Commission. Annually, the executive committee would address the Chesapeake Bay community with broad goals for reducing contamination in the bay. The goals were developed and enacted by an Implementation Committee, which was made up of high-ranking State, Federal, and local agency members. The USGS was asked to serve on the Implementation Committee. The first USGS representative was Ward W. Staubitz from MD-DE-DC. He was later replaced by Herbert J. Freiberger and David Grason, from MD- DE-DC, who alternated attending the monthly meetings. The USGS limited its input to technical information. Scott W. Phillips became the USGS representative late in the period and became the USGS Bureau Chesapeake Bay Coordinator in 1996 when USGS put about $1.2 million of Federal funding into work associated with the bay. The Chesapeake Bay Program structure also had several technical subcommittees on which USGS participated.

River Input Study

The river input study began in 1982 as a data-collection program to determine loads of water-quality constituents coming into the Chesapeake Bay from the Susquehanna, Potomac, Patuxent, James, and Choptank Rivers. The stations were funded by the States of Maryland and Virginia. In about 1985, Virginia funded four more stations on the Rappahanhock, Mattaponi, Pamunkey, and Appomatox Rivers. As the data bases grew in years, the information from these stations became some of the most important in the entire Bay Program. Not only did it quantify water-quality loads entering the bay, but it also served as the only real water-quality data used to construct, calibrate, and run a baywide watershed model. The data were used to define trends in nutrient loads, primarily nitrogen and phosphorus. In the early 1990's, the river-input data bases served as the foundation for other studies to look at water-quality conditions. The most notable study was a tri-State basinwide effort to locate the areas in the watershed that contributed the largest amounts of nutrients and the sources. The study combined the river input stations with the rest of the known water-quality information in the watershed that also had streamflow information. The study was headed up by Michael Langland of the Pennsylvania District, and the report of the study was a best seller in the Bay Program community. The data base also allowed the USGS to develop a load-estimator model to determine loads for the bay stations when actual data were not available. Tim Cohn, from national USGS Headquarters, headed up the effort. Those who worked on the river input study were Zynjuk (Project Chief), Noah, Feit, and Brower.

Delmarva NAWQA

The Delmarva NAWQA was one of seven 6-year national pilot projects that began in 1986. It was one of three ground-water pilots. With the help of then Regional Hydrologist, Stanley P. Sauer, the District recruited Robert J. Shedlock of the Indiana District to lead the project. The project area was the entire Delmarva Peninsula, which includes parts of Delaware, Maryland, and Virginia. The objectives of the project were to (1) describe present water-quality conditions, (2) define long-term trends in water quality, and (3) identify, describe, and explain factors that affect water-quality conditions and trends. The project was well funded (about $1 million in each of its 3 peak years). As a result, it was also well staffed. In addition to Shedlock, the project team consisted of Pixie A. Hamilton of the Virginia District, Judith M. Denver, Patrick J. Phillips, Leon J. Bachman, Roger J.

Starsoneck, William S. Banks, Michael T. Koterba, and Martha A. Hayes. The Delmarva study was always in the limelight as it was close to Reston and was producing good results. Headquarters wanted to showcase the results to help secure funding for the NAWQA Program after the pilots were completed. As a result, Shedlock and other project members were continually making presentations to a wide variety of audiences including members of Congress. The project succeeded in accomplishing the objectives and in addition developed relationships between soils (and their drainage characteristics) and ground-water quality. They referred the different soil-type areas as hydrogeomorphic regions. The project also developed a data-storage system and a quality-assurance/quality-control system that later was used by other NAWQA projects.

Potomac NAWQA

The Potomac NAWQA project headed by James M. Gerhart started in 1991 and was designed to satisfy the same objectives as the Delmarva pilot except that it looked at surface-water quality, ground-water quality, and biology. Project members included Joel D. Blomquist, Janet M. (Depew) Denis, John W. Brakebill, Humbert Zappia, Gary T. Fisher, Matthew J. Ferrari, Bruce A. Bernard, Stephen J. Maskol, Scott W. Ator, William H. Werkheiser, and James R. Jeffries. The Potomac NAWQA was complicated by many factors that affected water quality. The Potomac basin included parts of five physiographic provinces (coastal plain, Piedmont, valley and ridge, Blue Ridge, and Appalachian), all of which affected water quality differently. In addition, there were many different land uses (crop farming, urban, suburban, cattle operations, poultry operations, and coal mining) that all affected water quality differently. It was considered impossible to address all the above variables in one 6-year project, so the project, while collecting various information from all physiographic provinces, concentrated on agricultural operations in all provinces. The project produced many maps showing the areal concentrations of many water-quality constituents in the basin. Extensive use was made of a geographic information system (GIS) throughout the project period.

Regional Aquifer-System Analysis (RASA)

Northern Atlantic Coastal Plain RASA

In 1979, the USGS undertook a major Federal effort to analyze the 27 most extensive aquifer systems in the Nation. One of the systems was the Northern Atlantic Coastal Plain aquifer system, which extended from Long Island, N.Y., to North Carolina. Each of the WRD Districts in that unit (New York, New Jersey, MD-DE-DC, Virginia, and North Carolina) were funded to do similar tasks for analyzing the system in their States; then a regional team located in Trenton, N.J., pulled the information together to produce a regional report characterizing the entire aquifer system. The MD-DE-DC part of the project was led by William B. Fleck and included Leon J. Bachman. The result of the project was a ground-water flow model of the Delaware and Maryland coastal plain and a report of the investigation for the local area. The modeling results were sent to the Trenton office for consolidation.

Appalachian-Piedmont RASA

In about 1990, the Appalachian-Piedmont RASA project began and was headquartered in Richmond, Va. The project extended from New York to Alabama, and many of the Districts were funded to do various aspects of the work plan. The MD-DE-DC part of the project was to develop a ground-water flow model in a small hard-rock basin, a difficult task because very little modeling had been done in fractured rock basins. The District recruited James R. Nicholas, a veteran USGS employee who had just completed a year of graduate school at Stanford University through the USGS graduate school training program. Nicholas, who was Project Chief, and Kurt C. Hinaman developed the model in Howard County, Md. The model was a technical success as it enhanced MD-DE-DC's state of knowledge of fractured flow modeling.

Topical Interpretive Water Projects

Tri-State Bridge Scour Project

In 1989, the District began a tri-State bridge scour project with the Departments of Transportation in Delaware, Maryland, and Virginia. The funding split per year was USGS $60,000 and each of the

States $20,000. The major purpose of the project was to attempt to measure the amount of channel scour during storms. R. Peter Hansen was the first Project Chief until his resignation in 1990. Donald C. Hayes of the Virginia District served as Project Chief until the project ended. The project required bridges with specific types of openings to correlate results. Not many of these types of bridge openings existed in Maryland and Delaware, and as a result most of the measurement sites were in Virginia. Most of the more useful information came from a gaging station on the Pamunkey River at Hanover, Va.

Maryland Bridge Scour Potential Project

In 1991, the Maryland State Highway Administration (MSHA) approached the MD-DE-DC office about doing a bridge-scour potential assessment of all of the approximately 900 bridges in the State. The USGS accepted the project, which was funded mostly on an unmatched basis by MSHA. A huge bank of hydrologic and hydraulic information was collected for each bridge by county. The data were then analyzed, and all bridges were ranked by USGS and MSHA employees with respect to potential for scour and failure. A few bridges needed emergency service by MSHA to correct dangerous scour problems. Co-Project Chiefs were Bernard M. Helinsky and Edward J. Doheny. James R. Dine also worked on the project.

Flood Frequency

In Maryland, flood-frequency equations were developed to estimate the magnitude and frequency of floods in the State. David H. Carpenter developed the equations in the late 1970's and early 1980's. They were refined in the early 1990's, again by Carpenter, just before his retirement in 1994. The surface-water network had weaknesses in southern Maryland and the Delmarva Peninsula. These same areas had the highest errors of estimate for predicting floods. Cooperators for the Maryland flood-frequency studies were MGS and MSHA.

In 1991, the Delaware Department of Transportation cooperated with USGS to develop regional flood-frequency equations for Delaware. This was a difficult assignment as there were only 14 gaging stations in the State, although a number of Maryland Eastern Shore stations were used in the analysis. Frederick J. Kolberg was Project Chief until he resigned in 1992. Jonathan J. Dillow, a new recruit, completed the project.

Low-Flow Study

Low-flow statistics for the States of Maryland and Delaware were developed in the mid-1980's. All streams having 10 or more years of record and low-flow partial record stations were used in the analysis. Low-flow profiles, which used the 7Q10 streamflow statistics, were developed for both States. Maryland and Delaware used the results to assist them in their waste-allocation computations. David H. Carpenter was the Project Chief.

Drought of 1980–81

A statewide drought occurred in 1980–81 in MD-DE-DC. Less than normal rain fell in the winter and spring of 1980, and then continued low rainfall in 1981 caused streamflow and ground water to decline well below normal levels statewide. The drought provided an opportunity to obtain low-flow measurements to assist the analysis in low-flow investigations. Due to lack of funding, the low-flow network was never measured again during the period.

Time-of-Travel Studies

During the 1960's, personnel from MD-DE-DC conducted time-of-travel studies using Rhodamine-B dye in the Potomac River Basin, which covers most of the western shore of Maryland. Studies were done on the main-stem Potomac, Conococheague, Monocacy, and Antietam watersheds. In the mid-1980's the Interstate Commission for the Potomac River Basin (ICPRB) asked the USGS to complete the study by conducting a high-flow run on the Potomac River main stem and a complete two-level flow run on the Shenandoah River in Virginia to complete the network. The studies were led by Robert W. James, Jr., and personnel from the Maryland and Virginia District Hydrologic Data Sections. The ICPRB used the data to develop a computer model that would predict the time of a leading edge, peak, and trailing edge of a contaminant that might be spilled into the basin at any point. They were then able to warn downstream water suppliers to turn off their intakes at appropriate times to avoid pulling in the contaminated water. Kenneth R. Taylor pulled the data together and analyzed it and produced a state-of-the art report on time-of-travel techniques.

Baltimore Urban Hydrology Study

In 1979, the USEPA funded studies in several cities to determine the quality of urban runoff on a national basis. Baltimore was one of the cities that was chosen, and MD-DE-DC was chosen to conduct the study. Brian Katz and Gary Fisher led the study, and Rene Delise and members of the hydrologic data section provided sampling support. Samples were collected for organic and inorganic constituents as well as oils and greases. There were four sites in downtown Baltimore. The sites were pipe storm drains that were equipped with automatic water-quality samplers and meters to calculate flow. One of the sites, Biddle Street, was a 29-foot-diameter storm drain that was accessible by a street manhole cover requiring a 30-foot descent by ladder to sample and measure flow. The Baltimore project, along with others in the Nation, provided an assessment of water quality in highly urbanized environments.

Acid Rain

In the mid-1980's, the USEPA, the Maryland Department of Health and Mental Hygiene, and the MD-DE-DC cooperated on a study to determine the effects of acid rain on the quality of water in Maryland. There was an interest on the part of the Northeastern Region Research group to conduct the study. The District recruited Karen C. Rice from the University of Virginia to be co-Project Chief with Owen Bricker. The study area was in the Catoctin Mountain chain in the vicinity of Camp David, Md. Wet and dry precipitation collectors were located at several sites. Results of the study provided data that showed acid rain was polluting streams in Maryland as much as anywhere in the Nation. pH as low as 4.2 was measured.

Acid-Mine Drainage

The USGS, in cooperation with MGS, conducted a study in the early 1980's to study the effects of acidic mine drainage resulting from the Metikki mine in western Maryland. The Project Chief was Mark Duigon of the MGS. The study plan was to sample various outflows from the mine for inorganic constituents and metals and with a special emphasis on pH of a number of streams that could be affected by outflows from the mines. The results showed that the outflows were highly acidic and orange. The contamination prevailed for miles downstream until buffering from clean water diluted the contaminants. The mine went out of business in the late 1980's, and undesirable conditions subsided somewhat.

Ground-Water Effects from Stormwater Detention Ponds

In the mid-1980's, the concept of implementing stormwater detention ponds at new construction projects gained much environmental popularity. The concept was to build a pond that would capture the initial runoff of a storm (up to a 2-year event). The pond was intended to trap sediments and a variety of contaminants from the first flush of a major rainstorm. The Maryland Department of the Environment, through the MGS, and the USGS conducted a study to determine how much of the trapped contaminants would seep through the bottom of the storm ponds into the ground-water system. The project established three study sites for research. One was a storm pond in an urban coastal plain environment in Annapolis, Md. The site was instrumented with wells and samplers, upgradient and downgradient from the pond, which were sampled before, during, and after storms. Another site was in a shopping center in a Piedmont environment in Carroll County, Md. Similar sampling techniques were implemented. The third site was slightly different as it tested a new technique, porous asphalt paving, in a parking lot in Prince Frederick in southern Maryland. Results from all three sites showed some impairment to the quality of ground water in the vicinity of the ponds with respect to all water-quality constituents but especially chlorides from road-salting operations. Franceska Wilde was the Project Chief with technical assistance from Brenda L. Feit and David P. Brower. The results of the project were published in a report of investigations in the MGS report series.

Patuxent River Benthic Flux Study

Results from Chesapeake Bay Studies determined early on that nitrogen and phosphorus were major contaminants in the decline of the environmental health of the bay. One of the theories was that a large source of the nitrogen and phosphorus was from releases of the elements from the benthic sediments in the tidal zones of tributary streams and the bay itself. In 1982, the Maryland Department of Health and Mental Hygiene, through MGS, and the USGS conducted a project that would attempt to quantify

releases of nitrogen and phosphorus from sediments in the lower tidal Patuxent River in southern Maryland. Although the Patuxent River was not a major tributary to the bay, it was always considered a microcosm of the bay because as a system it acted like the bay. Ward W. Staubitz was chosen to be Project Chief and was supported technically by James J. Manning, Daniel J. Phelan, and Rene Delisle. Staubitz left the District in 1983 to enter the USGS graduate school training program at Cornell University. He was replaced by Bruce M. Lantrip. The technique used to test for nitrogen and phosphorus was developed by Theodore Callender of the USGS Northeastern Research group in Reston, and he became part of the project. The technique involved deploying a chamber into the river to isolate a segment of the sediments and then continually pump water and analyze for the nutrients over a predetermined period of time. The chambers were deployed from a 47-foot research vessel, the RV *Discovery*, which MGS contributed as direct services. The results of the project showed that the benthic zone was a significant contributor of nitrogen and phosphorus. However, later research showed that the more important issue was that the nitrogen and phosphorus initiated from sources in the upper watershed.

ABERDEEN PROVING GROUND PROGRAM

In 1984, the U.S. Army at Aberdeen Proving Ground (APG), Maryland, approached the USGS at MD-DE-DC to assist them in their goal to determine the degree and extent of ground- and surface-water contamination at its army base landfills and to develop hydrologic remediation techniques if applicable. The landfills at Aberdeen were different from ordinary trash fills in that they potentially contained highly toxic chemicals such as trichloroethylene, mustard gas, and agent orange as well as unexploded ordinance. MD-DE-DC management thought long and hard before accepting the project due to safety concerns for its employees who would have to work at the base. During the period, APG offered the District about $1 million per year to do work at landfills, namely 'O' Field, Carroll Island, Graces Quarters, 'J' Field and Canal Creek. Some of the unusual safety procedures that had to be implemented before even setting foot at the site, not the landfill itself, were mine sweeps by the Army to detect unexploded ordinance, the wearing of special tyvec clothing, medical surveillance before, during, and after the project, and remote drilling at least at one site, 'O' Field. Remote drilling entailed setting a specially equipped drill rig, operated by the Corps of Engineers, at the desired site for a well. The rig was operated remotely by appropriately clothed personnel watching the operation on closed circuit TV from the confines of a bomb shelter located several hundred yards from the operation. Studies at all the sites entailed setting up ground-water flow networks, which entailed significant drilling (not all remote), developing ground-water flow models, analyzing the systems, and in some cases evaluating hydrologically based remediation efforts such as pump-and-treat scenarios that used different inputs to the calibrated model. These scenarios were designed to pump out the trichloroethylene from the landfill. While the work on all the sites was technically challenging and exciting, work at 'O' Field and Canal Creek provided some work that was strictly cutting edge research. For example, at 'O' Field Don A. Vroblesky, with help from Thomas Yanosky of the Northeastern Region Research Group, developed a method of analyzing tree rings in selected trees at specific distances apart for selected chemical parameters. When graphed, times (years) of peak concentrations of constituents could be determined for each tree. Comparison of results of up-and-down gradient trees could determine how long it took for the constituent to travel a certain distance in the ground-water flow system. This allowed for the development of a coefficient of dispersion, an important variable in a ground-water flow model. At Canal Creek, Michelle Lorah-Devereux conducted novel research in developing methods for analyzing for toxic constituents in ground and surface waters in marsh environments, tidal and nontidal. She developed a network of hundreds of small-diameter wells sampled with specially built pumps that remained at each individual site. Many publications on marsh dynamics were published as a result of the project. Project Chiefs for the APG program were Don A. Vroblesky, Michelle Lorah-Devereux, Wayne H. Sonntag, W. Brian Hughes, Fred J. Tenbus, and Scott W. Phillips. Others who provided technical analyses, data collection, and logistical support were James R. Dine, Ronald A. McGregor, James P. Oliveros, E. Randolph McFarland, Lisa K. Ham, Brian N. Johnson, Jeffrey S. Clark, Hallie S. Westbrook, Fritz C. Kessler, Peggy R. Nemoff, Patrice Gernhardt, James G. Acker, Mastin M. Mount, Colleen A. Donnelly, Martha L. Cashel, Daniel J. Phelan, Joseph E. Beman, Elizabeth H. (Riley)

Marchand, Denise M. Coutlakis, and Randy L. Paylor. The APG program was perhaps one of the most technically and logistically demanding and exciting programs that the District had during the period. As mentioned earlier, the program brought in almost $1 million per year in income and provided a large number of hydrologists and technicians the opportunity to do good science.

Mid-Atlantic District Pilot, 1983–91

In 1983, WRD Headquarters was looking for ways to get Districts to look across State lines, to do more regional studies, and to share resources, both human and material. To do this, they merged three pairs of Districts and picked one District Chief to head each of the three merged pilot Districts. The pairs were Washington and Oregon, which became the Pacific Northwest District, Idaho and Nevada, which became the Idaho-Nevada District, and MD-DE-DC and Virginia, which became the Mid-Atlantic District (MAD). Herbert J. Freiberger was selected to be the District Chief of MAD, which was housed in the MD-DE-DC District Office in Towson, Md. Each of the three States became State offices of MAD, and each had a State Office Chief. They were Arthur L. Hodges in Delaware (later Gary N. Paulachok), David Grason in Maryland, and Gary S. Anderson in Virginia. The District established a District Advisory Committee (DAC), which included the management staff from all three Districts as well as reports personnel and a technician. The main purpose of DAC was to prioritize those areas where all three or at least two of the programs should strive to work together more. Some of the things that were done were to share a water-quality specialist (Dennis D. Lynch from Virginia), when appropriate, to assign personnel from one State to be a Project Chief in another State (example: John D. Powell from Virginia was assigned as Chief of the Andrews and Bolling Air Force projects in Maryland), and to coordinate the USGS Chesapeake Bay Program activities in Maryland and Virginia as one.

Mid-Atlantic Program Area, 1991–94

In 1991, the WRD installed the Area concept, in which the Nation was divided into 16 areas composed of groups of Districts. The MAD joined with the West Virginia District to form the Mid-Atlantic Programs (MAPS). The State offices of the previous MAD returned to District status with District Chiefs. The Delaware State Office returned to Subdistrict status. The MAPS was headed by an Area Assistant Regional Hydrologist (AARH), and Herbert J. Freiberger was selected for the position. David Grason and Gary S. Anderson were selected for the District Chief positions in MD-DE-DC and Virginia, respectively. David P. Brown was the District Chief in West Virginia. The objectives of the Area concept were similar to those of the pilot District mergers mentioned earlier. A Program Area Council (PAC) was implemented with similar membership and visions as the previous DAC. PAC agenda items included program development, technical specialists, and communication among the three Districts as its highest priorities. The positives of MAPS included full-time shared specialists, more multistate projects, and a slight increase in West Virginia's program, which historically struggled to make ends meet. The negatives were no savings in money, continued provincialism, and the 6-hour drive to Charleston, W. Va., which precluded a lot of one-on-one consultation. WRD Headquarters eliminated the AARH positions in the summer of 1994. Mixed reviews on the success of the Area concept aided their decision.

MASSACHUSETTS

By Ivan C. James II

INTRODUCTION

In 1979, during the reorganization of the New England District, the Massachusetts Subdistrict was established with Michael Frimpter as Chief. In the fall of 1979, the sudden accidental death of John Baker, the New England District Chief, delayed the District reorganization as Patrick Walker, New England Assistant District Chief, and Michael Frimpter had to cover the responsibilities of District Chief as well as their regular assigned jobs. This they ably did, pending the arrival of Ivan James as District Chief in July of 1980. Frimpter continued to manage the office until he transferred to the New England District Office in 1990. Frimpter was replaced by Michael Yurewicz who continued in that position until mid-1994 when he transferred to the Northeastern Region Office and was replaced in late 1994 by Wayne Sonntag.

The New England District Office and the Massachusetts Subdistrict were collocated on the

10th floor of the Analex Building at 150 Causeway Street in downtown Boston, Mass. The Geologic Division was closing down its offices on the 13th floor in late 1980 and with some space trading with the General Services Administration, gave the WRD office the opportunity to expand into other space on the 13th floor. The Massachusetts office moved to 28 Lord Road in Marlboro, Mass., in the spring of 1989 where it remained through the period, adding proximate space as the program grew.

The Massachusetts Subdistrict was renamed the Massachusetts State Office in the latter part of fiscal year 1982 and retained that designation until the reorganization of the WRD into Areas early in fiscal year 1991 when it became the Massachusetts/Rhode Island District. Michael Yurewicz had been selected Massachusetts State Office Chief, but upon his arrival with the new organizational structure his position was redesignated as Chief of the Massachusetts/Rhode Island District.

In 1979 the program consisted of a stable data-collection program of approximately 120 gaging stations, 34 observation wells, 6 multiparameter water-quality monitors, and a hydrologic studies program that focused on integrated ground-water, surface-water, and water-quality studies in each of the 23 geographic areas (usually river basins) in Massachusetts. Each of these studies culminated in a hydrologic atlas report. These reports were highly valued by water planners and the consulting community and provided a baseline of hydrologic information for planning and water-management decisions as well as the baseline hydrologic information required to do further modeling and water-management studies. In 1980, the Massachusetts Legislature passed Chapter 800, which established a $2.5 million bond fund to be matched by the USGS for a 10-year program of detailed ground-water appraisals, aquifer assessments, and other studies required to protect existing sources of ground water and to identify new sources. The projects that resulted from this funding had a significant effect on the size and direction of the program for the next 10 years.

ORGANIZATION AND MANAGEMENT

In 1979, the Massachusetts program staff included Michael Frimpter as Chief of the Hydrologic Studies Section with 13 permanent staff and 6 students, Ernest Denison, Chief of the Hydrologic Records and Information Section with a staff of 3, Norman Roy as Chief of the Boston Subdistrict Office (essentially the data Field Office) with a staff of 11, and William Silvey as Water-Quality Specialist. Minor administrative services were provided for two researchers, Dr. Charles Mongan on the MIT campus and Francis Kohout on the Quissett Campus at Woods Hole.

With the 1979 reorganization completed, Michael Frimpter appointed as the Massachusetts Subdistrict Chief and with the retirement of Ernest Denison, two positions remained to be filled: the Data Section Chief and the Studies Section Chief. In 1980 Russell Gadoury was selected a Data Section Chief, a position that he filled throughout the rest of the period covered by this history. Richard Brackley served as the acting Studies Section Chief until his retirement in 1983, followed by the appointment of Julio Olimpio who had transferred from Illinois as a Project Chief. Loretta Kwiatkowski was hired as the Subdistrict Clerk, later to be replaced by Beverly Raney. Late in the period, Julio Olimpio resigned and was replaced as Hydrologic Studies Section Chief by Kevin Dennehy. The studies section was divided into a Resource Assessment and Modeling Section, which Kevin Dennehy continued to supervise, and an Environmental Studies and Research Section, which was supervised by Michael Norris. When Dennehy transferred to Denver, the studies sections were combined under Norris, who later became the Assistant District Chief for Hydrologic Research and Data, managing the Highway Runoff Unit led by Peter Church, the Basin Hydrology Unit led by Kernell Ries III, the Surface Water Hydrology Unit led by Gene Parker, the Water Quality and Geochemistry Unit led by John Colman, the Hydrologic Studies Support Unit led by Gerald Girouard, and the Data Network and Operations Section supervised by Russell Gadoury.

At the end of the period the studies area required a staff of 43 permanent people and 21 students, most of whom were contracted Ecological Associates or student trainees. The Data Networks and Operations Section had seven permanent staff and two students. These organizational adjustments were made to accommodate the needs of program, specialization, and supervisory control. The Connecticut Basin NAWQA Section, led by Steve Garabedian, the Administrative Services Section, the Illustrations and Publications Unit, and the Computer Applications Unit were managed by the District Chief.

Administrative services initially were provided by the New England District Administrative Services Section. In 1984, JoAnn Kent was assigned as a Clerical Assistant for the Massachusetts State Office. In 1989 Jane Sturtz (later Cannarsa) was hired as a Budget Analyst for the office and later was selected as the Administrative Officer when the Massachusetts Office became a District. Diane Lumbert later transferred to the Section and Diane Shields also was hired. Henry Garland was the Clerk-Typist at the end of the period.

With the devolution of the New England District into the Northeast Program Area office in 1991, the Massachusetts/Rhode Island District took on some responsibilities for the Program Area including the Illustrations Unit, staffed by Kenneth Judd, Christine Mendelsohn, and Bruce Weinstock; the Publications Unit, staffed by Marianne Orlando and Diane Barrett; and the Computer Applications Unit, managed by the District Chief. Later Linda Rogers was brought in as District Reports Specialist and the Publications and Illustrations Units combined. Computer services were originally provided by the New England District, but later Jeff Strause was assigned as Computer Specialist, assisted by a number of short-term details. Edna (Jessie) Alvarez hired into the Unit, to eventually become the Unit Chief when Strauss went back to project work. George LeMay also worked in the Unit.

Personnel

At the beginning of the period, the Hydrologic Studies Unit was composed of Michael Frimpter, Richard Brackley, Eugene Walker, William Wandle, David Delaney, Frederick Gay, Bruce Hansen, Denis LeBlanc, Samuel Pollock, Bruce Krejmas, Anthony Maevsky, Barbara Ryan, Robert Fowler and several hydrologic field assistants. Ernest Denison, Donald Fogarty, and James Linney composed the Hydrologic Records and Information Section. Norman Roy, Russ Gadoury, Jerry Girouard, Bill McDonough, Hubert White, William Caswell, Diane Letty, Mark Peterson, Kernell Ries III, and James Adamik made up the Boston Subdistrict Office, which in 1980 became the Hydrologic Data Collection and Analysis Unit.

During the period there were many staffing changes. Denison, Krejmas, and Silvey transferred, the latter being replaced as Water-Quality Specialist by John Briggs. Fogarty, Walker, and Brackley retired in that order. Richard Willey transferred in from Vermont, staying a short time before transferring to the U.S. Environmental Protection Agency (USEPA), starting a movement of hydrologic talent to that agency that was to eventually include David Delaney, William Wandle, Fredrick Gay, and Alan Klinger. Barbara Ryan transferred to Rhode Island to run the investigation of radionuclide transport at the United Nuclear Facility.

With the staffing losses and a growing program, there were many new hires and transfers. In the Hydrologic Studies Section, Virginia de Lima was hired in 1980. David Lang, Steven Garabedian, Gene Parker, Rochelle Rittmaster, John Izbicki, Wayne Lapham, Dennis Kent, Kathryn Hess, and Charles Myette transferred in. Other new hires came and went after completing a project or two; these were Jayne Fifield (later Knott), Valerie Eames, Robert Brock, Alan Klinger, David Johnson, Beth Johnson, Elizabeth Flynn, Nancy Suurballe, Alison Simcox, Sarah Flanagan and James Persky. Julio Olimpio transferred in from Illinois to work on the Mattapoisett Chapter 800 study and was selected as Hydrologic Studies Section Chief. Samuel Pollock, who had been Project Chief on the "highway salting" project, took an Intergovernmental Personnel Act detail to the Massachusetts Department of Public Works and was replaced on the project by a new hire, Peter Church. John Izbicki transferred in to work on the Blackstone Chapter 800 study, later worked on the Induced Infiltration project, and in 1989 became the New England District Water Quality Specialist. In 1987 Tom Trombley, Paul Barlow, Lisa Bratton, and Jeff Strause transferred in. Alison Simcox and Peter Weiskel were hired. In 1988, Kevin Dennehy transferred in as Hydrologic Studies Section Chief, and Jamie Shanley, James Harrington, and Leslie DeSimone were hired.

In 1989 additions to the Resource Assessment and Modeling Section included Kernell Ries III, Gardner Bent, Yvonne Halpern, and Paul Friesz followed by Stephen Coppola and James Cerbone the following year. Additions to the Environmental Studies and Research Section in 1989 included John Risley, Peter Steeves, Harlow Pinson, and Richard (Chip) Quadri. Others who worked in hydrologic studies include Gregory Granato, David Armstrong, Paul Provencher, Kirk Smith, Victoria Stone, James (Jamie) Shanley, Michael Horgan, John Rader, Peter Murphy, Donald Searles, Joseph Whitney, Lance Ostiguy, George LeMay, John Masterson, Donald Walter, John Colman, Robert Lent, Forest Lyford,

Marcus (Cris) Waldron, Joseph Zanca, Robert Casey, and Joan Whitley.

Others who worked in the Hydrologic Data Collection and Analysis Unit (later to become the Data Network Operations Section) were Sandra Maxwell, David Johnson, Robert Brock, Roy Socolow, Dennis Kent, Lesley Rouse, Bruce Krejmas, Thomas Calderini, Mark Dufva, Marcus Root, James Cerbone, Linda Comeau, Charlie Shivers, Jr., Charles Leighton, Tom Shepard, and Domenic Murino.

Funding and Cooperation

At the beginning of the period, the funding for Massachusetts was $1,050,600, roughly distributed as 80 percent in the Coop program, 10 percent Federal program and 10 percent from other Federal agencies. The major cooperators were the Division of Water Resources (DWR) who supported the largest part of the streamflow-gaging network, the ground-water network, and the Hydrologic Atlas studies, of which three might be ongoing at one time. The Department of Environmental Quality Engineering (MDEQE) supported a water-quality monitoring network, some gaging stations, and other water-quality investigations. The Department of Public Works initially funded some gaging stations, and continued to fund projects to investigate the effects of highway salting on water quality throughout the period. This program began to grow significantly with unmatched money in the mid-1980's as a project to determine the effects of different highway construction and drainage systems were initiated. Another significant boost to this program came in the late 1980's when a project to document bridge sites for scour potential was started. Other cooperators included The Cape Cod Commission and Barnstable County. Other minor cooperators came and went during the period, but these Commonwealth agencies continued to be the major joint-funding program cooperators throughout the period.

In 1980 the Commonwealth of Massachusetts passed a $2.5 million bond issue to be matched by the USGS for more detailed ground-water-modeling investigations in each of the 23 identified planning basins in the Commonwealth. The first of these projects was started late in fiscal year 1980. This funding was available for up to a 10-year period and could be expended at any time. The limits on Federal matching funds and staffing were the only constraints on the growth and implementation of this program.

The U.S. Army Corps of Engineers was a steady cooperator throughout the period, funding part of the streamflow-gaging station network and the development and maintenance of high-flow rating curves at

Massachusetts District funds, fiscal years 1979–94

Fiscal year	Federal	Other Federal agency	State and local	Federal matching	Total
1979	$114,200	$113,000	$409,900	$413,400	$1,050,600
1980	$108,000	$111,200	$486,900	$433,500	$1,139,600
1981	$144,800	$122,200	$561,400	$474,100	$1,302,500
1982	$82,000	$85,600	$687,100	$591,500	$1,446,200
1983	$420,800	$142,500	$769,000	$714,400	$2,046,700
1984	$523,600	$149,600	$1,012,700	$855,900	$2,541,800
1985	$564,300	$147,200	$1,026,800	$875,100	$2,613,400
1986	$505,200	$156,300	$1,014,900	$772,500	$2,448,900
1987	$535,100	$386,700	$1,101,400	$828,000	$2,851,200
1988	$371,500	$495,300	$1,300,700	$850,500	$3,018,000
1989	$413,200	$452,400	$1,296,900	$859,800	$3,022,300
1990	$405,500	$446,400	$1,245,900	$670,000	$2,767,800
1991	$736,400	$285,800	$1,414,900	$858,900	$3,296,000
1992	$1,419,100	$677,400	$1,834,800	$962,500	$4,893,800
1993	$1,888,700	$723,000	$2,346,800	$971,600	$5,930,100
*1994	$2,274,300	$1,368,500	$2,788,200	$1,206,900	$7,637,900

*Note, 1994 figures include funding for Rhode Island cost center.

sites for either project planning or for assessing the benefits of a completed project. Their funding, particularly during the latter part of this period, often did not increase as fast as inflation, necessitating the reduction of funded stations or converting them to partial-record stations.

At the beginning of the period, the USEPA made some small direct contributions to a couple of projects on Cape Cod. The funding from this other Federal agency remained small until the middle of the period when programs were developed with the CERCLA (Superfund) and RCRA programs within the USEPA. The CERCLA program grew to a significant size as Superfund sites were identified and investigated. Over the period the National Park Service also supported projects focused on the National Seashore on Cape Cod.

Late in the period, the Massachusetts Air National Guard began funding a series of projects to investigate ground-water flow and water-quality changes that might result from various alternatives for cleaning up the sewage contaminant plume at the Otis Air National Guard Base on Cape Cod. These projects were begun in recognition of the expertise that the USGS had developed during cooperative studies of ground water with the Massachusetts Division of Water Resources and contaminant transport in ground water with the Massachusetts Division of Environmental Quality Engineering. The initial contaminant transport work here also evolved into a research site for the federally funded Toxics Program.

From the beginning program size of about $1,050,000 in 1979, the Massachusetts program had a steady growth, somewhat interrupted by the 1988–90 recession, and continued to grow to a total program size of about $7,640,000 at the end in 1994. This last year includes $510,000 of funding that was added when, for administrative purposes, the Rhode Island Subdistrict Office funding was combined in the Massachusetts/Rhode Island District funding in 1994. At this time the funding had shifted to 52 percent joint-funding program, 30 percent Federal program, and 18 percent other Federal agency program. At the beginning of the period the data program (projects 001 through 007) accounted for more than 50 percent of the Massachusetts program. At the end, growth in the interpretive program and somewhat less than inflationary growth of the data program left the data program with about 20 percent of the total program. Limitations on Federal matching monies for the joint funding program necessitated a large increase in unmatched monies from cooperators. At the beginning of the period there was no unmatched cooperator money, but at the end it had grown to $1.6 million in comparison to about $1 million that was matched.

Notable Programs and Projects

A number of significant projects and programs during the period gave a boost to the growth and the technical complexity of the Massachusetts office. At the beginning of the period, Michael Frimpter, working with Charles Kennedy of the Division of Water Resources and the Commonwealth Legislature, got legislation passed to provide bonding funding for intensive ground-water investigations in the 23 planning basins in the Commonwealth. This legislation became Chapter 800 of the laws of Massachusetts; hence, this program became known as the Chapter 800 program. Funding for each of these studies was sufficient to go the next step beyond the Hydrologic Atlas studies and collect the data necessary for quantitative ground-water flow models in each of the basins. This funding also was used for a project to determine recharge rates to Cape Cod and the islands using tritium age dating. These studies, in turn, laid the groundwork for a subsequent bond-issue funded set of quantitative water planning and management studies.

The completion of a project cooperatively funded by the MDEQE to delineate a primary treated sewage contaminant plume in Cape Cod's ground water provided the background information to use this site at the Otis Air National Guard Base as a nomination for the first round of the federally funded Toxics Program investigations. Denis LeBlanc, who had designed and carried out the original project, was selected to write the proposal for the site nomination in 1982. This site was selected by the Toxics Program, and funding began in 1983. Collaboration was developed with National Research Program (NRP) researchers in several parts of the country, Professor Lynn Gelhar of the Massachusetts Institute of Technology, and other ground-water researchers. More than 1,000 wells, each with 15 multilevel ports for sampling, were installed as a research facility to be used for a number of different studies of contaminant transport in a clean sand/gravel aquifer. LeBlanc became Research Coordinator for the site. Over time he hired a number of hydrologists to work with him on the project: Kathryn Hess, Jennifer Savoie and

Kimberly Bussey. The project continued and grew through the period with funding levels in the $360,000 to $520,000 range. The expertise and exposure gained on this project led to additional projects in 1989–90 and 1992–94 with the Massachusetts Air National Guard. These projects were staffed by John Masterson and Donald Walter and with funding in the $200,000 to $300,000 range.

In 1981 Federal matching money became unavailable for the water-quality monitors being funded by the MDEQE. This local match was reprogrammed into forward-looking research studies to help the MDEQE with their anticipated future management and regulatory needs. This corresponded well with the initiation of the WRD "Merit Funding" program in the joint-funding program. In this program $1,000,000 of Federal matching funds was withheld at Headquarters each year and a competition for these funds based on the scientific quality of the proposed projects was held. Many of the MDEQE projects had advanced scientific objectives that could be addressed by projects that competed well for this "Merit Funding." Massachusetts was very successful in the "Merit Funding" process, winning the largest number of merit-funded projects and the second highest cumulative dollar value of these projects. These projects included studies of rain and dry-deposition chemistry, metabolism of nitrate and sulfate in beaver-dammed streams, effects of storm direction on precipitation chemistry, stream reaeration studies, and a physically based statistical model for flood frequency, the latter done in conjunction with Professor Richard Vogel at Tufts University.

The USEPA Superfund (CERCLA) program that had a modest start at $50,000 in 1985 grew to $200,000 by 1988, over $400,000 by 1992, and over $900,000 by 1993. Notable among the projects done for the Superfund program was an aquifer test and ground-water model of Woburn wells G and H. Julio Olimpio, Chuck Myette, and David Johnson did the report on the aquifer test and Virginia de Lima did the ground-water model. These were to figure significantly in the legal arena surrounding this controversial issue. Competing models were developed for the principal responsible parties by Jack Guswa and Professor George Pinder. The book, "A Civil Action," by Jonathan Haar documented the legal controversy around this issue. The movie of the same name was a less accurate depiction of the case.

The program with the Department of Public Works, the successor name for the old Highway Commission, also had notable growth during the late 1980's and early 1990's. Through 1986 this program had funding of less than $200,000. By 1990 it had grown to over $600,000 and by 1993 was more than $1,500,000. Implementation of a project to determine the effect of highway construction and drainage practices on the fate of road salt gave a boost to program size in 1990. A project to document bridge conditions for bridge-scour analysis, started in 1993, resulted in an even larger growth to this program. Peter Church was Project Chief on the former project and Gene Parker Project Chief on the latter. The bridge-scour project documented channel conditions at 2,417 bridge sites over water in Massachusetts and created water-surface-profile models for 31 bridge sites with existing scour problems. Project staff included Peter Murphy, David Armstrong, Paul Frieze, Jean Campbell, Lisa Bratton, and some students. The final product on the bridge-scour project was an interactive compact disc with documentation for each bridge studied, one of the first such products in the WRD.

In 1991 the Connecticut, Housatonic, and Thames River Basin project in the National Assessment of Water Quality (NAWQA) Program began in the first set of 20 studies. Steve Garabedian was selected as Project Chief and staff hired into the Massachusetts office and utilized from other WRD offices in New England. By the time this project had ramped up to its high-intensity sampling phase in 1993 and 1994, the funding was in the $1.5 million per year range. This project accelerated the movement of the program in the now Massachusetts District towards water-quality studies.

Two reports on estimating high ground-water levels by Frimpter, one for Cape Cod and one for the rest of the Commonwealth, provided a direction for the ground-water basic-data program. With the information in these reports, one could estimate the springtime high ground-water level by measurements at any time of the year at the site in question and at an index well. Once this process was accepted by regulatory authorities, the demand for monthly water-level measurements became apparent to cooperators and resulted in solid support for an expanded monthly ground-water-level data program.

In the mid-1980's the development of Geographic Information System (GIS) skills for illustrations (Elizabeth Johnson) and projects (Julio

Olimpio) led to the formation of the Research and GIS Section in 1987, staffed by Julio Olimpio, Elizabeth Flynn, and Saiping Tso. This Section developed a project with the Massachusetts Office of State Planning to plan and establish a statewide GIS system, including selection of hardware and software, training of staff, and provision of hydrologic coverages. Much of the early GIS talent that developed in the Commonwealth came through, or was trained in or by, the Water Resources Division.

Epilogue

At the beginning of the period, the Massachusetts office was heavily focused on surface-water basic-data collection and the Hydrologic Atlas program, the latter being areal appraisals and heavily focused on ground water. The technology and program were stable though there were no computers in the office. By the end of the period, the program had evolved along with the needs of the cooperators. Areal appraisals, being completed, gave way to quantitative ground-water-modeling studies. These, in turn, set the stage for water-management studies that were to follow. Water-quality studies increased as the period progressed, with most of these projects being applied research. The Federal program grew as the Cape Cod Toxics Program project, the Northeast Glacial RASA, and the Connecticut Basin NAWQA project started. New staff hired to accommodate the expanding program and to replace departing staff brought on new skills and often a higher level of education and advanced degrees. These both broadened and deepened the skills that could be offered to cooperators and made the office competitive in attracting Federal program projects. Advances in word processing, computing, and network technology were implemented, which increased the productivity of the staff and allowed for better collaboration with staff in other Districts and the National Research Program. Implementation of state-of-the-art technology in borehole geophysics, surface geophysics, global positioning, data capture, GIS, and modeling, in conjunction with the new staff skill sets, allowed the office to offer capabilities to cooperators that were unavailable from any other single source. A virtual skill and technological revolution had been accomplished in these 15 years. However in this new world of rapid technological change, this will not be the last revolution, and indeed, the pace and scale of this revolution likely will accelerate.

MICHIGAN

By James F. Blakey

ORGANIZATION AND PERSONNEL

As the period began, the Michigan District Office was in Lansing at 6520 Mercentile Way, Suite 5, and it remained there throughout the period. There were 30 employees in the District Office in 1979 and about 30 employees in 1994. The Subdistrict Office located in Escanaba had a staff of seven people in 1979 and still had six people in 1994. The only Field Headquarters was in Grayling, and it was staffed with seven people in 1979 and had only four people in 1994.

In 1979 the District Staff included T. Ray Cummings as District Chief and Alonzo H. Handy III, Assistant District Chief. The Hydrologists included Floyd R. Twenter, Vincent D. Herreid, Michael G. McDonald, John B. Miller, Lawrence E. Stoimenoff, David J. Holtschlag, Norman G. Grannemann, and James R. Stark. The Hydrologic Technicians included Gary C. Huffman, Robert L. Gordon, Ronald L. LeuVoy, Charles R. Whited, Daniel E. Hitch, Gary L. Morin, Craig E. Oberst, Jerry R. Smithson, Randall J. Coleman, Lloyd C. Van Gordon, Glenn Lansky, Thomas F. Werth, Stephen J. Rheaume, and David P. Van Burgel. The Administrative Assistant was Alice L. Pifer, and she was assisted by Janet A. Brewer, Rita D. Miller, Janet M. Moore, and Denise M. Williams. The Secretary was Beverly A. Kuczera.

The Subdistrict Staff in Escanaba included Gordon Hulbert, Subdistrict Chief, and Hydrotechs Lauritz B. Hough, John L. Oberg, Richard R. Eagle, Clayton L. Ebsch, James M. Ellis, and William G. Fazer.

In the Grayling Field Headquarters, Theodore Sieger, Jr., was Technician-in-Charge. James C. Failing, Neal L. Horning, Russel J. Minnerick, Don A. James, and David H. Erickson were the Hydrotechs. Robert W. Larson, Hydrologist, was located in Grayling but reported to the District Office.

Gordon Hulbert vacated the Subdistrict Chief position in Escanaba in 1980, and the office was changed to a Field Headquarters with John Oberg in charge. Other personnel changes were limited to the continual rotation and decrease of part-time and temporary positions. By 1983, the District Office staff declined to about 20 and remained at that level through

1984. In 1985, a Regional Aquifer-System Analysis (RASA) team was established in Lansing under the Office of the Regional Hydrologist, Northeastern Region. The staff included Richard J. Mandle, Gary Dannamiller, and David B. Westjohn. By 1988, the RASA staff had grown to eight with the addition of five temporary technicians.

Floyd Twenter, Chief of Hydrologic Studies, retired in 1987 and was replaced by Robin G. Brown. John Miller, Chief of Network Operations, also retired in 1987 and was replaced by Stephen Blumer. In 1988, Robin Brown transferred to New York and Norman Grannemann became Chief of Hydrologic Studies. Grannemann replaced Mandle as Chief of the RASA program in 1990. The Hydrologic Studies position remained vacant until 1994 when James Nicholas transferred from Maryland.

After about 20 years as Michigan District Chief, Ray Cummings retired in 1991. He was replaced by Cynthia Barton. In 1993, Stephen Rheaume moved from the Hydrologic Studies Section to the Western Lake Michigan NAWQA unit as the Staff Biologist, but he remained in the Lansing office. The staff and program were very stable through the period. The District Office staff included Barton as District Chief, Nicholas as Chief of Studies, and Blumer as Chief of Operations. Kathy Maybee was the Administrative Officer, and her staff included Donna Hummel, Rose Corey, and Denise Harig. The Hydrologic Studies Section staff were David Holtschlag, John Gillespie, Michael Sweat, Gary Huffman, Sharon Baltusis, John Brannen, Erin Lynch, Clifford Winchester, Michael Kohn, and Carol Luukkonen. The Network Section staff were Thomas Behrendt, Ronald LeuVoy, Charles Whited, Craig Oberst, Paul Klimak, Glenn Lansky, Daniel Wydra, and Todd DeWitt. The Field Headquarters in Escanaba staff were Wallace Larson, Supervisory Hydrologic Technician, and Richard Eagle, Clayton Ebsch, James Ellis, John Knudsen, and Mary Soper. In the Grayling Field Headquarters, Russel Minnerick was Supervisory Hydrologic Technician and the staff were Don James, Robert Nettleton, and Jeffrey Walters.

Michigan is a small District in terms of staff and funds. Funding did not reach $2 million until 1987. The program was about 70 percent Coop (Cooperative program) with State and local funds and Federal matching funds totaling $1.1 to $1.5 million. The Federal program remained at about $0.2 million through the period. Funding from other Federal agencies (OFA) was primarily from the U.S. Army Corps of Engineers and the Military Installation Restoration Program. State cooperators were Michigan Departments of Agriculture, Natural Resources, and Transportation. Local agencies included the cities of Ann Arbor, Battle Creek, Clare, Coldwater, Elsie, Flint, Imlay, Kalamazoo, Lansing, Mason, Portage, St. Johns, Ypsilanti, Cadillac, Negaunee, and Norway; and the counties of Branch, Dickinson, Genesee, Macomb, Oakland, Otsego, Van Buren, Grand Traverse, Kalamazoo, and Wayne; and Michigan Tech University.

HYDROLOGIC DATA PROGRAM

The Michigan District program was more than 60 percent hydrologic data collection. The District operated 130 to 150 continuous surface-water discharge stations each year from 1979 to 1994. Water-quality data were collected at 20 to 25 stations each year, and sediment data were collected at about 20 stations per year. From the beginning of the period to the early 1990's, at least 175 wells were in the ground-water-level network. The number of wells declined to 120 in 1991 and to 60 in 1994. Water-quality data were collected at 15 to 20 wells per year.

HYDROLOGIC INVESTIGATIONS

The Michigan District published 110 reports during the period, and about 50 were interpretive reports. In the 1980's, Cummings and others authored several reports on the hydrology of Michigan including chemical and physical characteristics of ground water, traveltime studies, dissolved and suspended substance yield to stream basins, and county studies. Grannemann and others authored more than 10 reports throughout the period on ground water and geohydrology, including ground-water for public supply at Windigo, Isle Royale National Park, and the water resources of the Marquette Iron Range area. Holtschlag and others also authored more than 10 reports on surface water of Michigan. Studies include statistical models for estimating daily streamflow, flow model of the Saginaw River, and changes in stream quality in urban areas.

Westjohn and others authored 12 reports on geohydrology including geophysical and hydraulic properties of Pennsylvanian and Mississippian sandstones, and the use of geophysical logs to delineate the

position of freshwater/saline-water interface. Grannemann and Cummings authored a report in 1987 on the Installation Restoration Program at K.I. Sawyer Air Force Base. Cummings, Gillespie, Holtschlag, Stark, and Twenter authored four reports on the Installation Restoration Program at Wurtsmith Air Force Base.

NEW HAMPSHIRE–VERMONT

By Ivan C. James II

INTRODUCTION

At the beginning of the period, the New Hampshire-Vermont Subdistrict office was located in the Post Office building at 55 Pleasant Street near downtown Concord, N.H. Charlie Hale, as Subdistrict Chief, supervised a program of approximately 40 gaging stations in New Hampshire, 35 in Vermont, one ground-water project in New Hampshire, a ground-water data program in Vermont and a water-quality project on the Black River in Vermont. Total program size was about $470,000 of which the majority was in the data program.

John Cotton was the Project Chief of the intermediate, 1:48,000-scale, Lamprey River Basin ground-water study. This was followed by the Cocheco River Basin ground-water study. These studies were designed to improve the hydrogeologic mapping of important aquifers in New Hampshire that had been identified by the reconnaissance mapping that Cotton had previously completed statewide. Richard Willey was stationed in Montpelier, Vermont, working on sand and gravel aquifer maps with Dave Butterfield, a State employee. Ken Toppin was completing two water-quality projects, the Winnisquam limnological study (started by Lenny Frost) and the Salem 208 water-quality appraisal (started by William Silvey).

In 1980 the New Hampshire office moved from Concord to 525 Clinton Street in Bow, about 4 miles out of Concord, where it remained through the period.

A major change in the direction of the program occurred in 1982 with the start of the 1:24,000-scale "Nashua" area stratified-drift aquifer study. This led to a statewide series of 1:24,000-scale, bond-funded, ground-water studies that started in 1984 and was the major impetus for growth in program throughout the remainder of the period, both because of the statewide studies and because of other ground-water studies that the office could execute given the staff and equipment assembled for the statewide studies.

ORGANIZATION AND MANAGEMENT

At the beginning of the period, the New Hampshire–Vermont office was a Subdistrict of the New England District. The Subdistrict Chief, Charlie Hale, supervised all employees in the office. Hale retired in the spring of 1979 and John Cotton was appointed as acting chief. Robert Hammond was selected to replace Hale. Hammond continued to supervise all office employees, but as Frank Blackey was in a leadership position for publishing the annual data report, he was essentially the defacto lead technician. This supervisory structure continued until September of 1985 when Daniel Morrissey was transferred in from the Maine Subdistrict to lead the ground-water projects, as others beyond the Nashua and the first bond study were ramping up. Morrissey became the State Office Chief for New Hampshire-Vermont, formal sections were organized, Blackey filled the Hydrologic Data Collection and Analysis Section Chief position, and Morrissey, in a dual role, filled the new position of Hydrologic Studies Section Chief. In 1986, Blackey retired and Ken Toppin was selected to replace him. Morrissey continued in his dual role until he resigned. Brian Mrazik was selected as New Hampshire-Vermont State Office Chief in 1990 and was converted to District Chief in 1991 when the WRD went to an Area structure. John Cotton was appointed as Chief of the Hydrologic Studies Section in 1991. Thomas Mack was appointed New England Ground-Water Specialist in 1992. In 1993, Keith Robinson transferred in to lead the New England Coastal Basins study unit of the National Water-Quality Assessment (NAWQA) Program. The start of that study unit was delayed, and Robinson was assigned as chief of the Geohydrologic Investigations and Research Section when John Cotton retired in 1994.

PERSONNEL

At the beginning of the period, Charlie Hale supervised the Subdistrict Office in Concord, John Cotton worked on ground-water projects, and Ken Toppin on water-quality projects. Frank Blackey was the lead technician in the data program. Kenneth McKenna, Stephen Shore, Michael Coakley, James

King, and Ken Toppin rounded out the technician staff in the data group with Nanette Kelso serving as the data processing clerk-typist with responsibilities for typing and assembling the annual data report.

Richard Willey transferred from Montpelier to the Maryland District in the spring of 1979. Michael Coakey transferred to Montpelier to keep a presence in the cooperator's office. A year later the Vermont Field Office was relocated to the Federal building in Montpelier, and Kevin Smith, a part-time employee in New Hampshire was brought on full time in the Vermont Field Office. Jon Denner joined the Vermont data program in 1991. In 1983 Blaine White transferred in from Maine and remained until 1985 when he transferred to the Georgia District.

The staff remained stable until November 1983 when Richard Moore transferred in to work on the Exeter, Lamprey, and Oyster River Basins stratified-drift study, the first of the "bond"-funded studies. Kelso, who had become the administrative clerk, resigned in 1984. In November 1985, Tom Mack transferred in to work on the Bellamy, Cocheco, and Salmon Falls River Basins study. In 1986 Sarah Flanagan transferred in and Peter Stekl was hired to work on the Lower Merrimack and Coastal River Basins study; Carole Johnson transferred in from Maine to assist with the Lower Connecticut River Basin study; Sean Lawlor was hired to assist with the Bellamy, Cocheco, and Salmon Falls River Basin study, and Karen Rickard was hired as secretary. In 1987, William Johnson was hired to assist with the Contoocook River Basin study, Joseph Olimpio was hired to assist with the Pemigewasset River Basin study, and Joe Ayotte was hired to assist with the Middle Merrimack River Basin study. Also in 1987, the need for processing the "bond study" reports led to Debra Foster being hired as an editorial assistant and Diane Denzler as an illustrations aide. In 1988, Philip Harte was hired to lead the Contoocook River Basin study, Deborah Molnar was hired in the Administrative Services Unit, and Richard Perkins was hired to work in the Hydrologic Data Section. In 1989, the older of two drill rigs in Connecticut was moved to New Hampshire and Glen Berwick was hired as drill-rig operator and Susan Kell transferred in as the Administrative Operations Specialist. David Kraemer was hired in 1990 as an additional drill-rig operator and Marilee Horn transferred in as the water-use specialist for both the New England District and the New Hampshire-Vermont office. Michael Coakley transferred back from Vermont to the New Hampshire office in 1991. In 1992, Anthony Cannarsa transferred in as the Administrative Officer and Eric Mahlowitz as Computer Specialist. Other additions to the staff in the early 1990's include Laura Medalie to assist with the Saco and Ossipee River Basins study, Daniel Notargiacomo as cartographer, Richard Kiah and Chandlee Keirstead to assist with a variety of stratified-drift aquifer studies, Eric Boehmler and Donald Song to work on the bridge-scour project, and Pamela Sarol as administrative assistant. Also in the early 1990's, Stewart Clark from the Montpelier Office assisted in the Middle and Upper Connecticut and Androscoggin River Basins studies. John Mullaney was detailed from the Connecticut District to assist in the Upper Connecticut and Androscoggin River Basins study. In 1993, Keith Robnison transferred in to lead the New England Coastal Basins NAWQA. Near the end of the period in 1994, Scott Olson transferred in to work on the bridge-scour project in Vermont.

Other staff in the Vermont office included Bob Brown, hired in 1986; Stewart Clark transferred from the Geologic Division in 1990, and James Shanley transferred in from Massachusetts in 1991. Later staff additions to the Vermont Office included Ann Chalmers and Greg Hilgendorf in 1994.

FUNDING AND COOPERATION

The major joint-funding cooperator throughout the period was the New Hampshire Water Resources Board headed by George McGee and then Delbert Downing. Vernon Knowlton was the Chief Engineer. In 1987, the Board became the Water Resources Division of the newly formed Department of Environmental Services. Knowlton retired in 1991 and Ken Stern was appointed chief engineer. This cooperator was the lead State agency for cooperation with the USGS Water Resources Division and supported the stream-gaging program and the ground-water reconnaissance studies and was given the responsibility for managing the detailed ground-water studies funded by a $2.5 million State bond issue. In addition, this cooperator, who operated many of the major reservoirs in the State, handled all of the funds from FERC (Federal Energy Regulatory Commission) hydropower permittees and used these funds in cooperation with the New Hampshire–Vermont Office to support monitoring of FERC-permitted flow requirements.

New Hampshire–Vermont funding

Fiscal year	Federal	Other Federal agency	State and local	Federal matching	Total
1979	$64,666	$100,000	$146,600	$158,000	$469,200
1980	$78,900	$70,100	$161,700	$159,500	$470,100
1981	$96,200	$130,700	$197,200	$199,400	$623,500
1982	$73,800	$94,900	$181,200	$181,200	$531,100
1983	$66,800	$72,700	$191,400	$187,200	$518,100
1984	$56,300	$81,100	$241,400	$232,100	$610,900
1985	$68,700	$96,200	$249,000	$265,900	$679,800
1986	$93,500	$109,300	$330,400	$329,400	$862,300
1987	$83,700	$107,900	$448,600	$440,800	$1,091,000
1988	$118,200	$204,900	$577,700	$566,900	$1,467,700
1989	$65,400	$240,700	$556,700	$555,700	$1,418,500
1990	$237,600	$128,800	$630,800	$630,800	$1,628,000
1991	$636,400	$233,500	$692,900	$692,900	$2,255,700
1992	$854,610	$314,000	$555,500	$527,400	$2,251,500
1993	$744,800	$386,400	$499,300	$495,900	$2,126,400
1994	$981,500	$437,300	$775,300	$521,500	$2,715,600

Other New Hampshire cooperators included the Nashua Regional Planning Commission (Nashua stratified-drift aquifer study), the U.S. Army Corps of Engineers (stream gaging), and the U.S. Environmental Protection Agency. The latter funded several CERCLA (Superfund) studies, the Savage Well site in Milford, New Hampshire, being the largest and having several follow-on investigations.

Local match for the cooperative stream-gaging program in Vermont mostly came from the Water Quality Division of the Department of Environmental Conservation. Tom Willard was the Chief Hydrologist and Dave Clough was the Chief of the Water-Quality Division. Dave Butterfield was the contact for the ground-water program in Vermont.

At the beginning of the period, the Vermont program was about $240,000 and that of New Hampshire $230,000 for a total of approximately $470,000. By the end of the period the program had grown, mostly in New Hampshire, to more than $2,700,000, or almost a sixfold increase in these 15 years.

SIGNIFICANT PROGRAMS

A significant program opportunity for the New Hampshire–Vermont office occurred in 1982 when David Soule, the Director of the Nashua Regional Planning Commission, recognized that ground-water pollution was a major issue for the towns in his Planning Commission area. Soule began to educate himself about hydrologic principles and went to Congressman Judd Gregg to ask what Federal help might be available. Congressman Gregg responded by convening a meeting of Federal agencies to see what resources could be brought to bear on the situation.

At the meeting, Gregg asked around the room to several of the assembled the heads of Federal agencies what could be done for the ground-water contamination and supply issues in the Nashua Regional Planning Commission area. Several Federal agencies demurred, but when Congressman Gregg got to the U.S. Army Corps of Engineers, their representative said that this sounded like something that the USGS might work on. Gregg directed his next question to Ivan James, New England District Chief, who outlined a detailed hydrogeologic mapping and modeling study for the unconsolidated glacial deposits in the Nashua Regional Planning Commission area. When Congressman Gregg asked when such a study could be undertaken, James answered that Soule would have a detailed project proposal within 2 weeks, accompanied by a joint-funding agreement and that the USGS could commence as soon as the signed joint-funding agreement was returned. Gregg was impressed and said that he had never before seen a Federal agency that could respond that quickly. The project was a great success, so much so that the State legislature recognized that this kind of information was needed statewide.

However, before committing funding for this purpose, the legislature required an assessment of the status of water-related management programs, legal authorizations for these programs, identification and justification of short-term and longer term goals, and actions needed to reach these goals. In 1984, John Cotton was detailed to a three-person team within the Water Resources Board to satisfy this requirement. Based partly on this effort, the legislature created the New Hampshire Department of Environmental Services and passed legislation to establish and fund a 10-year, $2.5-million each-side effort to provide information statewide for the unconsolidated aquifers through 13 regional studies. David Soule was a tremendous help in testifying before the State legislature in support of the value of hydrogeologic mapping and modeling for local planning needs. Delbert Downing, having served in the State Senate, proved extremely influential in getting the required legislation passed. Downing initiated the first two studies with other funds, pending availability of the bond funds.

Regional projects completed by the "bond" funding include:

Upper Connecticut and Androscoggin River Basins
Middle Connecticut River Basin
Pemigewasset River Basin
Saco and Ossipee River Basins
Winnipesaukee River Basin
Lower Connecticut River Basin
Contoocook River Basin
Upper Merrimack River Basin
Bellamy, Cocheco, and Salmon Falls River Basins
Middle Merrimack River Basin
Exeter, Lamprey, and Oyster River Basins
Lower Merrimack and Coastal River Basins
Nashua Regional Planning Commission Area

To accomplish these studies, the second New England District drill rig, located in Connecticut, was moved to New Hampshire and USGS crews drilled wells or test holes at 674 sites to supplement existing data. Seismic-refraction surveys were conducted at 651 sites for the aquifer studies. Seismic-reflection studies were conducted in areas where large rivers and lakes are hydraulically connected to sand and gravel deposits. Forty-two aquifers were modeled and potential yield was estimated. To provide an assessment of general ground-water quality, samples of ground water from 240 wells and 20 springs were analyzed for common inorganic, organic, and volatile organic constituents.

Many new hires or transfers were needed to staff the "bond" studies, and this enabled a broadening and deepening of ground-water talent in the office. Talent hired or transferred in for the "bond" studies became a resource for the office to utilize in developing additional ground-water projects. Among these were the U.S. Environmental Protection Agency study of ground-water contamination in the Milford, N.H., area and the federally funded Toxics Program project in fractured bedrock at Mirror Lake in New Hampshire.

As reports from the "bond"-funded studies were published, it became apparent that not all towns had good unconsolidated glacial deposits available near population centers. This, and a growing interest by drillers and the hydrologic community in developing water supply in fractured bedrock, led to a statewide program for mapping photolineaments and statistical assessments of factors related to bedrock well yields. This project began in 1993; however, major funding was not available until 1994, the last year of the period.

From 1990 to 1992 USGS personnel from New Hampshire and Vermont, in cooperation with the State of Vermont, conducted a hydrogeologic study (and ground-water modeling) of two landfills in Bristol, Vt., which served as a model of methods and procedure for investigating landfills.

In 1990, the USGS selected Sleepers River Research Watershed in Danville, Vt., as one of five long-term research sites under the newly initiated USGS Water, Energy, and Biogeochemical Budgets (WEBB) program. James Shanley transferred from the Massachusetts District to run this project from the Montpelier Field Office. The project has funded two to three FTE's in the Montpelier Office and has benefited from academic collaborations including graduate student theses at the site. The WEBB project was initially done in collaboration with the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, N.H., which had been operating this original Agricultural Research Service (ARS) site established 1958. USGS involvement allowed continuation of historical long-term hydrologic and meteorologic data sets and initiation of directed research in the context of effects of global climate change. These research elements included hill-slope hydrology, isotopic approaches to identifying solute sources and hydrologic flow paths, and hydrochemical flushing

during snowmelt. In the early 1990's, the USGS Vermont office also developed collaborative studies with the University of Vermont, including a terrestrial mercury cycling study on the west slope of Mount Mansfield.

In 1990, increasing concern about eutrophication in Lake Champlain in Vermont came to the attention of U.S. Senator Patrick Leahy in Vermont. He arranged to have money earmarked in the U.S. Environmental Protection Agency (USEPA) budget to initiate and fund the Lake Champlain Management conference. The Conference was essentially a political committee composed of State executive agencies, politicians, interest groups and some funding Federal agencies. A companion Technical Advisory Committee, composed of university researchers and technical staff from some State and Federal agencies (including the USGS), made recommendations to the conference on how to expend funds to best achieve the conference objectives. The need to get good nutrient loading data for the lake resulted in a significant growth of gaging stations on streams influent to the lake in both Vermont and New York. For several years, USGS funds up to $250,000 were earmarked for the gaging and other studies that contributed to conference objectives. As a result, in 1990 Coleman and Clark surveyed PCB's and mercury in lake sediment and stream sediment from 34 major tributaries and 39 minor tributaries to Lake Champlain, establishing baseline data. Cumberland Bay PCB contamination in Lake Champlain was located (now a $10 million dollar Superfund site) and its source in Plattsburg, N.Y., identified.

Near the end of the period, a bridge-scour program was initiated with the State of Vermont.

EPILOGUE

At the beginning of the period, the New Hampshire–Vermont Subdistrict was little more than a Field Office. The significant growth of the office, brought on largely by the "bond"-funded ground-water studies, led to an expansion of the office and the staff capabilities such that the office could provide a complete range of hydrologic data collection, interpretive studies, and research to customers throughout New Hampshire and Vermont and compete as a full-service District Office.

NEW JERSEY

By Donald E. Vaupel
Reviewed by Mark A. Ayers, William R. Bauersfeld, Robert D. Schopp, and Dale L. Simmons

ORGANIZATION AND PERSONNEL

In 1980, the New Jersey District consisted of a management section that included the District Chief's Office, the Administrative Services Unit, and the Automatic Data Processing Unit, and two operational units, the Hydrologic Records Section and the Hydrologic Studies Section. Nearly two-thirds of the District's human and financial resources were used to support data-collection activities. By 1995, the District had six operational units—the Hydrologic Data Assessment Program, Information Management Program, Hydrologic Studies Program, Hydrologic Simulation Program, Geohydrologic Studies Program, and Environmental Studies Program—and approximately three-fourths of the human and financial resources were used to support analysis and interpretation of hydrologic data. This transformation of the District's programs was the result of increased support by its scientific cooperators, which in turn resulted in a large increase in financial resources and a significant recruitment of qualified personnel.

In 1983, the District, in cooperation with the New Jersey Department of Environmental Protection, undertook three large water-supply studies in support of proposed water-allocation regulations. The infusion of unmatched State funds allowed the District to acquire the latest scientific equipment and recruit the diverse scientific and support staff necessary to complete the investigations. In 1985, this rapid growth mandated a complete District reorganization, resulting in the establishment of two new positions: Associate District Chief for Hydrologic Data Assessment and Assistant District Chief for Hydrologic Systems Investigations. Each of these positions was responsible for three operational programs: the Associate District Chief for Hydrologic Data Assessment was responsible for the Hydrologic Data Assessment, Information Management, and Special Hydrologic Studies Programs; the Associate District Chief for Hydrologic Systems Investigations was responsible for the Hydrologic Simulation, Geohydrologic Studies, and Environmental Studies Programs.

As the water-supply studies were undertaken and completed, the expertise of the staff that had been assembled allowed District managers to develop several research proposals that competed favorably in the Divisionwide Merit Program. Ultimately, a total of 11 District projects were funded through this competitive program. In the early 1990's, the District expanded into two new areas of investigation: flood warning and vulnerability of water supplies to naturally occurring and manmade chemicals. These studies included projects supported by State agencies, as well as those conducted as a result of successful competition for funds from the Toxic Substances Hydrology Program. In 1994, the District assumed management of the Long Island–New Jersey study unit of the National Water-Quality Assessment (NAWQA) Program. A byproduct of the many assessment and research projects was the conclusion that additional data were needed. As a result, the District strengthened what was already one of the most robust data programs in the WRD, with significant activities in all of the major disciplines.

Perhaps the most significant change in the District during the period was in staffing. In 1980, the District had 20 professional employees and 35 support personnel. By 1990, the District employed 70 professionals but remained at 35 support staff. Correspondingly, in 1980 only 7 employees had advanced degrees, whereas in 1990 there were nearly 40 employees with advanced degrees, including 9 with doctorates. This personnel transformation put tremendous pressure on the support units—Administrative Services, Computer, and Publications as well as the technical support staff—but they rose to the challenge and provided excellent support to all ongoing activities.

Office of the District Chief

In 1980, the District was located in the Federal Building at 401 East State Street, Trenton, New Jersey. Because of its significant growth in the early 1980's, the District relocated to the Mountain View Office Park at 810 Bear Tavern Road, West Trenton, New Jersey, in January 1986. The District laboratory, however, remained in the Federal Building until 1995.

Donald E. Vaupel transferred from the Long Island office of the New York District in September 1979 to be the third New Jersey District Chief. In April 1991, he was reassigned to the newly created position Area Assistant Regional Hydrologist for Mid-East Programs, overseeing New Jersey and Pennsylvania. In September 1991, Janice R. Ward, Associate District Chief for Hydrologic Data Assessment and Information Management, became District Chief. In 1995, Ward transferred to the Office of Water Quality and became Office Chief. In September 1995, Eric J. Evenson, Associate District Chief for Hydrologic Data Assessment and Information Management, was selected to become the fifth District Chief.

Steven M. Hindall was Assistant District Chief in 1979 and served until his selection as District Chief of the Ohio District in March 1980. In 1981, Mark A. Ayers transferred from the Minnesota District to be Assistant District Chief. In 1985, the District reorganization resulted in the creation of two new positions, Associate District Chief for Hydrologic Data Assessment and Information Management and Assistant District Chief for Hydrologic Systems Investigations and Research. Ayers was selected as Associate District Chief, and P. Patrick Leahy transferred from the New Jersey-based Regional Aquifer-System Analysis (RASA) study of the North Atlantic Coastal Plain to become Assistant District Chief.

District secretaries, in chronological order, were Ingrid C. (Santana) Heerwagen, Jean H. Crawley, Shirley J. Walter, Diane C. Gilliom, Patricia E. Drew, and Maureen F. Bayer.

Administrative Unit

Anthony A. Cannarsa was Chief of the Administrative Services Unit and Administrative Officer until he transferred to the Office of the Regional Hydrologist in 1982. He was followed by Carolyn L. Bellante, who served from 1983 until the end of the period and beyond. Others who served in the Unit were Caroline E. Gurney, Nancy Muccioli, Karen J. Staub, Florence M. Marsley, Marilyn F. Burdick, Noreen A. (Mimm) Boranian, Ingrid R. Pope, Theresa A. Frymire, Susan C. Kell, Anna H. (Nancy) Archer, Carol A. (James) Bolden, Jacqueline T. Journigan, Susan C. Wild, Nancy B. Gibbs, Susan N. Shirey, and Christine A. Odom.

One of the most significant decisions made in the New Jersey District during the period was to take the lead, along with five other Districts, in developing, producing, and training the Division's administrative staff in the use of the first automated administrative financial management system (AFIMS). In 1986,

teams consisting of the District Chief, Administrative Officer, and Computer Specialist in each of the Districts completed their task, providing the Division with a system that was used for nearly a decade.

Computer Unit

Jan J. Ryan served as District Computer Specialist, site administrator, and Chief of the Computer Unit throughout the period and beyond. In this capacity, he coordinated District computer activities during the progression from the remote terminals first in use in the District to a series of mini-computers and, ultimately, to a terminal on every desk. The New Jersey District continually maintained an environment in which its employees had access to the best computer technology available, which contributed significantly to the District's expanding capabilities and rapid growth.

Other personnel who served in the Computer Unit were Harry A. Farsett, Harold E. Bivens, Edward B. Rodgers, Mary-Frances Rudolph, Elaine A. Templeton, Russell A. Nelson, and Connie (Shon) Pak.

During the reorganization of the District in October 1985, the Computer Unit become part of the Information Management Program.

Publications Unit

Arthur A.Vickers was Reports Specialist in 1980 and served until his retirement in 1983. He was followed by Irving G. (Butch) Grossman, who served from 1984 until his retirement in 1986. He was succeeded by Jo Ann Macy from 1986 to 1988, and by Dale L. Simmons, who transferred from the Long Island office of the New York District in 1988 and served until the end of the period and beyond. The cartographic needs of the District were fulfilled by outside contracts until Gregory L. Simpson was hired in 1983. In 1985, William H. Ellis brought his skill as a scientific illustrator to the District when he transferred from the National Oceanic and Atmospheric Administration. Others who served in the unit were Kathleen Stellerine, Sheila J. Perry, Ingrid C. (Santana) Heerwagen, Claire P. Dempsky, Melicia M. Morgan, Ruth M. Larkins, and Denis K. Sun.

During the reorganization of the District in October 1985, the Publications Unit became part of the Information Management Program.

Office of the Associate District Chief for Hydrologic Data Assessment and Information Management

This position, created in the District reorganization of October 1985, managed three operational units—the Hydrologic Data Assessment Program, the Information Management Program, and the Hydrologic Studies Program. Mark A. Ayers served in this position until 1988, when he was selected to coordinate the Delaware River Basin climate study. He was succeeded by Janice R. Ward, who served from 1988 to 1991 and then was selected to be District Chief. Eric J. Evenson served from 1991 to 1995, when he was selected to be District Chief.

Hydrologic Data Assessment Program

In 1980, this unit was the Hydrologic Records Section. In 1981, John J. Murphy transferred from the Pennsylvania District to become Chief of the unit. He served in this capacity until his retirement in 1983. He was succeeded by William R. Bauersfeld, who transferred to the District from the Office of the Delaware River Master in 1982. He subsequently managed the unit through the reorganization of 1985 to the end of the period and beyond. Others who served in the unit were Robert D. Schopp, George R. Kish, Brian D. Gillespie, Douglas A. Harriman, James B. Campbell, Thomas A. Chepiga, Edward W. Moshinsky (Chief of surface-water activities), Edward A. Pustay (Chief of water-quality activities), Frederick L. Schaefer (Chief of ground-water activities until 1985), Eugene Dorr, John T. Fisher, Richard S. Cole, Guerino (Woody) Centinaro, Joseph J. Hochreiter, William J. Pisch, Michael J. DeLuca, Walter D. Jones III (Chief of ground-water activities from 1985 to the end of the period and beyond), Nelson Rivera, Andrew A. Meng, Charles L. Qualls, Carolyn L. Bellante, Randy L. Ulery, Philip J. Noyovitz, John F. (Josh) Dudek, Nancy Muccioli, Anthony J. Velnich, Caroline E. Gurney, Jean G. (Pheasant) Campbell, Kenneth C. Angebrandt, Harold E. Bivens, Carin M. Pavlinchak, Mary-Frances Rudolph, Gregory L. Simpson, Edward B. Rodgers, James L. Fulton, Lloyd Davis, Mark A. Hardy, Charles E. Nahn, Mark O. Philips, G. Allan Brown, Philip T. Harte, Eric Jacobsen, Alfred Sturnioli, Robert G. Reiser, Timothy S. Rousseau, Robert D. Sachs, Rebecca J. (Smith) Burns, Yan-Ling M. Juang, Glenn R. Olshefski, Joseph D. Joyner, Timothy J. Reed,

Nicholas Leivers, David Kauffman, Walter F. Calvetti, Mark D. Eanes, Thomas Suro, Marie Campbell, Jeannette (Hutchinson) Oden, Victor Corcino, and Jeffrey J. Scudder.

Information Management Program

This unit was initiated in the 1985 reorganization as a result of the need to manage the rapidly increasing quantity and diversity of data collected by the District and the acquisition of computers to assist in the creation of data bases and in data analysis. Even the most sophisticated data base, either alone or together with a geographic information system, was no longer adequate to store, manipulate, and display the quantity and variety of information collected by the District. Consequently, the District developed or used a number of data bases to contain and manage its burgeoning array of data on streamflow, water levels, water quality, water use, geology, hydrogeology, geophysics, basin characteristics, topography, geography, and meteorology.

The Computer Unit and Publications Unit became part of the Information Management Program. Keith W. Robinson assumed management of the program in 1988 and served until his transfer to the New Hampshire District in 1994. Others who served in the program were Jan J. Ryan (Computer Specialist), Elaine A. Templeton, Russell A. Nelson, and Connie (Shon) Pak, computer activities; Irving G. (Butch) Grossman (Reports Specialist, 1984–86), Ingrid C. (Santana) Heerwagen, Claire P. Dempsky, Jo Ann Macy (Reports Specialist, 1986–88), Kathleen Stellerine, Ruth M. Larkins, Melicia M. Morgan, Nancy Muccioli, Frederick L. Schaefer, Kathleen L. Laubach, and Dale L. Simmons (Reports Specialist, 1988 to the end of period and beyond), publication activities; Gregory L. Simpson, William H. Ellis, and Denis K. Sun, scientific illustration activities; Jayne E. May, Marilee A. Horn, Charles L. Qualls, Deloris W. Speight, John P. Nawyn, Edward A. Pustay, and Eugene Dorr, Jr., data-base activities; Randy L. Ulery, Mark A. Fiorentino, and Curtis V. Price, geographic information systems; and Lisa Bratton, Prudence H. Brown, Timothy R. Lazaro, Elizabeth O. Titus, Vicki (Cowell) Principi, Nicholas M. Beeler, Debra E. Buxton, and Rick M. Clawges, project activities.

Special Hydrologic Studies Program

This unit was created in the reorganization of 1985 for the analysis of surface-water quantity and quality data. Due to a lack of projects, the unit was temporarily assimilated into the Hydrologic Data Assessment Program during 1989–90. Robert D. Schopp managed the unit from its inception in 1986 until 1988. He was followed by James L. Fulton in 1988. David M. Wolock managed the unit after it was reestablished in 1991. After Wolock's transfer to the Kansas District later that same year, David A. Stedfast managed the unit until the end of the period. Others who served in the unit were Mark A. Hardy, James P. Campbell, Mark O. Philips, Lauren E. Hay, Connie (Shon) Pak, R. Edward (Ward) Hickman, Rebecca J. (Smith) Burns, Tamara Ivahnenko, Debra E. Buxton, Paul Dunne, Thomas H. Barringer, and Kathryn Hunchak-Kariouk.

Office of the Assistant District Chief for Hydrologic Systems Investigations and Research

In 1980, the District's interpretive projects were managed by the Chief of the Hydrologic Studies Section. In 1984, a separate unit was created to manage three large water-supply studies. In the reorganization of 1985, the position of Assistant District Chief for Hydrologic Systems Investigations and Research was created to manage the rapidly increasing number of projects in which many types of hydrologic data were being analyzed. In an attempt to use state-of-the-art techniques to describe the complexities of the hydrologic system and predict the consequences of stresses placed on the system, three programs—the Hydrologic Simulation Program, the Geohydrologic Studies Program, and the Environmental Studies Program—were established to conduct the necessary analysis and research.

In 1980, William Kam managed the Hydrologic Studies Program; he served until his retirement in 1981. He was succeeded by George M. Farlekas, who managed the program until 1985, when he was reassigned as Ground-Water Specialist. In 1984, P. Patrick Leahy transferred from the New Jersey-based North Atlantic Coastal Plain RASA study to assume management of the unit overseeing the three large water-supply studies. After the reorganization, Leahy was selected to fill the position of Assistant District Chief. He served in this position until 1988, when he

transferred to the Office of Ground Water. He was followed by Herbert T. Buxton, who transferred from the Long Island office of the New York District in 1989 and managed the programs until the end of the period and beyond.

Others who served in the Hydrologic Studies Section during the period were Arlen W. Harbaugh, Thomas V. Fusillo, Carol L. Tilley-Grogan, Eric F. Vowinkel, Joan E. Alessi, William K. Foster, Otto S. Zapecza, J. Wayne Green, Richard L. Walker, Anthony J. Velnich, Prudence H. Brown, Jean H. Crawley, Alan J. Straus, Joseph J. Hochreiter, Lois M. Voronin, Mary M. (Martin) Chepiga, G. Allan Brown, Douglas A. Harriman, Steven D. McAuley, Anthony S. Navoy, Frederick L. Schaefer, Mary C. Hill, Philip B. Duran, Walter D. Jones III, Deborah G. Lord, Gerda E. Reimer, James A. Eckel, William W. Grelis, Philip T. Harte, Carin M. Pavlinchak, Stephen J. Rheaume, B. Pierre Sargent, Jean C. Lewis, Pierre J. Lacombe, and Jo Ann Macy. Others who reported directly to the Assistant District Chief during the period were Thomas V. Fusillo, Mary M. (Martin) Chepiga, Arthur L. Baehr, Theodore A. Ehlke, Thomas E. Imbrigiotta, Patrick J. Witkowski, George M. Farlekas, Anthony S. Navoy, Thomas H. Barringer, and Nicholas P. Smith.

Hydrologic Simulation Program

This program was created in 1985 to meet the needs of customers to more accurately predict the consequences of various stresses applied to the hydrologic system. Anthony S. Navoy served as Chief of the program from its inception until 1990 and again in 1995; Steven D. McAuley served as Chief of the program from 1991 until 1994. Others who served in the program were Gary N. Paulachok, Mary M. (Martin) Chepiga, Mary C. Hill, Amleto A. (Ham) Pucci, Douglas A. Harriman, Gary J. Barton, James A. Eckel, JoAnn E. Murashige, Elizabeth M. (Betsy) Ervin, Lois M. Voronin, Andrew J. Kalik, Joseph M. Oschwald, Donald A. Storck, Lisa Bratton, Jeffrey S. Clark, Robert Rosman, Eric P. Declercq, Daryll A. Pope, Eileen C. O'Rourke, George R. Kish, Philip T. Harte, Frederick J. Spitz, Paul F. Schuster, Thomas H. Barringer, Alison D. Gordon, Martha M. (Krebs) Watt, Pierre J. Lacombe, Robert S. Nicholson, Glen B. Carleton, Eric Jacobsen, Jean (Lewis) Brown, Matthew Lahvis, Jeffrey M. Fischer, Ronald J. Baker, Nicholas P. Smith, Rick Clawges, Maribeth H. Price, Julia L. Barringer, Stephen J. Cauller, and Melissa L. (Johnson) Storck.

Geohydrologic Studies Program

In 1985, the continued interest of its customers in the relation of the geologic framework to the quantity and quality of ground water caused the New Jersey District to develop the Geohydrologic Studies Program. Otto S. Zapecza managed the program from its inception in 1985 until the end of the period and beyond. Others who served in the program were Philip B. Duran, B. Pierre Sargent, Thomas H. Barringer, Jean (Lewis) Brown, Pierre J. Lacombe, Zoltan Szabo, Gerda E. Reimer, Eric F. Vowinkel, G. Allan Brown, William A. Battaglin, Lauren E. Hay, Eileen A. Murphy, Jeffrey M. Fischer, Jacob Gibs, Robert Rosman, Donald A. Storck, Lois M. Voronin, Kenneth S. Turner, Martha M. (Krebs) Watt, Teresa S. Czarnik, Dorothy F. Payne, Nicholas P. Smith, Donald E. Rice, Melissa L. (Johnson) Storck, Tamara Ivahnenko, Emmanuel G. Charles, Linford D. Martin, Kalman Isaacs, Timothy P. Wilson, and Allan C. (Chip) Kane III.

Environmental Studies Program

With increased customer interest in being able to measure the effects of anthropogenic stresses applied to water resources, the New Jersey District created the Environmental Studies Program in 1985. Janice R. Ward was chosen to manage the program; she served until her selection as Associate District Chief in 1988. Julia L. Barringer was Program Chief from 1990 to 1994; she was succeeded by Eric F. Vowinkel, who served to the end of the period and beyond. Others who served in the program were George R. Kish, Thomas E. Imbrigiotta, Joseph J. Hochreiter, Jacob Gibs, Deborah G. Lord, Jo Ann Macy, Cynthia Barton, James A. Smith, Patrick J. Witkowski, Patricia A. Johnsson, Jane Kozinski, Paul F. Schuster, Noemi de la Puent, Mark A. Hardy, Gary J. Barton, James A. Kammer, R. Edward (Ward) Hickman, Tamara Ivahnenko, Ronald J. Baker, Rick M. Clawges, Susan Koehnlein, Amleto A. (Ham) Pucci, Kenneth S. Turner, Cecilia L. McDonald, Teresa S. Czarnik, Edward Modica, Jean (Lewis) Brown, Eric Jacobsen, Vincent T. DePaul, Donald A. Storck, Glen B. Carleton, and Kalman Isaacs.

Field Operations Unit

In 1985, the large increase in the number and complexity of interpretive projects created the need for a support unit to provide such services as water-quality sampling, geophysical logging, interpretation of well logs, and measurement of ground-water levels. Richard L. Walker managed the Field Operations Unit from 1985 until 1991, when he left the USGS. Robert Rosman served as Acting Chief until Nicholas P. Smith was appointed Chief of the unit in 1994. Other people who served in the unit were Anthony J. Velnich, Bernard N. Sroka, James E. Fairchild, John P. Nawyn, James H. Schroeder, Glen B. Carleton, Lawrence A. Sioma, Melissa L. (Johnson) Storck, Robert D. Sachs, Donald E. Rice, Elaine Gee, Kristin Kerr, David Koller, and Vincent T. DePaul.

Delaware River Basin Climate Program

In 1988, the New Jersey District was assigned the task of determining the effects of climate change on the water resources of the Delaware River Basin. Mark A. Ayers managed the project, which ran from 1989 to 1991. Others who served on the project were Gregory J. McCabe, Lauren E. Hay, David M. Wolock, and Paul Dunne.

Long Island–New Jersey NAWQA Project

In 1994, the New Jersey District was assigned management responsibility for the Long Island–New Jersey study unit of the NAWQA Program. Mark A. Ayers returned to the District from his assignment as Assistant Regional Hydrologist for NAWQA to assume management of the project. Others who worked on the project were Paul E. Stackelberg, Anne K. O'Brien, Robert G. Reiser, and Jonathan G. Kennen.

FUNDING AND COOPERATION

As indicated in the table of funds, the size of the Federal-State Cooperative (Coop) program more than tripled during the period. Much of this increase occurred during 1984–88, when the State of New Jersey, Department of Environmental Protection, asked the District to undertake three large water-supply investigations on the Coastal Plain of New Jersey. This infusion of funds allowed the District to acquire several highly qualified scientists, which in turn encouraged the development of several new programs, many of which were funded by other Federal agencies (OFA) and direct Federal funds (Fed). Correspondingly, the size of the OFA program increased six times and the size of the Federal program increased seven times. The support of all customers remained strong throughout the period. At the end of the period the District had 21 Coop customers, 11 OFA customers, and 7 Federal programs.

SUMMARY OF PROGRAMS

Hydrologic-Data Collection

During the entire period, New Jersey was one of only two Districts in the Northeastern Region that maintained a comprehensive program of hydrologic data collection in all disciplines, including streamflow, water quality, ground-water levels, and water use. Although almost continually understaffed, the stalwarts of this program, William R. Bauersfeld, Edward W. Moshinsky, and Edward A. Pustay, continued to deliver the hydrologic data needed by the District's customers to manage the water resources of the State. Some of the more significant changes that took place during the period are (1) the establishment of computer data bases that allowed easy retrieval of data collected at hydrologic stations, (2) the significant expansion of real-time data sites for flood and drought

New Jersey District funds, fiscal years 1980–94

[Source: District program documents for 1980–94

Fund source	Fiscal year (Funds, in thousands of dollars)														
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	1,429	1,397	1,569	1,956	2,951	4,888	3,843	3,974	4,404	3,759	4,324	4,779	4,784	4,965	5,064
OFA	223	105	107	310	550	187	1,274	1,057	614	1,633	817	406	554	796	1,367
Fed	148	275	360	248	522	851	726	1,051	1,380	1,477	1,521	1,337	1,051	922	1,018
Total	1,800	1,777	2,036	2,514	4,023	5,926	5,843	6,082	6,398	6,869	6,662	6,522	6,389	6,683	7,449

management, and (3) the increase in both the quantity and types of water-quality data being collected.

Streamflow Stations

In 1980, 102 continuous-record streamflow stations were in operation. Because of inflationary pressures and static budget levels at both the Federal and State levels, this number declined slightly to 92 stations in 1995. The majority of these stations were supported by the New Jersey Department of Environmental Protection to provide data for management and allocation of surface-water resources. In addition, networks of crest-stage and low-flow stations were maintained throughout the period. Noteworthy stations maintained by the District include (1) Delaware River at Montague, which is mandated by the U.S. Supreme Court to provide data to the Delaware River Master to manage flow in the upper part of the basin, and (2) Delaware and Raritan Canal at Port Mercer, which is operated to measure interbasin transfer of water from the Delaware River Basin to the Raritan River Basin. It is also notable that the District was instrumental in developing the first computer programs, called the New Jersey ADR system, to assist hydrographers in analyzing field data. These programs resulted in improved records and increased efficiency and ultimately led to the development of the current system, ADAPS.

Water-Quality Stations

The number of water-quality stations operated by the District varied from 133 sites in 1980 to 89 sites in 1995. At the beginning of the period, samples were collected only at surface-water sites. By 1995, however, samples also were being collected at 24 strategically selected observation wells. Throughout the period, District personnel sampled hundreds of wells threatened by saltwater intrusion to document the movement of the saltwater front toward water-supply wells.

Ground-Water-Level Observation Wells

In 1980, the Statewide water-level network consisted of 182 sites, 26 of which were equipped with continuous recorders. By 1995, the District was collecting measurements at 172 sites, 83 of which were equipped with continuous recorders. In addition, in 1982, 1987, and 1992, hundreds of water levels were measured synoptically to provide a snapshot of potentiometric surfaces in the confined aquifers of the Coastal Plain that were being pumped heavily for water supply. These data were used by water managers to restrict pumpage in certain areas where water levels had decreased significantly as a result of excessive pumping.

Water-Use Data

The District compiled water-use data collected by the State throughout the period; however, the lack of a comprehensive data base and associated analytical computer programs limited the value of this information. The data were used to verify hydrologic models as part of studies investigating the effects of ground-water withdrawals on the hydrologic system and were published in reports describing ground-water withdrawals in the United States.

Interpretive Studies

Resource Assessment

In the early 1980's, several studies were undertaken to increase and improve the available information on the quantity and quality of hydrologic resources in the State of New Jersey. Among these projects were those conducted by Fusillo (water quality of the Potomac-Raritan-Magothy aquifer system), Farlekas (ground-water/surface-water relationships in the Potomac-Raritan-Magothy aquifer system), Hill (hydrologic model of the Ramapo River Basin), Schopp (development of flood equations for the State of New Jersey), Gillespie and Schopp (low-flow characteristics of New Jersey streams), Lord and Johnsson (effects of acid precipitation on the water resources of the Pinelands), and Harbaugh (hydrologic model of a portion of the Delaware River Basin).

Management Assessment

By the mid-1980's, the New Jersey Department of Environmental Protection had sufficient data to begin large studies related to the management and allocation of the State's water resources. The largest of these were three investigations in areas deemed critical because of large water use, predicted growth, and the potential for contamination from saltwater encroach-

ment. These studies were managed by Leahy and supervised by Paulachok (Atlantic City area), Navoy (Camden area), and Pucci (South River area). These studies provided the information necessary for the State to create two "critical areas," near South River and Camden, where pumpage from confined aquifers subsequently was significantly reduced. The study in the Atlantic City area confirmed the presence of adequate water resources by, among other analyses, drilling two offshore wells that verified the existence of freshwater in the confined aquifer as far as 5 miles offshore.

Other studies related to water management included those conducted by J. Barringer (lead contamination in Ocean County), Zapecza and Szabo (natural radioactivity in water resources in Triassic aquifers), Nicholson and Gordon (hydrologic assessment of the Rockaway River Basin), Johnson and Watt (hydrologic assessment of the unconfined aquifers of the Coastal Plain), Lacombe (hydrologic assessment of Cape May County), and T. Barringer and Spitz (optimal pumpage schemes for the Coastal Plain).

Applied Research

By 1990, it was apparent that some of the data that had been collected and analyzed raised questions about the mobilization and transport of certain contaminants. To answer these questions, the New Jersey District conducted several research studies to develop instrumentation to collect better data, develop simulation techniques, and formulate hypotheses to explain the occurrence of selected chemical constituents in certain areas. These investigations included those conducted by Szabo (radioactive contamination of water resources in the Coastal Plain), Spitz (optimization of pumping locations in Cape May County), Vowinkel (vulnerability of water resources to pesticides), Baehr (cleanup of hydrocarbon contamination), and Hill (parameter estimation).

Regional Studies

The New Jersey District played a pivotal role in the Northern Coastal Plain RASA study. In addition to the two Professional Papers by Zapecza (hydrogeologic framework of the northern Atlantic Coastal Plain) and Martin (ground-water flow model of the New Jersey Coastal Plain), the District was called upon to assist in completing the Professional Paper by Leahy and Martin (ground-water flow model of the northern Atlantic Coastal Plain).

In 1989, the District began a study of the Delaware River Basin to predict the effects of climate change on the hydrologic resources of the basin. This project was managed by Mark A. Ayers and produced approximately 20 reports, including Water-Supply Paper 2422 by Ayers, Wolock, McCabe, Hay, and Tasker, which summarized the effects of climate variability and change on the water resources of the Delaware River Basin.

In the early 1990's, the District was chosen to lead two study units of the newly funded NAWQA Program: Long Island–New Jersey and the Delaware River Basin. The Long Island–New Jersey study began in 1994, with Ayers as Project Chief.

NEW ENGLAND DISTRICT PROGRAM AREA

By Ivan C. James II

INTRODUCTION

In the 1979–94 period, the New England District experienced considerable growth in program size and a significant change in program emphasis. Each office had a strong data program in stream gaging and ground-water observation. Connecticut and Rhode Island had significant water-quality data programs; Massachusetts and Maine had more modest water-quality data programs—the one in Massachusetts being limited to a half dozen or so water-quality monitors. All offices had ongoing ground-water studies directed toward producing map reports showing the location of glacial-deposit aquifers and the yield that might be anticipated from wells in these aquifers. These ranged from reconnaissance-level efforts in Maine and New Hampshire to much more detailed and integrated hydrologic-atlas investigations in Massachusetts, Connecticut, and Rhode Island. During the period, the ground-water studies made a transition from areal appraisals to quantitative investigations featuring modeling to answer water-management questions. Surface geophysics also played an increasingly important role in ground-water investigations during the period. Water-quality studies became an increasing component of the program in several States.

During the period, the total program in the six New England States grew from $3.7 million to $14.0 million. This growth was fairly consistent through the period except for a flat period in 1988. The New England District was one of the most successful Districts in the country in winning funding for projects during the competition for Merit Project funding during the life of that system.

Organization and Personnel

In 1979, the New England District comprised the District headquarters in Boston, Mass.; Subdistricts in Boston, Mass.; Augusta, Maine; Concord, N.H.; and Providence, R.I.; and a Field Office in Montpelier, Vt., that reported to the New Hampshire/Vermont (NH/VT) Subdistrict office in Concord. The Connecticut District, headquartered in Hartford, Conn., was a separate entity. Staffing was approximately 34 in Connecticut, 25 in Maine, 43 in Massachusetts, 9 in New Hampshire, and 7 in Rhode Island.

When the period began, John Baker was District Chief, Patrick N. Walker the Assistant District Chief, Michael Frimpter the Hydrologic Studies Section Chief, and John Briggs the District Water-Quality Specialist. With the reorganization of the District, Frimpter became Subdistrict Chief for Massachusetts. Jeff Armbruster was the Subdistrict Chief in Maine, Herb Johnston in Rhode Island, and Bob Hammond in the NH/VT Subdistrict. Key changes that occurred in the early part of the period included the death of John Baker in a tragic automobile accident in the fall of 1979 followed by the selection of Ivan James as District Chief in July of 1980. The departure of Jeff Armbruster to be District Chief of Georgia in the spring of 1981 was followed by the selection of Derrill Cowing as Subdistrict Chief in Maine in September of 1981. John Briggs was detailed to Maine as Acting Subdistrict Chief for the summer of 1981. About that time a reorganization of the District that had been in process for 2 years was implemented in which the former Subdistricts were renamed as State Offices. Each former Subdistrict Chief became a State Office Chief. Line administration of programs now moved through the State Office Chiefs for both studies and data programs.

In the summer of 1982, the Connecticut District, under Dave McCartney as District Chief, was added to the New England District as a State Office. This completed the reorganization of the offices in New England into a District that included all of the New England States and geographically matched a number of quasi-regional entities such as the New England River Basin Commission, the New England Governor's Conference, and the New England Regional Planning Council and also matched the boundaries of Federal Region 1 (New England), which matched the regional organization of the U.S. Environ-

Total funding for the six New England States for fiscal years 1979–94

Fiscal year	Federal	OFA	State	Federal matching	Total
1979	$381,200	$527,500	$1,386,200	$1,386,800	$3,681,800
1980	$416,500	$344,000	$1,654,900	$1,513,100	$3,928,400
1981	$685,300	$424,400	$1,776,400	$1,680,200	$4,565,300
1982	$452,400	$309,100	$1,903,600	$1,770,400	$4,435,500
1983	$901,100	$433,000	$1,911,000	$1,839,600	$5,084,700
1984	$1,088,100	$469,000	$2,255,100	$1,991,300	$5,803,500
1985	$1,179,800	$966,800	$2,229,000	$2,090,400	$6,463,000
1986	$1,208,800	$908,000	$2,295,700	$2,012,200	$6,427,400
1987	$1,447,500	$1,011,100	$2,639,900	$2,260,700	$7,369,200
1988	$1,205,200	$1,351,800	$3,119,800	$2,586,600	$8,263,400
1989	$1,104,200	$1,328,200	$3,217,400	$2,564,000	$8,213,800
1990	$1,295,500	$1,240,900	$3,197,900	$2,443,500	$8,177,800
1991	$1,793,200	$1,084,700	$3,247,300	$2,624,200	$8,749,400
1992	$2,688,810	$1,768,100	$3,517,000	$2,502,600	$10,476,500
1993	$3,069,700	$2,300,400	$3,933,400	$2,489,700	$11,793,200
1994	$3,638,500	$2,733,800	$5,121,900	$2,485,200	$13,979,400

mental Protection Agency and some other Federal cooperators. The State Office Chiefs, the District Chief, the Assistant District Chief, the Water-Quality Specialist, and Annette Gagnon, the District Administrative Officer together formed the nucleus of the District Management Team, meeting bimonthly to decide upon issues related to program development, staffing, budgeting, and program execution.

In 1983, Dave McCartney joined the New England District management staff as Senior Staff Hydrologist. Chet Thomas, the former Assistant District Chief for Connecticut, was selected as the new State Office Chief for Connecticut. Pat Walker retired as Assistant District Chief in July 1985 and was succeeded by Terry Danielson. In September 1985, Dan Morrissey moved from Maine to New Hampshire to become the State Office Chief there until he left to help form McDonald-Morrissey Associates in February 1990. He was replaced by Brian Mrazik who arrived in November of 1990. Herb Johnston retired from Rhode Island in December 1990 and was replaced by Virginia deLima in January of 1991. Mike Frimpter retired in 1991, and Mike Yurewicz was appointed Massachusetts State Office Chief that fall.

With the reorganization of the WRD in 1990–91, the New England District became the New England Program Area. Ivan James became the Area Hydrologist and Derrill Cowing, Brian Mrazik, Mike Yurewicz, and Chet Thomas became District Chiefs for the Maine, NH/VT, Massachusetts/Rhode Island, and Connecticut Districts, respectively, Rhode Island having been combined with Massachusetts at that time. In 1992, New York was added, and the New England Program Area was renamed the Northeast Program Area. Because the New England District has been operating in a manner not too different than was envisioned for a Program Area, the transition was relatively easy except for the Publications and the Computer Units, which were moved to the Massachusetts/Rhode Island District, although they both continued to support functions for the Northeast Program Area.

The administrative operations of the New England District were overseen by Annette Gagnon, who began her career with the Federal Government during World War II. She continued in that role until her retirement in 1985. She was replaced by Tony Cannarsa. Administrative clerk assistance was provided by Maria Azconas until she resigned and was replaced in 1982 by Diane Lumbert. Each Subdistrict Office, or later State Office, maintained some staff for local administrative services, typically an administrative operations assistant except in Rhode Island where this function was performed by the secretary.

The Hydrologic Records and Information Unit staffed by Denison, Fogarty, and Linney at the beginning of the period became the District Program Support Unit in 1980 under the supervision of the Assistant District Chief, Patrick N. Walker. John Briggs joined the unit as District Water Quality Specialist in 1981 and remained there until transferring to Reston in 1988. Linney continued as the District Public Information Specialist until his retirement in 1987. The functions of the unit were absorbed by the Associate District's office under Terrence Danielson in 1988.

At the beginning of the period the Computer Applications Unit was headed by Robert Wakelee and assisted by Dianne Letty. Wakelee transferred to Reston in 1980 and was replaced by Steve Klesert who continued in that position until he resigned in 1988. Larry Kessler started as Steve's assistant in 1988 and became the Chief the next year. He transferred to Nevada in 1992 at which time the computer system was relocated to Albany to be managed by the New York District.

The Publications Unit included Janet LeBlanc and Cheryl Carvalho, later joined in 1980 by Alicia Brown. At the time the unit was transferred to the Massachusetts District Office in 1992, the staff consisted of Marianne Orlando and Diane Barrett. The Illustrations Unit formed in 1987 consisted of Beth Johnson and Linda Bishoff. It was later staffed by Kenneth Judd, Christine Mendelsohn, and Bruce Weinstock, and this staff remained when the unit was transferred to the Massachusetts District in 1992.

Reorganization, 1991

What had begun with the "District Viability Study" in the Northeastern Region as a process to look at potential combinations of States into multi-State districts, like the New England District and the Mid-Atlantic District, was embraced by the WRD into a major reorganization study. The WRD Planning Committee was charged with looking at alternative organizational structures that could better staff and finance hydrologic research and investigations on the scale of regional studies like RASA and NAWQA.

To accommodate the new organizational model, the New England District was broken up into four Districts—the Connecticut District, the Maine District, the Massachusetts/Rhode Island District, and the New Hampshire/Vermont District. The New England District became the New England Program Area.

Ivan James was selected as Area Assistant Regional Hydrologist for the New England Program Area, Chet Thomas became the District Chief for Connecticut, Derrill Cowing the District Chief for Maine, Mike Yurewicz the District Chief for Massachusetts/Rhode Island, and Brian Mrazik the District Chief for New Hampshire/Vermont. Terry Danielson continued in a role of managing the operations of the Area including supervising the Publications Unit and Computer Unit until his transfer to Las Vegas, Nev., in 1993. In 1992, the New York District, with L. Grady Moore as District Chief, was added and the New England Program Area was renamed the Northeast Program Area. The Area's Assistant Regional Hydrologist, the District Chiefs, and the Rhode Island Subdistrict Chief became the nucleus of the Area Management Team, still meeting every other month, with ad hoc attendance by other staff and specialists as needed.

Office Locations

At the beginning of the period, the New England District office was located on the 10th floor of the Analex Building at 150 Causeway Street. The office remained there until personnel moved to the 9th floor of the new Tip O'Neill Federal Office Building at 10 Causeway Street in 1988. In 1992, the office moved again, this time to 28 Lord Road in Marlboro in space adjacent to the Massachusetts/Rhode Island District office. Office locations of other offices in New England are covered in the individual State sections.

Program and Staffing Management in a Multi-State District

With the reorganization of the District in 1979 and 1980, more local authority to develop and manage programs was given to the Subdistrict Offices. At the same time, a cooperation was developed among the Subdistrict (later State Offices) to effectively redeploy technical talent throughout the District to best meet program and project objectives. Thus, Dan Morrissey, when in the Maine Office, did the modeling for a recharge-area delineation project in Rhode Island. Similarly, the strong surface-water and hydraulic talent in the Maine and Connecticut offices was used to conduct FEMA flood studies in the rest of the District, particularly New Hampshire and Massachusetts.

A conscious decision by the District Management Staff to increase the surface-water engineering talent in the District led to the hiring of Joseph Nielson, Scott Olson, and Glenn Hodgkins in Maine where they could train under the surface-water expertise of Rick Fontaine and Bill Bartlett. Scott later transferred to New Hampshire where he could apply his talent to projects in that office. As expertise in water quality and geochemistry developed in Massachusetts, these capabilities were used in other New England States. By the end of the period, 26 staff members in the various Districts had New England-wide responsibilities as technical specialists, data-base coordinators, or program administrators.

With the growth of the ground-water program in New Hampshire, the drilling operation that had been coordinated and managed out of Connecticut was split up and one rig and crew relocated to New Hampshire to cut down on mobilization time for projects in northern New England. These rigs provided drilling services to all of the New England States, New York, and New Jersey.

Large Federal-program projects were coordinated by the District (later Area) Management Team. The Otis Air National Guard Toxics project on Cape Cod required additional staff for field experiments and used staff from Maine, New Hampshire, and Connecticut. The WEBB (Water, Energy, and Biogeochemical Budget) project at Mirror Lake in New Hampshire was originally proposed by a District-wide committee chaired by Rick Fontaine (District Surface-Water Specialist headquartered in Maine) that included James (Jamie) Shanley from Massachusetts. Shanley later became Project Chief after the project was approved. The Connecticut, Housatonic, and Thames River Basin NAWQA project was headquartered in Massachusetts with significant staff in Connecticut and technical and field assistance from other New England offices. The Northeastern Glacial RASA (Regional-Aquifer System Analysis) study headquartered in New York had subprojects throughout the New England States. Planning and staffing for these projects were accomplished through the Management

Team or through bilateral negotiations between State Office (later District) Chiefs.

Epilogue

By the end of the period, the program in all New England States had changed considerably. Groundwater studies had gone from reconnaissance appraisals to mostly quantitative and modeling studies. Water-quality projects had grown in scope and complexity and had become much more interpretive with significant research components. New technology had been implemented in the data program with a variety of new stage sensors replacing manometers and all gaging stations now on satellite telemetry. Surface and borehole geophysical techniques permeated the groundwater program. NAWQA and other water-quality projects had gone to ppb (part per billion) sampling protocols.

NEW YORK

By L. Grady Moore, *including information provided by* Allan D. Randall, Peter Murdoch, Kenneth A. Pearsall, Deborah S. Lumia, Richard Lumia, John H. Williams, Gary D. Firda, Gerald K. Butch, William M. Kappel, William F. Coon, Paul E. Misut, *and reviewed by* Anne J. Finch, Ward O. Freeman, and Robert J. Rogers

ORGANIZATION AND PERSONNEL

During 1979–94, the New York District maintained its headquarters office in the Albany area and two Subdistrict Offices and various Field Headquarters. The District staff during the period ranged from 78 to 127 permanent employees (101 to 157 permanent and part-time employees). The personnel ceilings during the early 1980's resulted in the use of temporary staff that ranged from 28 to 76 employees. The District also underwent several reorganizations and renaming of sections during the period. The District began the 1979–94 period with a staff of 144 permanent and part-time employees.

District Office, Albany

Office of the District Chief — The District Office and water-quality laboratory remained in the U.S. James T. Foley Court House at 445 Broadway, Albany, through 1994. Negotiations were begun in 1994 to relocate these facilities to the Rensselaer Polytechnic Institute's Technology Park in Troy, about 7 miles away.

Lawrence A. Martens, the fourth New York District Chief, served until he transferred to the Northeastern Region Office in 1988. Martens was replaced in January 1989 by L. Grady Moore, who was the North Dakota District Chief. William B. Gannon served as Assistant District Chief until his retirement in December 1988. The Assistant District Chief position was not filled during the period 1989–94. Leanna Sweet served as Secretary for the senior staff throughout 1979–94, and Carol Woodward served as the Administrative Officer throughout the period.

SUBDISTRICTS AND FIELD OFFICES

Albany Subdistrict.—The Albany Subdistrict Office continued to be collocated with the District Office, in the James T. Foley U.S. Court House on Broadway in Albany. Subdistrict Chiefs were Salvatore Schiavo (who joined the New York State Department of Environmental Conservation in 1979), Perry Olcott (1980–82, who transferred to Reston), Daniel Hahl (1982–88, who retired), and John Ritter (1989–94, who retired).

Middletown Field Headquarters.—Andrew Cohen served as Technician-in-Charge until the office was closed in October 1979. Cohen and Patrick Simmons were transferred to Albany. Frank Capochino transferred to the Federal Prison System.

Potsdam Field Headquarters.—The office was moved from Sandfordville to Market Square Mall in Potsdam in 1993. Howard Lent served as Technician-in-Charge throughout the 1980–94 period.

Ithaca Subdistrict.—The office was at 521 West Seneca Street until 1993, when it was relocated to 903 Hanshaw Road. Office Chiefs were Harold Shindel (1979–80, who transferred to Columbus, Ohio), Richard Novitzki (1980–89, who transferred to Illinois as District Chief), Robin Brown (1989–94, who transferred to Iowa as District Chief), and Edward Bugliosi (1994 to present).

Long Island Subdistrict.—The Subdistrict Office was at 5 Aerial Way, Syosset, Nassau County, from 1974, until it was moved to Suffolk County Water Authority space in Building 4, 2045 Route 112 Coram, Suffolk County, in 1994. The office and

warehouse facilities are provided by the Suffolk County Water Authority as part of the Cooperative Agreement. Office Chiefs were Irwin Kantrowitz (1979–81, transferred to the Florida District) and Donald Bingham (1981–89, transferred to Reston). The position was vacant during 1990–93 and was filled by Bronius Nemickas in 1994.

FUNDING AND COOPERATION

As indicated in the table of funds, the Federal-State Cooperative (Coop) program increased by 67 percent during the 15-year period. The other Federal agency (OFA) and the Federal (Fed) programs had funding increases and decreases as programs grew and were then terminated.

The increases in the Coop program beginning in 1988 resulted from the expansion of the New York City Department of Environmental Protection (DEP) watershed studies in the Catskill Mountains area and the King and Queens County aquifer study to evaluate the use of ground water as an emergency public supply during extreme drought. These increases mask the effects of the New York State Department of Environmental Conservation (DEC) budget cuts in the data and interpretive programs. The DEP program accounted for almost $4,000,000 in unmatched Coop funding. The DEP also funded part of the Hudson River Salinity Flow Model project, which began in 1988.

The increases in Federal funds for 1991 reflect the beginning of the Hudson River National Water-Quality Assessment (NAWQA) project.

SUMMARY OF PROGRAMS

Hydrologic-Data Collection

Streamflow-gaging stations.—The District was operating 205 continuous-record discharge stations, 115 crest-stage gages, 26 stage-only gages, and 20 lake-level stations at the beginning of 1980. During the 1979–94 period, 48 continuous-record stations, 60 crest-stage gages, and 3 stage-only stations were discontinued. By the end of 1994, the District was operating 220 continuous-record stations, 73 crest-stage gages, 24 stage-only gages, and 78 low-flow partial-record stations.

During the 1979–94 period, the Albany and Ithaca staff experimented with the use of "control bubblers" to prevent ice from forming on the control structure. After having ice rip the units out each spring, the test was abandoned. In 1984, Data Collection Platforms (DCP's) were installed at stations in the District to use satellite data transmission as a method for collecting near-realtime data. The Ithaca staff installed and operated the first Ultrasonic Velocity Meter (UVM) in the District in 1990.

Water-quality stations.—The DEC collected most of the water-quality monitoring data for New York. The District was collecting water-quality data at 77 gages at the beginning of the period and at 60 gages at the end of the period. Much of these data were project related. The NASQAN program and water-quality data collected for projects made up the USGS water-quality data program. NASQAN supported 15 sampling sites. Two of these sites had 8 years of record, and 13 had 14 to 22 years of record. During the period, the District also collected PCB samples in the water column at seven sites along the Hudson River in the 50-mile reach from Fort Edward to the Federal Dam at Troy.

New York District funds, fiscal years 1980–94

[Funds, in thousands of dollars]

Fund source	Fiscal year														
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	4,089	4,668	4,461	4,133	5,411	4,522	4,907	5,050	5,545	5,354	5,569	6,463	7,009	6,026	6,847
OFA	579	614	879	757	813	733	1,184	1,577	1,542	1,534	1,201	669	969	680	1,305
Fed	490	557	425	418	492	582	614	746	749	617	577	1,054	1,568	1,920	2,259
Total	5,158	5,839	5,765	5,308	6,716	5,837	6,705	7,373	7,836	7,505	7,347	8,186	9,546	8,626	10,411

Ground-water observation wells.—The District began the period with water-level observations at 130 wells by Long Island staff and at 44 observation wells by the Albany and Ithaca staff. At the end of the period, water levels were being reported for 754 wells on Long Island, 31 upstate wells by Albany staff, and 22 wells by Ithaca staff.

Water-use data.—The Water-Use program in New York began in fiscal year 1979 as part of the National Water-Use Information Program (NWUIP) of the USGS. The original project proposal stated that the primary objective of the program was to "... collect, store, and disseminate water-use data to complement data on availability and quality of the State's water resources ...." This objective is still valid. The original State cooperators were the New York State Department of Environmental Conservation (NYSDEC) and the New York State Department of Health (NYSDOH). Since 1980, only the NYSDEC has formally cooperated with the USGS on the Water-Use program; the NYSDOH, however, continues to contribute a significant amount of water-use data.

The water-use data are organized by water-use category as defined by the NWUIP. In 1980, surface-water and ground-water withdrawal data were collected for the categories of public-water supply, rural use (water for domestic and livestock use), irrigation, industrial use, and withdrawals for the generation of thermoelectric power. Water used for the generation of hydroelectric power was also included. This information was published by the State in the national Circular, "Estimated Use of Water in the United States in 1980." Similar Circulars are published nationally every 5 years.

From 1980 to 1995, emphasis was placed upon broadening the scope of the data. In 1985, the water-use categories of commercial, mining, and wastewater treatment were added. The rural use category was divided into the categories of domestic and livestock. In 1985, data were collected and stored by county for the first time; previously, data were collected only by drainage basin. In 1990, the agriculture category was divided into livestock and fish farming to identify the growth or decline of fish farming in the United States. Withdrawal data also were collected by a smaller drainage basin unit than in previous years. Each 5-year report includes additional detail, such as irrigation by specific type of irrigation system, refinement of deliveries by public water suppliers to user categories, and the consumptive use of water in specific categories.

Since 1980, the New York District has received site-specific data on public water suppliers from the NYSDOH and on thermoelectric powerplants and wastewater-treatment plants from the NYSDEC. Withdrawals and deliveries for the other categories of water use were largely estimated by the New York District and by the cooperator through a wide variety of water-use and ancillary information from national, State, local, and private sources. The goal of the water-use program, since its inception, has been to identify, develop, and refine sources of water-use data and methods of water-use estimation to deepen the knowledge of water use in New York State.

INTERPRETIVE STUDIES

Northeast Glacial Aquifers RASA (Regional Aquifer-System Analysis).—This large project, which was led by F.P. Lyford, headquartered at the New York District Office and covered New England, New York, northern Pennsylvania, New Jersey, and Ohio; it was active from 1982 to 1991, although report rewriting extended well past 1994. Because the region contains thousands of independent glacial stratified-drift aquifers, the RASA project supported intensive study of representative localities and tried to enunciate concepts and typical values that could be applied widely in evaluating individual aquifers. Major reports dealt with principles and regional patterns of aquifer geometry (Professional Paper 1415B, by A.D. Randall), geophysical methods useful in deciphering aquifer geometry (Professional Paper 1415A, by F.P. Haeni), recognition and estimation of upland runoff as a major source of recharge to valley-fill stratified drift (papers by Lyford and Cohen, Morrissey and others, and Williams and Morrissey, published by the American Water Resources Association and the American Society for Testing and Materials), and a new MODFLOW computer program by Angelo Kontis that simulates recharge to a valley-fill aquifer from upland runoff and direct precipitation, as constrained by head in the aquifer and in the uplands (Professional Paper 1415C, OFR 00–173, WRIR 96–4086). Several members of New York District undertook intensive local studies or regional appraisals for the RASA program: T.S. Miller (evaluation of aquifer geometry in the Valley Heads moraine at Dryden); R.M. Yager (magnitude and uncertainty of vertical streambed hydraulic conductivity at Kirkwood estimated from an aquifer model); R.J. Reynolds (continuous water-

borne seismic reflection profiles to delineate stratigraphy along the Susquehanna River); R.J. Rogers (origin and geochemical evolution of dissolved constituents in ground water in stratified drift and bedrock in several localities); T.S. Miller and D.H. Tepper (a map showing distribution and inferred yield of stratified-drift aquifers in the glaciated Northeast) and A.D. Randall (mutually consistent contour maps of 1951–80 precipitation, runoff, and evapotranspiration in the glaciated Northeast, the first New York District report released only in electronic form).

Radioactive-Waste Burial-Ground Investigations.—A study of subsurface migration of radioisotopes from the low-level commercial radwaste burial ground at the Western New York Nuclear Service Center (commonly referred to as West Valley) in the town of Ashford, funded by the USGS Office of Radiohydrology, began in 1975 and was led principally by D.E. Prudic. It generated the first of several publications in 1979 and culminated in Professional Paper 1325 in 1986. The study concluded that most water in the waste-burial trenches had entered through cracks in the trench covers caused by collapse and seasonal desiccation, but that tritium-laden trench water had migrated less than 3 meters into the underlying till in 7 to 11 years, and that radioisotopes would continue to migrate downward for thousands of years, not laterally to small stream channels beside the trenches. The USGS study complemented and interacted with concurrent investigations by New York State's (NYS) Geological Survey, NYSDOH, and NYSDEC) and by Brookhaven National Laboratory, providing a good example of interagency cooperation.

By the early 1980's the project was turned over to the Ithaca office and the Ithaca project team of M.P. Bergeron, R.M. Yager, W.E. Harding, and W.M. Kappel began data-collection efforts. The objective of this phase of the work was to determine the hydrogeology for two sites and develop ground-water-flow models for future site-remediation efforts. The project consisted of drillhole installation and water-level monitoring around the high-level waste site and around the main processing plant and surface-water-flow data collection at several ephemeral streams and a series of springs along the edge of the North Plateau area.

Following the data collection and analysis, two ground-water-flow models were developed—M.P. Bergeron completed the modeling efforts around the high-level repository while R.M. Yager completed the ground-water-flow model for the waste-plant site. The project work was completed on time and to the satisfaction of the Nuclear Regulatory Commission. The site was subsequently turned over to the U.S. Department of Energy, and USGS involvement at the site was slowly phased out by the early 1990's.

Basinwide ground-water appraisals.—Several products for water-resources studies launched in the 1960's, whose completion or publication was delayed by the collapse of Coop funding in 1969, were finally published in the 1980's, including maps of ground-water availability in the Allegheny, Black, and Genesee River Basins by M.H. Frimpter, R.M. Waller, J.C. Kammerer, and W.A. Hobba, and a report on stratified-drift aquifers in the Susquehanna River Basin by R.D. MacNish and A.D. Randall that contains a comprehensive procedure for estimating aquifer recharge. In cooperation with NYSDEC, new maps showing well records, surficial geology, and ground-water availability in the Mohawk River Basin were prepared by R.J. Reynolds and were based in large part on mapping and well inventory conducted in the 1960's by J.M. Whipple and R.G. LaFleur. Similar but less thoroughly documented ground-water availability maps of the St. Lawrence, mid-Hudson, and Delaware–lower Hudson River Basins were prepared by E.F. Bugliosi and S.W. Wolcott, thereby completing coverage of all major watersheds in upstate New York.

From 1979 through 1982, studies of several distinctive aquifers in the Susquehanna River Basin were undertaken in cooperation with the Susquehanna River Basin Commission. A.D. Randall, D.S. Snavely, and others investigated several broad headwater valleys around the basin perimeter that contain aquifers capable of providing large seasonal ground-water supplies with minimal depletion of streamflow. Similar valley reaches near Cortland and Smyrna, also not traversed by major streams, were modeled or evaluated by R.J. Reynolds and G.A. Brown. The Susquehanna River valley in Broome County was modeled by A.D. Randall.

Upstate aquifer mapping.—A concerted effort to map the aquifers of upstate New York was begun in 1980 with the development of a list of the 18 most heavily used unconsolidated aquifers (called primary aquifers by the State). By the late 1980's, detailed mapping of these aquifers at the 1:24,000 scale was nearly completed and investigation of a number of other significant aquifers (called principal aquifers by the State) was underway. In 1988, five "strip" maps

that presented the distribution of unconsolidated aquifers across upstate New York were published at the 1:250,000 scale. By 1994, 29 detailed aquifer maps had been published.

Borehole geophysics.—Traditional borehole-geophysical logging methods such as gamma and electric were routinely used in unconsolidated aquifer investigations on Long Island during the 1980's. Starting in the late 1980's and early 1990's, new and innovative techniques were used and included electromagnetic induction logging in saltwater-intrusion studies on Long Island and borehole image, radar, and flowmeter logging in upstate fractured-rock studies. These applications were the precursor for the New York District becoming a leader in the use of advanced borehole geophysics for ground-water investigations.

Niagara Falls area regional studies.—New studies began in the Niagara region in the mid-1980's at the request of the U.S. Environmental Protection Agency (USEPA) Region 2 office. Ground-water-flow conditions in the Niagara Falls area (U.S. side) and the influence of the Niagara Power Project (diversion of the Niagara River to Canadian and U.S. hydropower projects) on the direction of ground-water flow was of concern to the USEPA and NYSDEC. Project work was shared by Todd Miller and Bill Kappel for the 2.5-year project.

The most interesting aspect of the project was the unknown, but soon to be discovered, influence of the power project facilities on the ground-water-flow system. The huge 4.5-mile-long power tunnels that were excavated into the Lockport Dolomite diverted water from the river to a forebay canal. The canal is located between the Robert Moses hydropower dam and the upstream Lewiston pumped-storage reservoir. The exterior tunnel drainage system in the twin bedrock trenches was found to have greatly altered the natural flow regime and affected ground-water levels on a daily basis. The study was completed on time and was an excellent addition to the earlier work done by Richard Johnston.

Several years after the "Power Project" study (around 1989), the USEPA asked if the USGS could develop a three-dimensional ground-water-flow model of the Niagara Falls region. The study area was from the Lockport (Niagara) Escarpment to the north, the Niagara Gorge to the west, the middle of Grand Island to the south, and an arbitrary eastern boundary (approximately a north-south line falling east of the eastern Niagara River channel upstream from the Falls). USGS worked with our Canadian counterparts—the Ontario Ministry of the Environment from Hamilton Ontario—in the development of an international data-collection effort using multilevel piezometers to determine the hydrogeologic framework in the Niagara Falls area. Four deep piezometer systems were installed on the U.S. side and five were installed on the Canadian side of the Niagara River. The deep bedrock holes were drilled through the Lockport Dolomite and into the Queenston Shale to determine bedrock stratigraphy and the hydraulic heads within the bedrock units. The Grand Island hole was the deepest (about 525 feet) and the shallowest was the Niagara-1 drillhole (about 435 feet), which was drilled just north of the Niagara Falls/U.S. Air Force airport/airbase. Data from these wells indicated that the Rochester Shale (lying just beneath the Lockport Dolomite) and very high natural gas pressures (methane and hydrogen sulfide) were effective barriers to downward water/contaminant movement except near the Niagara Gorge and along the Niagara power tunnels. Five additional installations, which were drilled in the U.S. study area, were drilled through the Lockport/Rochester sequence to confirm the initial findings.

These USGS data-collection efforts were used in the development of the 3-D ground-water-flow model. Niagara study staff included Richard Yager (modeler), Dorothy Tepper (geologist), and Bill Kappel (integrator). The project was completed late, and the only tangible output was the model and model report, which satisfied the USEPA and NYSDEC. A storehouse of data is available for inclusion into several reports, should funding become available.

Constructed wetlands.—Two constructed wetland projects were developed by the Ithaca Subdistrict, in the mid- to late 1980's, through the efforts of Jan Surface. The first project was in cooperation with Tompkins County Department of Waste and Sanitation. The county was looking for an economical way to treat leachate generated at the county landfill. The Coop funding for the project was obtained through NYS Energy Research and Development Agency (NYSERDA), Tompkins County, and the USGS. Jan designed and oversaw construction of the waste-treatment beds filled with gravel and phragmites (wetland plants). The project was moderately successful in treating the leachate, but Tompkins County returned to hauling the leachate to the wastewater-treatment plant, as the NYSDEC would not allow the discharge of the treated leachate to a nearby wetland.

The second project also was funded by NYSERDA, in cooperation with Monroe County, to treat leachate from a new landfill. While the project was similar to the Tompkins County study, the constructed wetland was built differently: the leachate from the new landfill was much more concentrated than that from the Tompkins County landfill. The project was initially led by Jan Surface, but she retired from the Survey and the project responsibilities were turned over to Dave Eckhardt. Results of this study were mostly successful, but the facility was not maintained by the county after the study was completed. Results indicated that there was a high level of maintenance needed to make the wetland facility function efficiently.

Monroe County studies.—The Irondequoit Creek watershed, Monroe and Ontario Counties, was included in the Nationwide Urban Runoff Program, 1980–81, and was studied by William Kappel, Richard Yager, and Phillip Zarriello. The creek transported 50 to 75 percent of the annual loads of most constituents during late January to early May and reflected constituent buildup in the snowpack and aggravated erosion during springtime sustained high flows. The most highly urbanized basins contributed the highest sediment and chemical loads (WRIR 85–4113).

From 1986 to 1990, William Coon studied hydraulic characteristics and computed roughness coefficients at 21 sites on streams throughout New York State. Roughness coefficients varied among sites and with water-surface elevations in predictable patterns based on energy gradient, dominant bed-particle size, stream-top width, and channel-vegetation density (WSP 2441, 1998).

Beginning in 1986, Phillip Zarriello, Donald Sherwood, and William Coon conducted studies to assess the effectiveness of stormwater-detention basins (WRIR 92–4003) and artificial wetlands to reduce peak flows and sediment and nutrient loads. Removal efficiencies of sediment and chemical loads can be improved by increasing stormwater-detention times in the basins and wetlands.

Since 1990, William Coon has studied a palustrine cattail marsh near the mouth of Irondequoit Creek in Monroe County to assess its water-quality-improvement function on stormwater discharges passing through it. The marsh serves as an area for removal of sediment and particulate chemicals (WRIR 00–4032). The removal of dissolved nutrients is variable and depends on the season and water levels in the marsh.

Flood studies and bridge scour.—In the mid-1960's, the New York District began a cooperative program with New York State Department of Transportation (NYSDOT). The program has historically entailed various types of flood-data collection, compilation, and analysis. Richard Lumia has been Project Chief since 1980. Some of the major aspects of the program are (1) crest-stage gage program, (2) documentation of notable floods, (3) hydraulic and hydrologic analyses at local bridge and culvert sites, (4) regional and statewide flood-frequency analyses, (5) bridge-scour analysis, and (6) n-value (roughness coefficients) verification study.

The District operated and maintained about 100 crest-stage gages through the mid-1970's. An evaluation of the streamflow-data program in 1970 resulted in the crest-stage gage network increasing to 146 sites in 1976, primarily to enhance the small-stream flood-data-collection aspect of the network. Because of limited funding and other funding priorities, the network was reduced to 73 sites in 1987. Again, because of budgetary restraints, the program and network were further reduced in the mid-1990's to a level of 48 crest-stage gages throughout New York.

Regional and local flooding is a serious problem throughout New York. Information on floods and analysis of flood data are needed to aid in the design of bridges, culverts, and highways. New York's cooperative program with NYSDOT has historically provided funding to document notable floods. Several major floods have been documented through Water-Resources Investigation Reports, including floods throughout northern New York in 1985 and flooding in the Catskill Mountain region in 1987. These reports provide one of the few documents showing the magnitude and frequency of the floods at specific gage locations throughout the flooded areas. Floods recorded at all gaging stations also have been periodically documented in several reports showing the maximum known stages and discharges of New York streams. Several of these types of reports have been published over the years, the most recent being "Maximum Known Stages and Discharges of New York Streams, 1865–1989, with Descriptions of Five Selected Floods, 1913–85."

Flood damage is a constant threat along flood plains and thus is a concern for local and regional managers and planners. Through the cooperative

program with NYSDOT, funding was provided for studies and reports providing techniques for estimating the magnitude and frequency of floods on rural, unregulated streams in New York. Multiple regression techniques have been used in the two most recent analyses (1979 and 1991). These analyses and resulting flood-frequency equations are widely used by various agencies, managers, and planners. NYSDOT uses these techniques extensively in the design of bridges and culverts spanning New York rivers.

Prior to the USGS Coop program, more general and less accurate methods were available for flood-frequency estimates. The addition of the small-stream, crest-stage gage network in the mid-1970's provided valuable data that helped vastly to improve the accuracy of flood-frequency estimates for New York streams.

Significant flooding in the Catskill Mountains region of New York in April 1987 resulted in the collapse of the New York State Thruway (I–90) bridge over Schoharie Creek, causing 10 deaths. This catastrophe was the impetus for a major cooperative project with NYSDOT to study bridge scour in New York. In 1988, Gerald Butch, Project Chief, selected sites near USGS stations along streams that contain erodible bed material, or that appeared unstable, and began collecting bridge-scour data at 77 bridges throughout New York. Scour and cross-section data collection continued through mid-1990's. Most of the studied streambeds are armored by gravel and cobbles. Many high flows of short duration did not cause scour, but the deepening of scour holes by prolonged or multiple high flows indicated that the length of time a flow exceeds a given discharge at a site is a critical factor. Local scour holes generally increased with water depth and stream velocity but did not refill during flow recessions. Eight reports were written during the study. The final report describes a best-fit linear-regression equation that estimates the depth of scour that would result at a bridge pier from a single peak flow in coarse streambeds. The scour-depth estimate is proportional to the magnitude of stream momentum near a pier and inversely proportional to grain size.

Four types of scour-monitoring instruments were evaluated for the Federal Highway Administration's Project 97, "Scour Monitoring and Instrumentation" (a magnetic sliding collar and three sonar systems). Data collected from these instruments were compared with field observations to verify spatial and temporal changes in streambed elevations.

The above projects resulted in a need for assessment of roughness coefficients (n-values) that are representative of stream channels throughout New York State. In cooperation with NYSDOT, Richard Lumia, Project Chief, conducted a statewide roughness-coefficient study during 1983–88. The results of the study, published in a 1995 report, allow for more accurate selection and computation of roughness coefficients for stream channels in New York, which should provide more accurate and efficient design of bridges and culverts over streams throughout the State.

Saltwater encroachment.—Saltwater encroachment is an ever-present threat to the Long Island aquifer system. In the 1930's, overpumping led to the abandonment of ground water as a source of supply in many of the western counties due to saltwater encroachment. In the 1960's elevated nitrate concentrations in the aquifer system led to sewer installations over large parts of the island. This led to renewed and heightened concerns about saltwater encroachment within the aquifer system as population and demand for potable water continued to increase in the eastern counties. From 1980 to 1994 the USGS has conducted many local and regional studies involving saltwater encroachment on Long Island. Many studies have used innovative electromagnetic technologies and computer modeling to investigate saltwater movement. In the late 1970's, an appraisal of the water resources of the South Fork was initiated because of the increased demand caused by the seasonal population. This work was followed by a more focused study in the Montauk area. Concurrently, an extensive evaluation of the ground-water resource in the western part of the island was begun to determine the changes in water quality. In addition in 1986, work began in Nassau County to update the position of the saltwater interface on the south shore of the county, and in 1990 a saltwater intrusion study was initiated on the north shore of Nassau County. In 1989, work began on the North Fork of the island to define the availability of the ground-water resource, and in 1992 work began within the entire Peconic Estuary to investigate ground-water flow and hydrologic budgets in the estuary.

Ground-water modeling on Long Island.— The USGS–WRD has experienced a rapid development of ground-water computer modeling projects on Long Island. This occurred approximately from 1979 to 1994. Conditions were ideal: (1) The Long Island hydrogeologic framework was well understood and had already been the subject of extensive electric-analog modeling studies in the 1960's and 1970's; (2) Long Island's economy, including water demand, was accelerating; and (3) significant technical advances were achieved in computers that allowed solution of new classes of mathematical problems, previously unimagined. Many practical problems were solved with unprecedented levels of accuracy during this time, including the following: in 1982, water-table declines to be caused by sewer construction were predicted; in 1985, saltwater intrusion was predicted in the Montauk point area; in 1986, the effects of remedial actions were predicted for the Brookhaven National Laboratory landfill plume; in 1986, a geographic information system (GIS) display of the hydrogeologic framework of Long Island was released to the public; in 1987, a technique for coupling a Long Island regional model to subregional models was demonstrated; in 1991, water-source areas to confined aquifers were delineated; in 1992, ground-water residence times throughout the entire ground-water system were estimated; in 1992, land use was correlated to shallow water quality; and in 1994, water-source areas to pumping wells were delineated. All of the hydrologists who were involved in these and other results are too numerous to mention here, but the key players were Keith Prince, Tom Reilly, Lehn Franke, E.J. Wexler, Herb Buxton, and Doug Smolensky. By 1994, they had all moved to other regions or left the USGS.

OHIO

By Steven M. Hindall, *including information provided* by Jeffrey T. de Roche, Harold L. Shindel, and Richard V. Swisshelm, Jr.

INTRODUCTION

As the 1979–94 period began, the Ohio District consisted of a large District Office in Columbus and a small Field Office in New Philadelphia. The District Office remained in the same location, at 975 West Third Avenue, after USGS water programs were reorganized into a single Division in 1965. A Field Office was established in New Philadelphia (before 1957) and remained at the same location throughout the 1979–94 period. The Ohio District maintained a well-balanced technical program, not only between hydrologic surveillance and interpretive studies but also among the surface-water, ground-water, and water-quality disciplines.

Major Events

Several significant administrative and programmatic events occurred in the Ohio District over the 1979–94 period, beginning with the transfer of District Chief David E. Click and the appointment of Steven M. Hindall as new District Chief, a position that Hindall held through the period. The last major event in the period was the arrival of the National Water-Quality Assessment (NAWQA) Program.

FUNDING

Funding for the Ohio District during 1979–94 was highly variable; but overall, funding more than kept pace with inflation. The District saw a significant funding increase in the early 1980's, during the Coal Hydrology period. This spurt in funding was short lived, and the demise of the Coal Hydrology Program

Ohio District funds, fiscal years 1979–94

[In thousands of dollars]

Fund source	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	1,756	1,780	1,707	1,815	1,673	1,810	1,721	1,770	1,819	1,955	1,806	2,115	2,641	2,339	2,439	2,653
OFA	556	691	580	525	427	358	289	361	566	1,043	1,555	1,329	1,078	2,770	3,283	2,856
Federal	490	848	780	394	390	430	517	466	289	196	250	286	406	418	369	500
Total	2,802	3,319	3,067	2,734	2,490	2,598	2,527	2,597	2,674	3,194	3,611	3,730	4,125	5,527	6,091	6,009

caused a significant dip in funding through the mid-1980's. By the late 1980's, work with the U.S. Air Force (USAF), primarily at Wright-Patterson Air Force Base (WPAFB), turned the Ohio District's funding around with a significant increase in early 1990 and further increases in the 4 years thereafter.

Cooperative (Coop) program funding increased steadily over the period except in the mid-1980's, when Coop funding was fairly level because of Federal budget cuts. Increases during the late 1980's and early 1990's were partly the result of increases in Federal matching funds but were more directly related to cooperator willingness to put up unmatched funds for their cooperative programs.

Other Federal agency (OFA) funds declined significantly in the first half of the 1980's because of cutbacks in the U.S. Army Corps of Engineers (Corps) water-quality program on the Ohio River. During the last half of 1980's and into the early 1990's, the OFA program grew considerably, owing to the start of the Federal Emergency Management Agency (FEMA) flood program in 1985 and the USAF work at WPAFB in 1987. Work with the USAF program continued, reaching a high point in 1993 and then beginning to decline in 1994.

The Federal program alternately grew and declined during 1979–94; however, the Federal dollars for 1979 and 1994 were almost identical. Federal funding reached a high during the Coal Hydrology years of 1980 and 1981. Funding for Ohio's part of the Regional Aquifer-System Analysis (RASA) program in 1982 stabilized funding through the mid-1980's, until the completion of the project resulted in a sharp decline in 1987 and 1988. The start of the Management Systems Evaluation Area (MSEA) program in 1990 and the Lake Erie–Lake Saint Clair Basin (LERI) NAWQA project in 1994 brought Federal funding up to the level it was in 1979; however, considering inflation, the Federal program was effectively about twice in 1979 what it was in 1994.

Cooperation

The number of agencies that cooperated in investigations with the Ohio District during 1979–94 varied considerably, from a high of 25 in 1987 and 1988 to a low of 12 in 1981. At the beginning of the period, the District had 10 State and local and 5 OFA cooperators, a total of 15. By 1981, these numbers had declined to 9 State and local and 3 OFA cooperators, a total of 12. From this low there was a continual increase through late 1980's to a total of 25, with 20 State and local and 5 OFA cooperators in 1987 and to 21 State and local and 4 OFA cooperators in 1988. From this 2-year high, the District experienced a second decline to 17 State and local and 5 OFA cooperators—a total of 22—in 1994.

Five agencies—Ohio Department of Natural Resources (ODNR), Ohio Department of Transportation (ODOT), Ohio Environmental Protection Agency (OEPA), U.S. Department of Energy, and the U.S. Department of Defense (USDOD), either the Corps or USAF—shared the top three spots in terms of size of program for each year during 1979–94. ODNR maintained the number one spot for every year except during 1993–94, when USDOD was in the top spot.

Six cooperators supported the Ohio District program continuously throughout 1979–94. They were ODNR, ODOT, the Cities of Columbus and Canton, the Miami Conservancy District, and the Corps. The Ohio Environmental Protection Agency supported the District program in one way or another every year except 1993 and 1994. FEMA started its support in 1984 and the City of Fremont in 1985, both continuing their support through the end of the period.

Number of Employees

At the beginning of 1979–94, the Ohio District had 99 employees, 71 permanent and 28 other than permanent. There were almost two technicians to every hydrologist (59 to 26, respectively). The District also had 14 administrative and reports support personnel.

In 1987, the number of District personnel reached a low point for the period at 47 employees, 44 permanent and 3 other than permanent, with almost an equal number of technicians (15) and hydrologists (19). District support personnel also reached a low of 10 people that year.

At the end of the period, the number of employees had risen to 67, with 57 permanent and 10 other than permanent. The technician-to-hydrologist ratio had reversed from that in 1979, with hydrologists outnumbering technicians by more than 2 to 1 (35 hydrologists to 16 technicians). The District's support personnel had risen to 16 employees, 2 more than at the start of the period.

DISTRICT STRUCTURE AND ORGANIZATIONAL CHANGES

The organization of the District in 1979 was fairly typical of most USGS Districts: a District Chief, an Assistant District Chief, and three sections—District Services, Hydrologic Surveillance, and Hydrologic Studies. The District Services Section handled administrative and computer services, report processing, instrumentation, equipment and construction, laboratory services, and analytical quality control. The Hydrologic Surveillance Section was subdivided into a Columbus Unit, with three major drainage basins, and the New Philadelphia Field Office, with two major drainage basins. The Hydrologic Studies Section was made up of four units—Project Support, Hydrology and Hydraulics of Surface-Water Systems, General Hydrologic and Environmental Assessments, and Hydrology and Hydraulics of Ground-Water Systems.

Three technical discipline-specialist positions for ground water, surface water, and water quality were also formally created in 1981. The Ground-Water Specialist was in the Hydologic Studies Section, the Surface-Water Specialist was in the Hydrologic Surveillance Section, and the Water-Quality Specialist was in the Laboratory Services Unit.

In 1981, the New Philadelphia Field Office was upgraded to a Subdistrict Office to handle the Coal Hydrology Program work in eastern and southeastern Ohio and the anticipated increase in interpretive projects in the Cleveland area and Lake Erie Basin. However, the Cleveland and Lake Erie work did not materialize to the extent expected, and the Coal Hydrology Program declined as rapidly as it had increased. Consequently, in 1984, the Subdistrict was downgraded and once again became a Field Office.

In 1983, the Administrative and Laboratory Services Units were removed from the District Services Section and placed directly under the District Chief. When the Assistant District Chief transferred to California in 1985, the position was abolished and the remaining units within the District Services Section were also placed under the District Chief. A significant reorganization occurred in the District in spring 1989: the Computer Services Section was moved to the Hydrologic Surveillance Section to create the Hydrologic Surveillance and Information Management Section. The new section now contained three units: Hydrologic Surveillance, Computer Services, and Hydrologic Surveillance Special Studies. The Surveillance Unit now had three areas: New Philadelphia, Columbus 1, and Columbus 2. Program development was added to the Hydrologic Studies Section, and the new section consisted of five units: Hydrologic Studies and Modeling, Geohydrologic Studies and Modeling, Environmental Studies, Laboratory Services, and Hydrologic Investigation Support.

Early in 1992, a new section called the Environmental Quality and Hazardous Waste Hydrology Section was created to handle the rapidly increasing program with USDOD and WPAFB. Toward the end of 1992, the ground-water unit from the Hydrologic Investigation and Program Development Section was moved to the new section and the name changed again to the Geohydrologic and Environmental Investigations Section.

At the end of 1994, the District had four technical sections and multiple units. The Hydrologic Surveillance and Information Management Section was made up of the Columbus Unit covering southern and western Ohio, the New Philadelphia Unit covering eastern Ohio, and the Computer Services Unit. The Geohydrologic and Environmental Investigations Section was made up of the Geohydrologic Studies Unit and the Environmental Studies Unit. The Hydrologic Investigations and Program Development Section was made up of the Hydraulic Studies and Modeling Unit and the Water Quality and Ecological Studies Unit. The Laboratory Services Unit reported to the Water Quality and Ecological Studies Unit. The LERI NAWQA Section was largely self-contained and operated under the general oversight of the District Chief.

Three units reported to the Office of the District Chief: Administrative Services Unit, Report Processing Unit, and Northeastern Region Editors Unit. The three major technical discipline specialists also reported to the District Chief but remained under the supervision of the appropriate Section Chief.

DISTRICT ADMINISTRATION AND SERVICES

Office of the District Chief

At the beginning of the 1979–94 period, David E. Click was serving as the third District Chief in Ohio. Early in 1979, he transferred to Pennsylvania as District Chief. In spring 1980, Steven M. Hindall was

selected to succeed Click, and he remained District Chief throughout this period.

There were three Assistant District Chiefs in the Ohio District during 1979–94. Richard O. Hawkinson served from 1977 to 1980, when he was reassigned to the Colorado District. Frank W. Giessner was selected as Assistant District Chief in 1981 and served until 1985, when he was reassigned to California. The position of Assistant District Chief was abolished when Giessner left and reestablished in 1989, when Richard V. Swisshelm, Jr., was appointed Assistant District Chief while retaining his Section Chief responsibilities. Swisshelm continued to serve as Assistant District Chief through the end of the period.

During 1979–94, Jane E. Hintershied was the only person to hold the position of District Secretary, a position that was abolished when she retired in 1994.

Administrative Services Unit

Norma J. Stewart was the District Administrative Officer at the beginning of the 1979–94 period and retired from the position in 1981. Herbert K. Fugitt served as the Administrative Officer from 1982 through 1993, when he resigned. Selected as Administrative Officer in 1994, Denise M. Payne continued in that role through the end of the period. Others who served in various capacities in the Administrative Unit were Jane A. Sturtz, Hildegard M. Nichols, Janet J. Welday, Mary M. Underwood, Linda D. Camp, K. Scott Jackson, Sandra J. Beck, Toby L. Arebalo, Rhonda K. (Phillips) Toland, Cynthia L. Siders, Naomi L. O'Harra, R.L. Carter, Clay H. Thompson, Rebecca L. Guthrie, S.D. Downey, Karen L. Dickson, Cathy M. Virosteck, Leah N. (Jackson) Hout, and Shonnie A. (Tripp) Grell.

Reports Processing Unit

The District Reports Processing Unit was under the District Services Section during 1979–85. District Reports Specialists during that time were Stanley E. Norris (until 1981) and Frank E. Giessner (1981–84). Other personnel in the unit at that time were Bonnie J. Bricker, Janis A. Printz, Richard P. Frehs, Charlene C. Vince, Michael Eberle, Kathy A. Geary, and Linda D. Camp.

In 1985, the Reports Processing Unit was under the office of the District Chief, where it remained through the remainder of 1979–94. Eberle was named Reports Specialist in 1985 and served through 1989; at that time, the title was changed to Reports Coordinator and Frehs was appointed to this position, which he held through the end of the period. Additional personnel that served in the Reports Processing Unit during this period were Joyce A. McClure and Betty B. Palcsak.

In 1992, a new unit was formed from the Reports Processing Unit to handle report editing for the Northeastern Region. This unit was staffed by Eberle and Palcsak, reported to the District Chief, and was called the Northeastern Region Editors Unit. This Unit remained in place through 1994.

Computer Services Unit

It was during 1979–94 that the USGS and the Ohio District really joined the computer revolution. The teletypes and primitive microcomputers in operation at the beginning of the period were supplemented in 1983 by a minicomputer, which was supplemented in 1991 by workstations. Besides being networked locally and nationally, there was a workstation or terminal on nearly everyone's desk.

In 1979, the District's computer operations were handled by the Computer Services Unit in the District Services Section. R. Michael Hathaway headed the unit from 1979 to 1982 and was assisted by Gracie F. Ward, Ann E. Arnett, Mary Y. Smith, and Phillip L. Holler. Others who worked in the unit were Joyce A. McClure, Gary E. Miller, Charles W. Staples, Michael P. Doyle, Melanie E. Robbins, Joseph H. Liddle, and Michael K. Bogan. In 1983, the Computer Services Unit was moved to the Hydrologic Records Section from the District Services Section, where it remained for the rest of the period. Vance E. Nichols took over the Unit when it was moved and was appointed the District's Computer Specialist at that time, a position he held through the end of the period. Others who worked in the Unit after it was moved were Janet J. Welday, D.T. Vehr, Stuart P. Ravary, Ronald J. Veley, Bruce L. Finch, Robin M. Timmons, and Danny W. Bunner.

Laboratory Services Unit

At the beginning of the period, the Ohio District laboratory did sediment analyses not only for Ohio but also for the Michigan, Indiana, Illinois, Wisconsin, Pennsylvania, and New York Districts. This line of

service work was on its way out, however, as sediment programs in all the Districts dwindled and as pressures for use of contract laboratories increased. By 1985, when the laboratory was placed under the Hydrologic Surveillance Section, the laboratory was serving only Ohio; most of its work by then was in support of field personnel, either in preparation of supplies for sampling trips or assistance in shipping samples to outside laboratories. Personnel who served in the laboratory from 1979 to 1985 were C.G. Angelo, J.C. Boyle, J.D. Christman, G.E. Davison, R.R. Fawcett, K.A. Geary, R.E. Horky, B.L. Jamieson, J.H. Liddle, B.B. Palcsak, K.L. Royce, W.B. Simons, D.S. Skalsky, B.C. Steiner, M.N. Strickling, S.R. Workman, E.A. Yocum, and M.M. Zielke.

Instrumentation Equipment Unit

Serving surveillance and studies personnel alike, this unit went through a major boom-and-bust cycle in the early 1980's. In 1979, the Unit was operating as the Instrument, Equipment, and Construction Unit and had four members. Within a year, the unit had increased to six members, and its work was largely concerned with automated water-quality monitoring and sampling equipment. ("Construction" was no longer part of its name.) The decline in coal-hydrology work in 1982 and a decline in the monitor program beginning shortly thereafter meant the end of the unit's better days. By late 1983, the unit was back to four employees, and two of those four shared their time with the Hydrologic Surveillance Section. By January 1985, the unit was gone, and the last member (Max S. Katzenbach, the Unit Chief throughout the period) became a full-time member of the Hydrologic Surveillance Section. Other personnel who served in the Instrumentation Unit from 1979 to 1985 were B.E. Butters,V.M. Guy, M.H. Hammitt, K.S. Jackson, J.H. Liddle, J.K. Mitchell, C.N. Owens, R.C. Santell, L.W. Sturtz, and J.S. Weiss.

Regional Aquifer-System Analysis Unit

Late in 1988, the Midwestern Basin and Arches was selected as a national Regional Aquifer-System Analysis (RASA) project in the Northeastern Region, and the Regional Hydrologist chose a team of hydrologists and hydrologic technicians in the Ohio District to conduct the study. The project was led by Edward F. Bugliosi, with Sandra M. Eberts, George D. Casey, and Lori L. Lesney serving as principal scientists. Others who worked on the Midwestern Basins and Arches RASA project were Michael L. Strobel, Michelle Ridenour, R. Jeffrey Swope, Danny W. Bunner, Paul R. Nerswick, Robert H. Hanover, Robert L. Joseph, Frank D. Voss, H. Gile Beye, Eunice J. Adamany, Anthony D. Robinson, and Laura Van Slyke.

The members of the team reported to the Regional Hydrologist and were not part of the Ohio District; however, they worked for the Water Resources Division during 1979–94 and are included in the Ohio District chapter to be sure they are recognized as part of the 1979–94 WRD history. By the end of 1994 the Midwestern Basin and Arches RASA project was completed, and the staff either was assimilated into the Ohio District or other Districts or left the USGS.

National Water-Quality Assessment Section

Another milestone was reached in 1993 when the Lake Erie–Lake Saint Clair (LERI) study unit of the NAWQA Program began its operation in the Ohio District. By the end of 1994, the section was staffed by Donna N. Myers, Michael E. Wieczorek, Mary Ann Thomas, John S. Tertuliani, Kevin D. Metzker, and Dennis P. Finnegan, and the project was well under way with planning and retrospective analysis.

HYDROLOGIC SURVEILLANCE PERSONNEL AND PROGRAM

Personnel

At the beginning of the period, James W. Board was head of the Hydrologic Surveillance Section. He retired in l980. Harold L. Shindel was appointed as head of the section and remained Section Chief through the end of the period.

Columbus office.—In 979, the Columbus office was divided into three subsections headed up by three supervisory technicians: Jesse H. Klingler, Lawrence L. Stewart, and James P. Mangus. With the general downsizing of the section and the retirement of Klingler and Stewart, Mangus became the only remaining supervisory technician. The loss of personnel was of greater proportion than the loss of stream gages and water-quality monitors. Other members of the Columbus section were John W. Roberts, Stephen H.

Vivian, Steven W. Hatch, Daniel J. Shifflet, Tom Eaton, Alban W. Coen III, John M. Smith, Michael J. De Grand, Dean F. McFadden, Clayton H. Thompson, Alan C. Sedam, Peter B. Klausemeyer, Max S. Katzenbach, Al Davis, Edward J. Duffy, Robert W. Boulger, A. Brice Gordon, William P. Van Liew, Jonathan S. Weiss, Betty B. Palcsak, Robert J. Janosy, Joyce A. McClure, Jonathan B. Evans, Frank L. Santoro, Melanie E. Robbins, Charles N. Owens, Robert C. Martin, Robert W. Masters, Santford L. Jolley, Earl E. Webber, C. Michael Eberle, Cleve N. DeVault, Donald F. Easterling, T.E. Brumfield, and A.R.Castrillo.

From 1989 through 1994, the Columbus section was called the Hydrologic Surveillance and Information Management Section.

From 1983 through 1994, the Computer Services Unit was part of the Surveillance Section. During 1985–89, the Laboratory Services Unit was part of the Surveillance Section because much of the water-quality work at that time was noninterpretive. Members of the Laboratory Services Unit during that time were Betty B. Palcsak, Joseph C. Boyle, Robert R. Fawcett, and Clifford G. Angelo.

New Philadelphia office.—In 1979, Glenn D. Francis was in charge of the New Philadelphia Field Office. Francis retired in 1981 and Ronald R. Schwartz arrived early in 1982 as Subdistrict Chief and head of the newly established New Philadelphia Studies Section. During 1981–84, the New Philadelphia office was not part of the Surveillance Section. With the decline of the Coal Hydrology work, Schwartz transferred and the New Philadelphia Studies Section was no more. Lowell E. Trimble was placed in charge after Schwartz transferred, and the office once again came under the Surveillance Section. Other members of the New Philadelphia office during 1979–94 were Cheryl A. Hawkins, Steven R. Frum, Ted D. Graff, Anthony J. Tomasina, Lester M. Hicks, Bernard N. Sroka, Donald A. Storck, Paul A. Drewes, M. Davis, and David L. Perry.

Part-time employees were Jerry Biddle, Milton Harris, Jameel Dawan, Jason Baer, and Greg Hren. Volunteers for this period were Erica Lee and Angela Gray.

Program

In 1979, the Ohio District's annual data report consisted of two volumes and an appendix volume for the coal areas.The format changed in 1981 to two volumes: Volume 1, which contained data for the Ohio River drainage, and Volume 2, which contained data for the St. Lawrence (Lake Erie) tributaries, as well as statewide project data.This was the format used for the rest of the period.

The annual report for water year 1980 published flow data for 169 gaging stations, stage and contents for 39 lakes and reservoirs, water quality for 57 gaging stations and 83 wells, and water levels for 183 observation wells. Also included were data from 84 crest-stage gages, 91 low-flow sites, and 537 coal-hydrology sites as special projects.

The annual report for water year 1994 published flow data for 123 gaging stations, peak gage heights and flows for 21 crest-stage gages, stage and contents for 4 lakes and reservoirs, water quality for 25 gaging stations and 302 wells, and water levels for 251 observation wells.

Between 1979 and 1994, several significant changes were made to the surveillance program:

1. The crest-stage program was discontinued, as were the low-flow program and the Coal Hydrology Program.

2. The water-quality monitor program was much reduced when the Ohio Environmental Protection Agency dropped out of the Coop program with the USGS in 1988. The number of monitors declined from 29 in 1980 to 5 in 1994. The remaining monitors were being run for municipalities, the Corps, and ODNR. There was not much change to the stream-gaging program because cooperative funding for most of the stations was picked up by other agencies.

3. In order to reduce costs, the Corps districts eliminated all Ohio District involvement with their reservoir sites, had the equipment transferred to them, and began operating their lake and reservoir sites themselves. The remaining lake and reservoir sites run by the Ohio District were mainly for the City of Columbus.

4. As another cost-cutting measure for the Corps, the Ohio District in 1992 established a set of Continuous Record Annual Peak stations, where a full gage-height record is kept, but streamflow measurements are made only at high stages to confirm/change the high end of the rating. Only

the annual peak is published. In 1994, the Ohio District published 21 records in this category.

5. In the ground-water program in 1980, the Ohio District measured 40 wells and ODNR measured 50. In 1984, the Ohio District measured 10 wells and ODNR measured the rest. In 1994, the Ohio District did not measure any wells but reviewed and published data from about 120 wells.

Several special studies were administered through the Surveillance Section. Most of these studies were basic data-gathering activities Some of the more significant are the following (Project Chief's name in parentheses):

—Sediment study on the Black River (Alban W. Coen)
—Lake Erie tributary loading study (John W. Roberts)
—The Shadyside flood study (Harold L. Shindel)

INTERPRETIVE STUDIES PERSONNEL AND PROGRAM

Personnel

The Hydrologic Investigations and Program Development Section

The section called Hydrologic Investigations and Program Development Section in 1994 was the Hydrologic Studies Section in 1979 and became the Hydrologic Investigations Section in 1985; Program Development was added to the name in 1989. The section was under the direction of Richard V. Swisshelm, Jr., for the entire 1979–94 period.

The section expanded from 19 permanent employees in 1979 to 25 in 1980, and the number of other-than-permanent employees increased from 5 in 1979 to 10 in 1980. The funding for Coal Hydrology studies, however, decreased almost as rapidly as it had increased; by 1983, the section had 19 permanent employees and only 3 other-than-permanent employees. The section remained at this approximate size through the mid-1980's but began gaining employees toward the end of the decade. The section peaked at 33 employees in 1990, after which the rolls declined to 20 employees in 1994.

Despite the generally modest size of the section, nearly 100 people worked there at one time or another. The following is a list of all section personnel on record during 1979–94: G.D. Anderson, O.B. Arewa, E.S. Bair, W.P. Bartlett, M.W. Bender, T.R. Berry, J.P. Boyle, K.J. Breen, M.M. Bostwick, D.D. Brooks, J.D. Christman, A.W. Coen, S.C. Cooper, W.L. Cunningham, K.L Davidek, M.J. DeGrand, J.T. de Roche, P.A. Drewes, D.H. Dumouchelle, S.M. Eberts, M.J. Engelke, A.L. (Jones) Enderle, K.J. Ernstrom, J.B. Evans, D.P. Finnegan, D.S. Francy, R.J. Haefner, L.L. Hahn, J.A. Hambrook, M.V. Hammond, R.H. Hanover, J.O. Helgesen, D.R. Helsel, R.E. Horky, Janet Hren, K.S. Jackson, M.L. Jagucki, K.L. James, R.J. Janosy, D.P. Johnson, S.L. Jolley, R.L. Jones, J.A. Klingshirn, A.A. Koberstein, G.F. Koltun, R.I. Lane, J.W. Massman, C.K. Mast, R.W. Masters, G.C. Mayer, R.I. Mayo, K.D. Metzker, D.N. Myers, V.E. Nichols, C.J. (Childress) Oblinger, M.R. Ogden, C.J. Ostheimer, C.N. Owens, B.B. Palcsak, K.L. Pate, C.L. Pfaff, S.P. Ravary, A.C. Razem, J.L. Renninger, D.N. Riley, J.W. Roberts, A.D. Robinson, D.K. Roth, G.L. Rowe, K.L. Royce, A.J. Rubin, C.W. Schalk, J.E. Secrest, A.C. Sedam, T.S. Sharp, R.A. Sheets, J.M. Sherwood, B.N. Sroka, B.C. Steiner, D.M. Stoeckel, D.E. Straub, J.S.Tertuliani, M.A.Tibbetts, R.M. Timmons, J.D. Vasbinder, C.M. Virosteck, T.E. Warner, E.E. Webber, J.S. Weiss, S.L. Westover, D.A. White, M.T. Whitehead, K.S. Wilson, S.J. Yang, W.P. Yost.

The Geohydrologic and Environmental Investigations Section

The Geohydrologic and Environmental Investigations Section (G&EIS) was formed in November 1992 under the leadership of Jeffrey T. de Roche. It replaced the short-lived Environmental Quality and Hazardous Waste Hydrology Section (May–October, 1992) and was formed by combining the Environmental Studies Unit and Geohydrologic Studies and Modeling Unit formerly under the Hydrologic Investigations and Program Development Section. The section was created in response to the rapidly expanding ground-water program at Wright-Patterson Air Force Base. Frank Giessner, Assistant District Chief, made initial contact with WPAFB in 1986. The first project at WPAFB began in 1987. Between 1987 and 1991, the WPAFB project increased steadily in funding and staff. In late 1991, James M. Parnell was detailed from Kentucky to prepare the Basewide Monitoring Plan (BMP) for the WPAFB project. In Fiscal Year 1992, funding increased to $2.1 million for the WPAFB Project, resulting in the hiring of additional staff and the ultimate creation of the G&EIS.

Before its decline, the BMP Project at WPAFB contributed more than $8 million to the District program.

This new section was further subdivided into the Geohydrologic Studies Unit (GSU) and Environmental Studies Unit (ESU). Greg M. Nalley served as supervisor of the GSU during 1993–94. Between 1992 and 1994 GSU staff were working on projects for Geauga County and the City of Columbus and completing studies in the eastern Ohio coal fields. The ESU, under the guidance of William L. Cunningham, was devoted to work at WPAFB. Work consisted of drilling and installation of wells, water-quality sampling, and evaluation of the hydrogeology. Others who worked in the ESU were Linda R. Roberts, Peter R. Wright, Alban W. Coen, James M. Parnell, Kathy M. Sarver, Jonathan B. Evans, Robert A. Darner, and D.N. Riley.

Interpretive-Studies Program and Products

During the late 1970's and early 1980's the Ohio District (as well as other Districts in coal-mining States) were extremely busy with coal-related studies. Ohio had lead authorship on three reports in the national coal-area hydrology series: Area 4 (Roth and others, Water-Resources Investigations (WRIR) 81–343), Area 7 (Engelke and others, WRIR 81–815) and Area 11 (Roth and Cooper, WRIR/Open-File Report 84–233). A considerable amount of coal-related study also took place through cooperative investigations (with both State and Federal cooperators). Helgesen and Razem authored WRIR 81–913 on surface-mining-related changes in ground-water hydrology in two watersheds in Coshocton and Jefferson Counties, in eastern Ohio. Razem followed up with a detailed description of ground-water hydrology at the Coshocton County watershed (WRIR 83–4155) and the Jefferson County watershed (WRIR 83–4215) before, during, and after surface mining, and Hren analyzed further changes in ground-water quality resulting at the Jefferson County site (WRIR 86–4108). Razem and Sedam wrote about the ground-water quality and geochemistry of aquifers in the coal-bearing areas (WRIR 85–4034); Helgesen, Larson, and Razem presented a technique for simulating flow through stratified rocks in that same area (WRIR 82–4019). Nichols reported on the effects of a large-scale coal-mine reclamation effort near Lake Hope, Ohio (WRIR 83–217, WRIR 85–4197).

Concurrent with the coal studies were two investigations of eastern Ohio sandstones. Breen and others studied chemical and isotopic signatures from brines from oil- and gas-producing sandstones in eastern Ohio, with emphasis on geochemical tracing (WRIR 84–4314). Norris and Mayer published a definitive study on water resources of the Black Hand Sandstone in southeastern Ohio (WRIR 82–170).

By 1982, the Ohio District was moving forward in the area of quantitative hydrology. William P. Bartlett, Jr., became the Surface-Water Specialist and Allen C. Razem became the Ground-Water Specialist. Reports from both disciplines began to take a decidedly quantitative turn. In two reports (WRIR's 80–56 and 83–4022), Razem developed steady-state and transient simulations of the aquifer in southern Franklin County and set the stage for a long-term series of reports on that area (where a well field for the City of Columbus was developed). Reports by de Roche and Razem (WRIR's 81–919 and 84–4238) discussed ground-water quality in the planned well-field area and were followed with a report by Sedam, Eberts, and Bair (WRIR 88–4138) that addressed potential hazards to the new well field.

In 1985, Carolyn J. Childress became the District Water-Quality Specialist, and quality-assurance concepts were fully employed within the District at that time. In general, the Ohio District's water-quality program was rapidly gaining strength. It was during the mid-1980's that three Ohio District scientists (Janet Hren, Donna N. Myers, and Carolyn J. Childress) became involved in a project that was funded by USGS Headquarters to assess the utility of water-quality data collected by various agencies in Ohio and Colorado in answering questions about water-quality conditions and trends (Water-Supply Papers 2295A–C); this pilot study foreshadowed the kind of retrospective analysis and thinking that eventually became routine with the NAWQA Program.

In terms of public information and Ohio water law, two studies published in the mid-1980's were particularly noteworthy. In the first study, de Roche investigated the hydrogeology of an area just north of the Columbus well field (WRIR 85–4222). The most significant hydrologic feature in this area was a large cone of depression created by a local aggregate quarry. This report, and its predecessor by de Roche and Razem (WRIR 81–919), provided the basis for a change in Ohio's water law from the old English Doctrine to one of Reasonable Use (Cline v. American

Aggregates). The Ohio Supreme Court overturned the old rule, in effect since 1861, which did not recognize a landowner's water rights because there was no adequate means for measuring ground-water flow. In the second study, Sedam investigated the occurrence of uranium in ground water at the Department of Energy uranium enrichment facility at Fernald, Ohio (WRIR 85–099). The report detailed the area hydrogeology and documented the presence of uranium in ground water and surface water at the site. This report helped provide the impetus for the eventual multimillion-dollar cleanup of the site.

By the early 1990's, the Ohio District conducted its first quantitative bacteriological analysis. Bacteriological expertise increased markedly thereafter, and by 1994, Ohio was becoming a leader in this area among WRD Districts. Studies on bacteriological topics that began before 1994 included those on *Escherichia coli* and fecal-coliform bacteria as indicators of recreational water quality (Francy and others, WRIR 93–4083), distribution and variability of fecal-indicator bacteria in Columbus-area rivers (Myers, WRIR 92–4130), analysis of the regrowth of bacteria injured by chlorination (Francy and others, WRIR 96–4199), and effects of hydrologic, biological, environmental processes on sources and concentrations of fecal bacteria in the Cuyahoga River (Myers and others, WRIR 98–4089).

During the early 1990's, the Ohio District also expanded its technical capability in the area of the analysis and definition of flood profiles and delineation of flood plains. Gregory F. Koltun became the District Surface-Water Specialist and was subsequently selected to serve on the national Sediment Action Committee.

Also during the 1990's, the analysis of ground water was expanded to include transient-state particle tracking and more quantitative geochemical analysis. Ground-water projects at this time represented a finishing of certain lines of inquiry (coal hydrology in particular), continuation of others, and a few new lines of inquiry. Sedam and Francy completed a report discussing the geological setting and water quality in active coal-mining areas of Ohio (WRIR 93–4094), an area of almost one-third of the State. Dumouchelle and Bair (WRIR 94–4136), in cooperation with the U.S. Environmental Protection Agency (USEPA), released an investigation into ground-water levels and flow near a contaminated landfill in northeastern Ohio (WRIR 94–4136). This project was the beginning of a long-term and beneficial cooperation between the USGS and USEPA. Ralph J. Haefner had just begun work on the Flue-Gas Desulfurization project, and Martha L. Jagucki was completing work on the Management Systems Evaluation Area agriculture-related project in Piketon. Gary L. Rowe, Jr., began studying the use of chlorofluorocarbons as tracers for ground-water flow near Dayton. Rodney A. Sheets was wrapping up an investigation of the Teays River Buried Valley System, and Charles W. Schalk was preparing a report on capture-zone analysis of the south well field in Columbus. William P. Yost and Gary L. Barton were working on studies that would generate publications after the end of the 1979–94 period (hydrogeologic studies in southwestern and northeastern Ohio, respectively.)

Besides generating a wealth of basic data for the Air Force, the WPAFB program left behind three reports that were issued during or before 1994. Dumouchelle and others published a comprehensive report (WRIR 93–4047) detailing the hydrogeology of WPAFB and describing ground-water flow and ground-water quality. Sheets prepared a report describing contributing recharge areas to water-supply wells at WPAFB (WRIR 94–4231). Cunningham and others followed up by evaluating ground-water flow at WPAFB by particle tracking (WRIR 94–4243).

PENNSYLVANIA

By David E. Click and Lloyd Reed

INTRODUCTION

During this history period, the content of the Pennsylvania program was closely aligned with National Thrusts. In addition to operating comprehensive hydrologic data-collection networks, District projects investigated ground-water contamination, water supply and demand, stream quality, hydrologic hazards, acid rain, hydrologic effects of fossil fuel and mineral extraction, erosion and sedimentation, and wetlands, lakes, and estuaries.

No major, widespread, extreme hydrologic events or hydrologic hazards occurred in Pennsylvania during 1979–94. However, there were isolated events where new high-flow peaks were measured, and both agricultural and hydrologic drought occurred for

several months in the mid-1980's in many counties of the Commonwealth.

The Pennsylvania District was not unique in applying computer technology to accomplish work tasks, but it was done, and this conversion was the single most important factor that increased productivity of staff during this time period. This conversion started with computer word processing of reports; gaging-station telemetry was expanded to nearly 100 percent of the stations, and many observation wells also were equipped with telemetry. By the end of the period every member of the staff had a networked computer on his or her desk.

After nearly 10 years of attempting to relocate the District and Harrisburg Subdistrict Offices from the Harrisburg Federal Building to a more desirable and efficient location, the offices were moved in 1991 to 840 Market Street in Lemoyne, Pa.

Organizational Structure and Key Staffing

In 1979 the District operated from five offices. The District and Susquehanna River Basin (Harrisburg) Subdistrict Offices were located in the Federal Building in Harrisburg. The Ohio River Basin Subdistrict Office was in the Federal Building in Pittsburgh, and the Delaware River Basin Subdistrict Office was in cooperator-provided space in the Great Valley Corporation Center in Malvern. Field Offices were located in Meadville and Williamsport. In addition to the five District offices in Pennsylvania, the Office of the Delaware River Master was located in Milford, but the staff reported to the Regional Hydrologist.

District Office

The District Office was organized into the office of the District Chief, two Project Offices, Administrative Services Unit, Reports and Publication Unit, Hydrologic Data Collection Section, Project Coordination Section, Sediment Laboratory, and Hydrologic Analysis and Computer Applications Unit. Don Perkins managed the District in an Acting District Chief position after the retirement of Norman Beamer in June of 1978 until a new District Chief reported in August 1979. Perkins retired shortly after the new Chief reported.

David E. Click was the new District Chief, and Jack McCoy reported as the Assistant District Chief in 1980. Charlotte Arnold was the District Secretary. The Delaware River Basin Flow Modeling Project was staffed with James O. Shearman and James M. Bettandorff. The Schuylkill River Quality Assessment Project was staffed with Gary L. Pederson as Project Chief, assisted by Tom H. Yorke and John K. Stamer. John T. Gallaher and one aide staffed the Meadville Office.

William C. Roth served as the District Ground-Water Specialist and was in charge of the Reports and Publications Unit. Carney P. Humphreys served as the District Surface-Water Specialist and was in charge of the Hydrologic Data Collection Section. John R. Ritter served as the District Quality of Water Specialist and was in charge of the Project Coordination Section. Allen B. Commings was in charge of the District Sediment Laboratory. Ralph E. Zettlemoyer was the Administrative Officer. The Hydrologic Analysis and Computer Applications Unit was staffed by Joanne V. (Funt) Irvin and Lettie L. Weight.

In 1979 District Staff totaled 38 people: 2 technical managers, 14 hydrologists, 9 hydrologic technicians, 3 reports support, 3 computer support, and 7 in the Administrative Services Unit.

Organizational and personnel changes occurred late in 1981 and 1982 with the completion of the Schuylkill River Project. Three new organizational units were established at the District level. A Hydrologic Studies Section was established, and Ritter was the Section Chief. An Operations and Network Coordination Section was also established and Humphreys was Section Chief. With the forthcoming installation of a minicomputer at the District Office, a Computer Service Unit was created, and for the first time a Computer Specialist was hired for the District. In 1983 Deborah Keen became the Administrative Officer after the retirement of Ralph Zettlemoyer.

In 1985 a new District policy was put into effect stating that, with few exceptions, all hydrologic network and investigative projects would be done in Subdistrict Offices; thus, District organization again changed. Humphreys served as an Assistant District Chief for Operations, and Ritter was Assistant District Chief for Project Quality. Gregory Senko was hired as the District's Computer Specialist, and Connie Loper supervised the Sediment Lab after the retirement of Allen Commings. Leona McLanahan was in charge of the Reports Processing Unit. An Information Unit was established and Robert Helm served as the District Information Specialist.

Associate District Chief Jack McCoy retired in 1987 and the position was abolished. Sharon Kuhnlein reported as the Administrative Officer after the transfer of Deborah Keen, and Douglas Warnock took charge of the Sediment Lab.

With the retirement of Humphries and the transfer of Ritter, the District Office organization again changed in the late 1980's. A Scientific Publications and Information Section was established and Kim Wetzel was the Supervisory Hydrologist. Three Program Coordinators were established. Al Becher was the Coordinator for the Ground Water Program, Mark Hardy transferred in to become the Coordinator for the Water Quality Program, and Clayton Kauffman was the Coordinator for the Surface Water Program. Russell Ludlow was in charge of the Sediment Lab. With the start of the Lower Susquehanna National Water-Quality Assessment (NAWQA) project, a NAWQA Operations Section was created in 1991, and Kevin Breen was the Supervisory Hydrologist. No other major organizational changes were made at District level for the period of this history volume.

The Susquehanna River Basin (Harrisburg) Subdistrict Office

Donald L. Bingham was the Harrisburg Subdistrict Chief. The Subdistrict was not officially subdivided into sections and units but functioned as two units (Projects and Basic Data). The Williamsport Field Office reported to the Harrisburg Subdistrict. The Subdistrict was staffed with 1 technical manager, 8 hydrologists, 13 hydrologic technicians, and 1 admin/reports person. The Williamsport Field Headquarters was staffed with one technical manager and four hydrologic technicians. John Truhlar was in charge of this office.

Tom Yorke was assigned as Subdistrict Chief after the transfer of Bingham in 1981. In 1985, a Hydrologic Studies Section was established, and the Subdistrict Chief assumed a dual role of also being the Section Chief. A Hydrologic Data Section was created, and Clayton Kauffman was assigned as Chief. After the death of Truhlar, Robert Hainly became Chief of the Williamsport Field Headquarters.

David J. Wangsness replaced Yorke as Subdistrict Chief in 1987 after Yorke's transfer. Hainly transferred to the Harrisburg Subdistrict as Hydrologic Section Chief when Kauffman became District Surface-Water Specialist. William Schaffstall replaced Hainly in the Williamsport Office.

As the technical studies expanded in the Harrisburg SubDistrict Office, a supervisory Section Chief position was established and Cynthia Barton was transferred into the position. With this expansion, and the assignment of Assistant District Chief duties, the position of Subdistrict Chief was upgraded to GS–14. Gary Paulachok was selected for this position when Dave Wangsness transferred in 1991. William H. Werkheiser replaced Cynthia Barton as Chief of the Hydrologic Investigations Section after her transfer in 1992.

The Delaware River Basin (Malvern) Subdistrict Office

John J. Murphy was the Malvern Subdistrict Chief. Subdistrict staffing consisted of a total of 23 people: 1 technical manager, 8 hydrologists, and 8 hydrologic technicians, 4 part-time aides, and 2 people for administrative support.

The Subdistrict was not organized into any suborganizational categories in 1979, but it functioned with Murphy serving as staff coordinator, conducting hydrologic studies, and Dale Glatfelter serving in a lead role in the collection of hydrologic data for the Delaware River Basin.

During 1980, Murphy was assigned to the New Jersey District and Charles R. Wood was promoted to the position of Subdistrict Chief. The Subdistrict was not organized into formal subsections until 1984, but some key personnel were transferred and reassigned. In 1981, both Tom Ross and Dale Glatfelter transferred from the office. Ron Sloto served as a lead role in Hydrologic Studies, and Andy Voytik was assigned to oversee the collection of Hydrologic Data.

In 1984, the Subdistrict was reorganized and a Hydrologic Studies Section and a Hydrologic Data Section were created. James R. Kolva served a dual role of Assistant Subdistrict Chief and Chief of the Hydrologic Data Section. Sloto was assigned as Chief of the Hydrologic Studies Section. In addition, a Computer Support Unit was established and Cynthia Gilliam served there. In 1992, Kirk White was assigned Chief of the Hydrologic Surveillance Section after Kolva's transfer. Staffing in this section remained fairly constant over this time period.

Several staffing changes occurred in the Hydrologic Studies Section: some of the people involved

were Gary N. Paulachok, DeWayne Cecil, Karen Vogel, Lisa Senior, and Curtis Schreffler. Of special note is Craig R. Moore, one of the first biologists to be hired in the District.

The Ohio River Basin (Pittsburgh) Subdistrict Office

David B. Richards served as the Pittsburgh Subdistrict Chief for the entire time covered in this history. Staffing consisted of one technical manager, six hydrologists, eight hydrologic technicians, and one administrative support person; the numbers changed very little during the time period. The Pittsburgh Subdistrict was not organized into any suborganizational units until 1984 when many changes were made in the organization of the District.

Prior to the establishment of a Hydrologic Studies Section, Richards served in a leadership position conducting Hydrologic Studies. Donald Williams, Jeff Stoner, Don Stump, Ted Buckwalter, John Felbinger, Kenn Pattison, and Emitt Witt. Joe Lescinsky, Martin Coll, and Ray Siwicki, among others, provided the leadership for the collection of hydrologic data.

When the organization changes were made, Lescinsky served in a dual role of Assistant Subdistrict Chief and Supervisory Hydrologist of the Hydrologic Data Collection Section. Don Williams provided the leadership of the Hydrologic Studies Section.

As transfers occurred, Jim Sams, Curtis Schreffler, Tom Noonan, and Naomi Weisbeker became part of the Hydrologic Studies Section. In 1987, Rose Drazinski, the Clerical Assistant, was replaced with Thomas Sinwell; also in 1987, Gregory Wehner, a Computer Assistant, was added to the staff.

PERSONNEL

In 1980 the Pennsylvania District's personnel ceilings were assigned at 73 full-time and 30 part-time employees. The actual distribution of staffing consisted of 70 full-time, 20 part-time, and 13 intermittent employees. A graph showing the distribution of staffing types is in figure 1. The total number of employees, regardless of type of appointment and distribution of staffing categories, did not change much over the 15 years of this history.

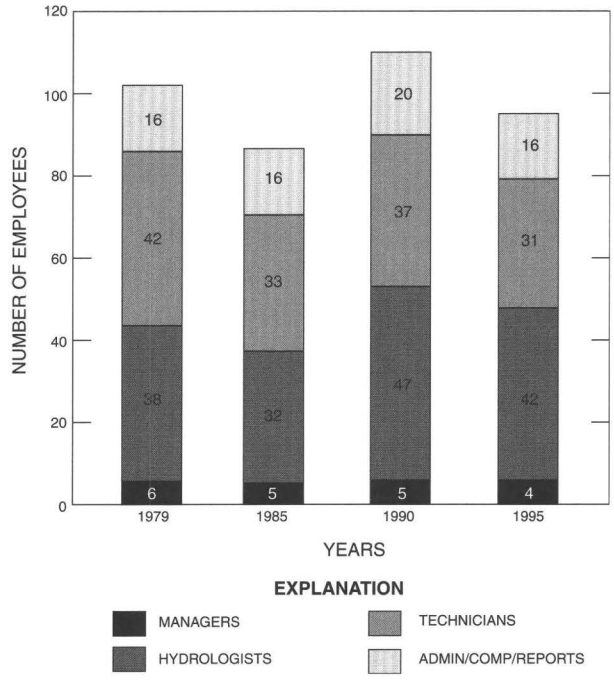


Figure 1. Distribution of position types 1979–94.

FUNDING

Funding for the Pennsylvania District was generated from three general programs: Federal-State Cooperative (Coop) program, the Federal (Fed) program, and the other Federal agency (OFA) program. The combined funds from these three programs totaled $4,444,148 for fiscal year 1979 and about doubled in size over the 15-year period to $8,873,588 in 1994.

Cooperative Program

The formal title of the Cooperative program is "The U.S. Geological Survey Federal-State Cooperative Water Resources Program." This program is described in detail in periodic Open-File Reports.

Within the Cooperative program were five types of funding in 1980: (1) matched funds were cash funds offered by cooperators, (2) direct funds were in-kind funds offered by cooperators, (3) Federal matching funds were USGS funds offered to match cooperators offerings, (4) unmatched funds were offered by cooperators but not matched by USGS, and (5) a special category was called reverse flow funds. This was cash funds in water-use projects that were transferred to the cooperator for the purpose of collecting water-use

data. The use of reverse flow funds was discontinued about 1985.

Cooperators included four bureaus of the Pennsylvania Department of Environmental Resources; the Susquehanna and Delaware River Basin Commissions; the cities of Bethlehem, Harrisburg, and Philadelphia; Greene and Chester Counties; and others.

USGS Federal (Fed) Program

Funds allocated to the Pennsylvania District by Headquarters included some small amounts for collection of basic records as part of a few national networks. In addition, funds were allocated to conduct interpretive projects as part of some National Thrust programs or part of the National Research Program.

Other Federal Agency (OFA) Program

The Baltimore, Philadelphia, Pittsburgh, and Buffalo Districts of the U.S. Army Corps of Engineers each provided funds for support of gaging stations in Pennsylvania. In addition, some work was being done for the Bureau of Mines, the U.S. Environmental Protection Agency, and the U.S. Soil Conservation Service (now the Natural Resources Conservation Service).

Funding Category Trends from 1979 to 1994

The 1980's were extremely difficult years for the Pennsylvania District from a funding perspective. The decade started with the District having substantial uncompleted and unfunded project work, while at the same time total funding was decreasing because Federal funding was sharply reduced and the allocation of USGS matching funds was nearly constant. Controlling costs through relocating personnel to balance the budget was difficult, as the District had limited ability to move people.

During the period of 1985 to 1990, the makeup of funding types changed and the totals remained nearly flat. The amount of Federal funding dropped to very low levels, but this was counterbalanced with some increase in USGS matching funds and unmatched funds in the Coop program and some increase in the OFA funding.

With new programs and increased funding in 1990, the District began to fulfill commitments on time and complete overdue reports. The stacked bar graphs in figure 2 depict how the funding varied from 1979 to 1994.

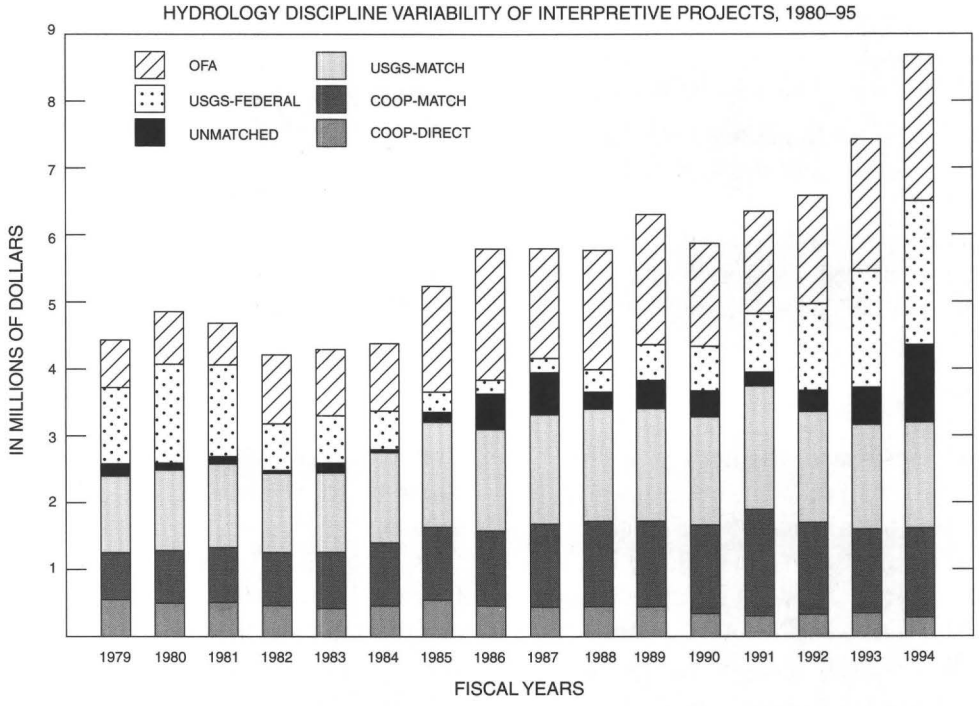


Figure 2. Pennsylvania District funding by type.

District Programs

Continuous-Record Type Projects

The Pennsylvania District has always had a strong data-collection program. During 1979 to 1994 the District continued the operation of four statewide projects for the collection of surface-water, groundwater, water-quality, and suspended-sediment records. These basic data projects provided a steady undergirding of funding for the Pennsylvania District program. In addition, a new continuous-record project was started in 1978 for the collection of water-use data. Total funding for these five projects ranged from about 40 to 50 percent of the total District funding for this time period, with the surface-water program accounting for about 70 percent of the continuous-record funding.

Surface-Water Stations Project

Historically, the data collected from the operation of stream-gaging stations in Pennsylvania not only provided basic hydrologic information but also critical information for flood forecasting to reduce flood damage and loss of life. Because of its demographics, Pennsylvania experiences about 10 percent of the annual flood damages in the United States. Use of surface-water data continued to broaden during this time period to include management of water supply, waste-load assimilation, in-stream use, and recreation, among other basic and traditional uses. The Coop, OFA, and Fed programs provided the fiscal support for the surface-water project. The largest source of funds was from the Coop program, which provided about 60 percent of the total funds. The Coop program had nine cooperators. The largest participant was the Pennsylvania Department of Environmental Resources Bureau of Resource Management, which provided about 41 percent of the Coop program funds. The U.S. Army Corps of Engineers provided about 36 percent of the funds, and Federal funds amounted to only 4 percent.

The actual operations of the network were performed in each of the three Subdistricts, but Carney P. Humphreys, District Surface-Water Specialist, conducted the overall coordination of the project at the District level. Clayton Kauffman provided coordination after Humphreys' retirement. Leadership in the Subdistricts was provided by Kauffman and Hainly in the Susquehanna River Basin, by Glatfelter, Tom White, Andy Voytik, and Jim Kolva in the Delaware River Basin, and by Lescinsky and Marty Call in the Ohio River Basin. The numbers of continuous-record surface-water stations are shown in figure 3.

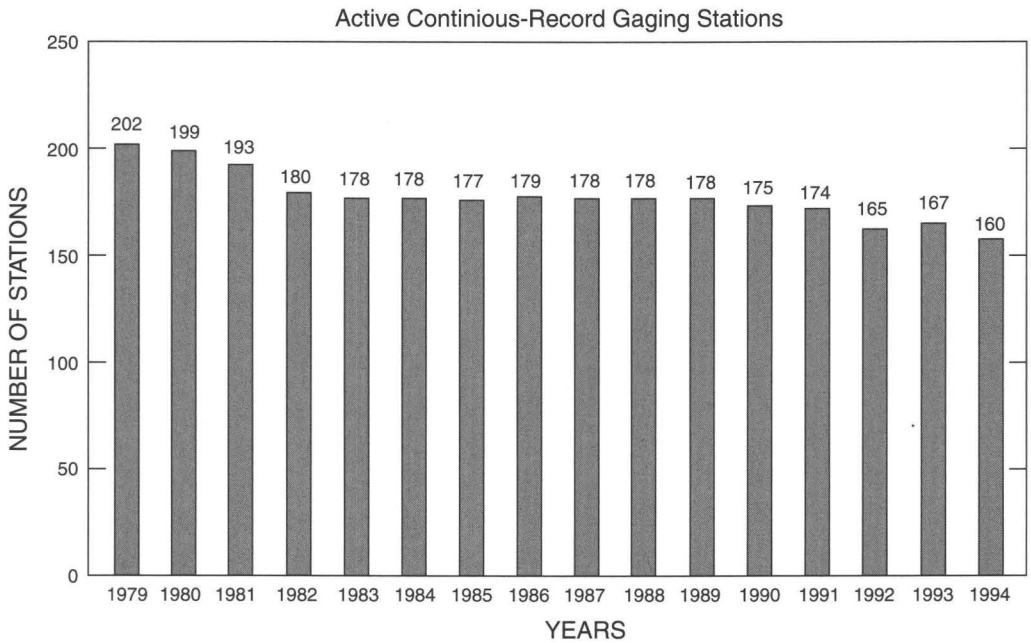


Figure 3. Numbers of continuous-record gaging stations.

Ground-Water Stations Project

A small network of observation wells was operated in the State for the purpose of evaluating climatic variations, effects of development, and management of the resource.

With the exception of a small amount of Federal funds, all of the funds supporting this project were from the Coop program. The Pennsylvania Department of Environmental Resources Bureau of Topographic and Geologic Survey was the principal cooperator.

The goal of the program was to operate one observation well in each county in the State, but because of funding shortages, this goal was not achieved during the 1979 to 1994 period. The network consisted of 64 observation wells. Continuous recorders were installed at 59 of the wells, and observers made weekly measurements at 5. Charles W. Poth, Jack McCoy, and Al Becher provided sequential leadership of this project.

Quality of Water Stations Project

The District did not operate a statewide network of water-quality stations because the Pennsylvania Department of Environmental Resources maintained a network. As of 1979, data from this network was published in the annual reports. However, the District did operate several smaller regional networks for specific cooperators. Cooperators supporting this work were the Baltimore and Philadelphia Districts of the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, Chester County, and the Delaware River Basin Commission. At nine stations, mostly in the Delaware River Basin, temperature, dissolved oxygen, pH, and specific conductance were monitored on a continuous basis. A network of stations collecting biological data was operated in Chester County. John R. Ritter, District Water-Quality Specialist, coordinated this project.

Suspended-Sediment Stations

In 1979, 15 stations were operated that collected daily values of suspended sediment. Seven of these stations could be considered as part of a network of continuous-record sediment stations, while the other eight were operated as part of a limited-duration project. At the end of this history period (1994), only one station remained in operation, with the exception of the ones that were operated for finite-length projects. Funding support for the long-term stations was from the Corps of Engineers and the Fed program. Ritter was the coordinator for the network stations.

Water-Use Data Project

The goal of the Pennsylvania Water-Use Data project was to collect data and maintain a computer data base of industrial, public supply, and irrigation water-use data from Pennsylvania to satisfy the Pennsylvania portion of water-use amounts in compiling a national data base of water-use data.

The water-use project was started in Pennsylvania in 1978 and by 1979 was well established. The character of water-use work performed by Pennsylvania District staff was much different than most other Districts with water-use projects. When WRD established water use as a new, continuous data-collection project in each District, the Commonwealth of Pennsylvania already had an established system of collecting this type of data. By 1979 the Commonwealth had developed a computer system that was capable of receiving the water-use data; however, the data were collected manually and were not being keyed into a digital computer.

The Pennsylvania District Staff began to assist the Commonwealth in the task of loading manually collected data into their computer system and to negotiate with the Commonwealth so the system could provide output that would be usable as a portion of the national system WRD was developing. This was accomplished by providing funds to the Commonwealth by a process known as reversal of funds, for the procurement of equipment and hiring of staff. In addition, Lettie Weight keypunched some of the data.

Sequential leadership of this project was provided by Wayne Balmer, Connie Loper, Kim Otto, Scott Hoffman, and Russ Ludlow.

Interpretive Projects

In addition to the five continuous-record projects described above, in 1979 the District operated 28 interpretive projects.

At the beginning of this history period, two national issue projects were operated by the District and were funded with USGS Federal funds. These projects were Coal Hydrology and River Quality Assessment and were the dominant District projects. After these projects were completed, Federal funds

were sharply reduced and not replaced until the Lower Susquehanna River Basin was selected to be funded as part of the National Water Quality Assessment in the early 1990's.

With the exception of a few projects funded by OFA funds, the Coop program funded most of the interpretive projects operated by the District. Emphasis on water quality was well established in interpretive project work at the start of this history period and continued to grow during subsequent years. Of particular note was the Bridge Scour Project, an 8-year project funded by $15 million of unmatched funds, which started near the end of this time period.

Detailed descriptions of the projects that were operated during 1979 to 1994 can be found in the eight reports of District activities published by the District. It would therefore be redundant to describe them further. The intent here is to provide the reader a general depiction of how the water-resource-discipline content of projects changed in the time period. Figure 4 shows how the water-quality discipline was the largest portion of project work in the early years of this period, then decreased, only to become even a greater portion in the later years.

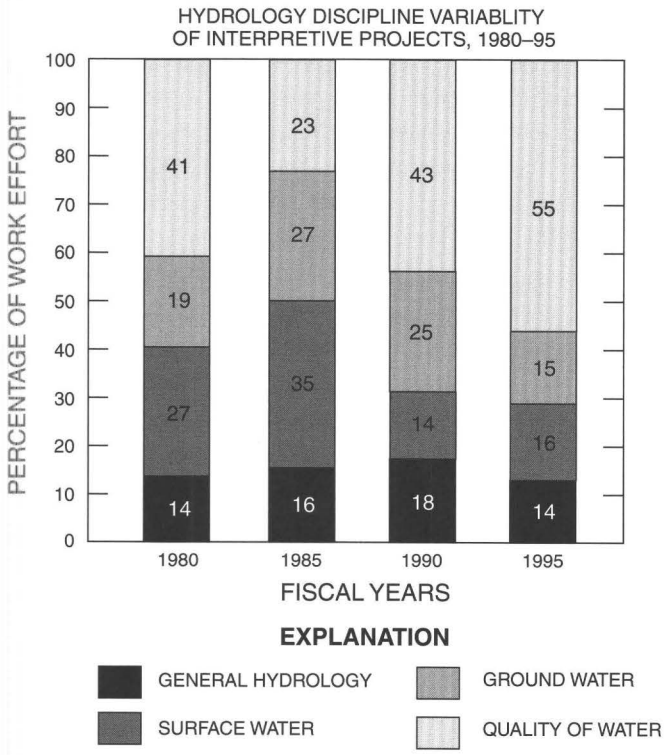


Figure 4. Hydrology discipline variability of interpretive projects, 1980–95.

Technology Use

The use of computers for the preparation of reports after the authors complete their work provided a major improvement in report preparation as it allowed for the ability to electronically cut and splice typing and tables, and so forth. The Pennsylvania District was one of the first Districts to purchase and use true word processors, which were first installed in the Reports Section. These machines also had the capability to send and receive data by the telephone between other computers at other locations. When the capability of the machines became known, more were purchased for clerical and administrative work.

The Pennsylvania District was not unique among the WRD Districts with the integration of the minicomputer into its work applications, but it was one of the leading Districts in using telemetry and the minicomputer to collect and process basic data. The District was very supportive in the need and development of the DCP (data-collection platform), which was developed by WRD and later became a commercially available product. Processing multiparameter water-quality data by using the DCP and minicomputer proved to be a major time saver in addition to producing improvements in processing surface-water and ground-water data.

The District was also unique in using the minicomputer for District-level MIS (management information systems). The District was one of the major supporters in the development of the design and development of software for a national standardized District-level MIS, now known as AFIMS. This software became a major factor in assisting Districts in managing fiscal affairs.

Report Production

During this history period, the Pennsylvania District produced a variety of publication products ranging from flood-prone area maps to Professional Papers, but the vast majority were in the Water-Resources Investigations Report series. Figure 5 shows the type and numbers of reports produced during 1979–94. In addition to the reports in figure 5, during 1979 to 1982 about 70 flood-prone area maps were produced.

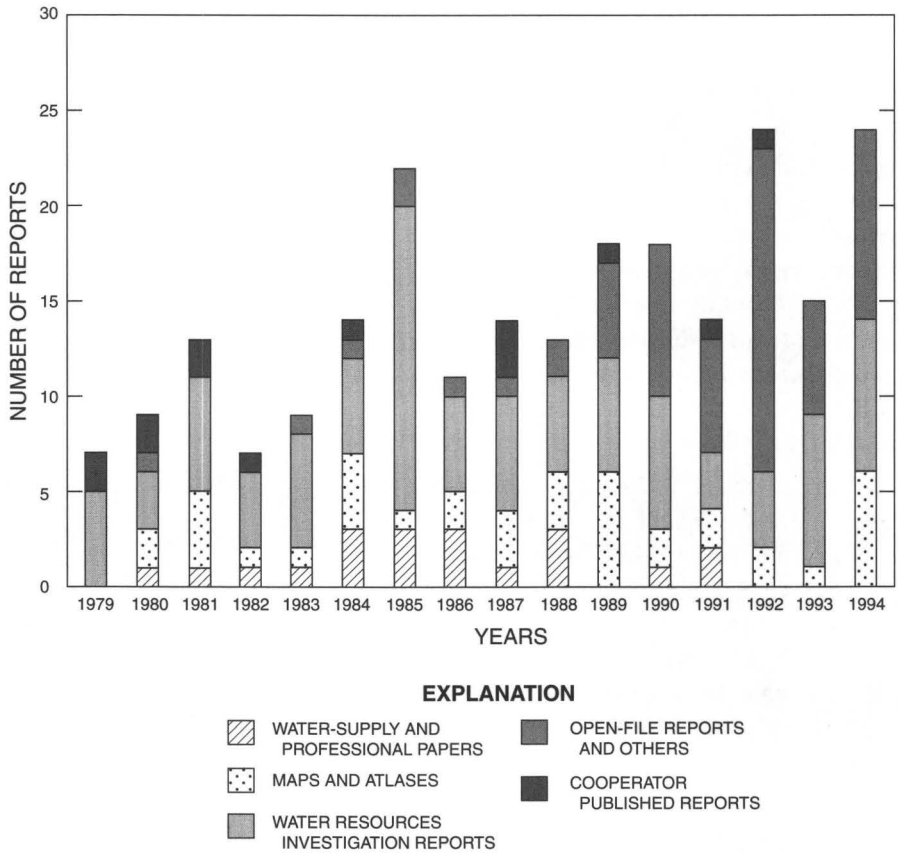


Figure 5. Number and types of reports produced, 1979–94.

RHODE ISLAND

By Herbert E. Johnston

INTRODUCTION

Rhode Island, with a land area smaller than counties in many States, had a population of nearly one million people during 1979–94. More than 80 percent of all freshwater used in the State was obtained from surface reservoirs. Demand for public water supply increased only moderately during 1979–94; however, concern was high over the quality, quantity, and availability of developed and undeveloped water resources needed for future use.

Construction of a water-supply reservoir that was expected to meet foreseeable public supply needs of the more densely populated central and eastern parts of the State was vetoed by the U.S. Environmental Protection Agency (USEPA) primarily because it would have flooded a large area of wetlands. This action effectively eliminated development of additional large surface supplies because there were few areas where new reservoirs could be built. Furthermore, resources from existing reservoirs were nearly totally committed. Adding to the heightened governmental and public concern over its water resources during 1979–94 was the contamination of several high-yield public supply wells.

As a result of there being few potential reservoir sites, interest focused largely on the State's abundant ground-water resources. The most important of these are in highly permeable, unconfined glacial aquifers in stream valleys. Unfortunately, these aquifers are very susceptible to contamination, and most high-yield wells in them derive much of their water from induced infiltration of streamflow. Protection of ground-water quality, improvement of stream-water quality, and a better understanding of the interconnection between ground water and surface water became the priorities of State and local water-resources managers.

Although funded only at modest levels, the USGS Federal-State cooperative (Coop) program made important contributions toward resolving the many of the water-resources issues in Rhode Island.

These contributions and the personnel responsible for them are described in the following paragraphs.

PERSONNEL AND MANAGEMENT

Rhode Island was designated a Subdistrict Office from 1979 to 1982, a State Office from 1983 to 1990, and a Subdistrict Office again from 1991 to 1994. Throughout these years, Rhode Island reported to District Headquarters in Massachusetts where offices were in Boston from 1979 to 1989 and in Marlborough for the remainder of the period. Herbert Johnston was Chief of the Rhode Island office from 1979 until his retirement in 1990. He was succeeded by Virginia de Lima, who transferred from the Massachusetts Subdistrict in 1991.

The Rhode Island headquarters was located in the John O. Pastore Federal Building and U.S. Post Office building in downtown Providence until June 1994, when it was moved to renovated space in the former Brown and Sharp mill complex at 275 Promenade Street in Providence.

During 1979–94, the full-time office staff numbered from 3 to 13 annually. Of these, two to eight were hydrologists and(or) physical scientists. Only two full-time hydrologic technicians were employed during the period. Part-time and intermittent employees and a large number of students hired under the College Work-Study program from local colleges and universities made up the balance of the staff. The position of clerk-typist was part time from 1979 to 1985 and full time from 1986 to 1990, after which the position was abolished. Administrative services were provided by the District Office throughout the period.

Hydrologists, in addition to Johnston and de Lima, included David C. Dickerman and Barbara J. Ryan (1981–84), Elaine C.T. Trench (1982–87), Richard W. Bell (1987–91), and Michael J. Baer (1987–90). Trench began employment in the Rhode Island office as a hydrologic field assistant; Bell and Baer began as hydrologic technicians. Ryan left in 1984 to attend Stanford University under the USGS graduate school training program. Trench transferred to the Connecticut District in 1987; Bell transferred to the Tennessee District in 1991. Baer resigned in 1990 to work in the private sector. Two other full-time employees, John D. Kliever (1990–94) and Patrick A. Craft (1990–94), were hired as physical scientists. Kliever was later converted to hydrologist.

Hydrologists employed on intermittent appointments included Bernard J. McNamara (1983–84), Paul M. Barlow (1986–87), and Anne I. Veeger (1990–91). McNamara, initially employed as a hydrologic technician, resigned in 1984. Barlow began as a volunteer in 1981 and later worked intermittently as a hydrologic field assistant and hydrologic technician when he was not attending graduate school. Upon completion of graduate school, he was hired by the Massachusetts office. Veeger, a geochemist and an assistant professor in the Department of Geology at the University of Rhode Island, worked mostly during summer months.

Hydrologic technicians employed full time during 1979–94 were Hubert (Skip) L. White (1979–88) and Lansen Ramsbey (1987–94). Hubert died of a heart attack in February 1988 as he was about to drive home from work.

Hydrologic technicians employed either part-time or intermittently during the period included Joel Russell (1979–94) Eugene L. Peterman (1979–94), David J. Hazebrouck (1985–86), James S. Soja (1985–86), Kevin D. Mulvey (1987–88), Henry L. Lemoine (1989–90), Emily Burns (1989–91), and Alisa Richardson (1989–92).

Hydrologic field assistants on intermittent appointments during the period included Laurel J. Eschelman (1980), Andrea Johnson (1980–81), David A. Bristol (1983–84), Kenneth L. Conca (1982–84), and Robert DeSaulniers (1984). Clerical assistance during 1979–94 was provided by Marian W. Johnston (1979–84) and Marjorie M. Lawrence (1984–90).

Because hiring freezes were common during 1979–94, employees from the Connecticut, New Hampshire, Massachusetts, and Maine Subdistricts/Offices assisted in completing many Rhode Island projects. Several of them were Project Chiefs.

Desktop computers linked to a mainframe computer in Boston were installed in the Providence office in 1981. These computers greatly improved data processing and in-house production of report drafts. Final drafts of illustrations and final preparation of reports for publication were done in the District Office.

FUNDING AND COOPERATION

Total program funding ranged from a low of about $253,000 in 1979 to a high of nearly $510,000 in 1993, as shown in the following table. During most years, the Federal-State Coop program provided

Rhode Island District funds, fiscal years 1979–93

Fiscal year	Federal	OFA	State	Federal matching	Total
1979	9,400	0	116,500	126,900	252,800
1980	26,600	800	119,700	119,700	266,800
1981	82,000	8,300	133,600	133,500	357,400
1982	147,400	0	109,200	106,700	363,300
1983	135,700	1,500	114,900	115,000	367,100
1984	111,700	1,600	109,500	109,500	332,300
1985	32,800	1,900	136,600	136,500	307,800
1986	24,400	4,300	167,800	159,800	356,300
1987	17,100	4,500	170,700	175,600	367,900
1988	22,900	2,900	269,100	269,100	564,000
1989	15,700	1,900	264,300	264,300	546,200
1990	21,400	2,000	272,800	272,800	569,000
1991	21,400	8,600	244,700	244,700	519,400
1992	18,700	4,100	199,100	199,100	421,000
1993	23,600	9,600	238,200	238,200	509,600

90 percent or more of funding. However, from 1981 to 1984, a federally funded research program provided as much as 41 percent of annual program funds. In other years, the Federal and other Federal agency (OFA) programs provided less than 10 percent of funds, chiefly for operation of stream gages and a few observation wells for monitoring water levels.

The largest percentage of funds for the Coop program was provided by the Rhode Island Water Resources Board (RIWRB) and the Rhode Island Department of Environmental Management (RIDEM). Smaller but important contributions also were provided by Rhode Island Governor's Office of Housing, Energy, and Intergovernmental Relations (GOHEIR), and the Town of New Shoreham (Block Island).

SUMMARY OF PROGRAMS

Hydrologic-Data Collection

Hydrologic data were collected periodically throughout 1979–94 at stream gages, observation wells, and water-quality stations and were published in annual water-resources data reports for Massachusetts and Rhode Island. Although selected individuals had primary responsibility for data collection, other employees were cross trained to do these jobs. Streamflow data were collected and prepared for publication by Skip White, with the assistance of Joel Russell until 1972, and by Lansen Ramsbey for the remainder of the period. Peterman was largely responsible for making monthly water-level measurements in observation wells. Joel Russell was principally responsible for collecting water-quality samples from streams. Russell also was responsible for retrieving observation well data and water-quality data for the annual data reports for most of the period.

Streamflow Stations. During the reporting period, the number of continuous-recording stream gages monitoring flows of Rhode Island streams fluctuated between 16 and 18. Most stations were funded in cooperation with the RIWRB and RIDEM. One station was funded in part by the Federal program and one station was funded in part with OFA funds.

Ground-Water Observation Wells. Statewide network of observation wells for periodic monitoring of ground-water levels was operated throughout 1979–94, continuing a program begun in 1944. The network was originally designed to monitor long-term trends in ground-water levels, chiefly in glacial sand and gravel aquifers that form the State's principal ground-water reservoirs. From 1979 to 1991, the network included 21 wells, which were funded in cooperation with the RIWRB. Between 1991 and 1993 the number of wells was increased to 40, the additional wells being funded in cooperation with RIDEM. The additional wells, constructed mostly in glacial till, which covers about two-thirds of the State, were added

to provide RIDEM with index wells for predicting seasonally high water levels.

Water-Quality Stations. In 1978, the USGS joined with RIDEM in a continuing project to monitor the quality of Rhode Island's streams, as part of a federally mandated program. Throughout 1979–94, water samples were collected several times each year at six water-quality stations, including one station in Massachusetts just across the Rhode Island State line. These were analyzed for common inorganic constituents, heavy metals, pesticides, and bacteria. Samples of bottom sediment collected from the same sites were analyzed for pesticides and other organic constituents. A continuous water-quality monitor operated at a seventh site in cooperation with the RIWRB provided a continuous record of temperature and specific conductance of streamflow during this period.

INTERPRETIVE STUDIES

Interpretive studies were the core of the USGS program in Rhode Island during 1979–94. Completion of many of the studies was accomplished with the assistance of hydrologists from the Connecticut, Massachusetts, Maine, and New Hampshire offices.

Surface-Water Investigations. Estimates of freshwater inflow to Narragansett Bay—one of Rhode Island's most important natural resources—were required by several investigators during 1979–94. In particular, data were needed to (1) determine contaminant loads carried by streams discharging into the bay, and (2) calibrate models used to simulate circulation patterns and water quality in the bay. Kernel Ries, a hydrologist in the Massachusetts office, statistically analyzed data from stream-gaging stations in Rhode Island and nearby Massachusetts to arrive at estimates of mean monthly and mean annual freshwater inflow to the bay from gaged and ungaged areas. The study and report (WRIR 89–4164) were done as part of a project funded by USEPA and administered by RIDEM.

A study of low-flow characteristics of streams in Rhode Island was begun in 1991, in cooperation with RIDEM, to obtain a better method of estimating low flows of ungaged streams. The study resulted in development of a regression equation relating the type of glacial deposits in drainage areas to the 7Q10 flow. The report (WRIR 93–4046) was prepared by Michael Cervione and Lawrence A. Weiss of the Connecticut Subdistrict Office and Alisa R. Richardson of the Rhode Island Office.

Water-Quality Investigations. Data collected periodically at the six stream-water-quality stations were the subject of two interpretive reports published in cooperation with RIDEM. The first (WRIR 84–4367), done by John C. Briggs and J.S. Feiffer of the New England District Office, assessed water-quality data collected during 1978–83. The second (WRIR 90–4082), a followup study by Briggs, evaluated the data collected during 1978–88. The studies showed that concentrations of heavy metals (cadmium, chromium, and lead) were at or above USEPA drinking-water criteria at several sites, and that heavy metals (cadmium, chromium, copper, lead, and silver) concentrations exceeded acute aquatic-life protection criteria at all sites. Several pesticides were found in bottom material at all sites.

Ground-Water Investigations

Ground-water investigations have been the primary focus of the Federal-State Coop program in Rhode Island since the program began following WWII. The emphasis on ground-water studies continued during the current reporting period.

Pawcatuck River Basin Investigations. The Pawcatuck River drains most of southern Rhode Island, where ground water is the only source of public supply. Glacial sand and gravel aquifers separated from one another in stream valleys constitute the principal ground-water reservoirs. These have been designated as sole source aquifers by USEPA.

From 1970 to 1994, the RIWRB constructed and tested more than 40 large-diameter wells in these ground-water reservoirs. The purpose of the program was to identify potential sites for public supply wells and then to preserve and protect them for future use. The USGS assisted in collecting, analyzing, and publishing the data for this program. These data were subsequently used to assess the geohydrology and potential ground-water development alternatives within these ground-water reservoirs. Development alternatives were evaluated using numerical ground-water flow models constructed for individual ground-water reservoirs. The models also were used to estimate the effect of withdrawals from selected schemes of wells on streamflows and on water levels beneath abutting wetlands. Dickerman was senior author of three of these modeling studies (WRIR 85–4190,

WRIR 89–4031, WRIR 92–4119) during 1979–94, coauthors on one or more of the studies included Russell, Bell, Trench, and Melih M. Ozbilgin, a graduate student at the University of Rhode Island. Ozbilgin and Dickerman also developed and documented an application of a two-dimensional finite-difference model that resulted in improved simulation of stream-aquifer interaction (WRIR 83–4251).

Investigation of Radioactive Waste Contamination of Ground Water. During the RIWRB test-drilling program in the Pawcatuck River Basin, the USGS discovered that liquid radioactive waste stored in lagoons at an enriched-uranium cold-scrap recovery plant had contaminated part of a major ground-water reservoir. Contamination extended from the plant to the Pawcatuck River in a plume later determined to be 2,300 feet long and about 300 feet wide. In 1981, the USGS began a 3 1/2-year research investigation of the site to identify chemical and radiochemical constituents in the plume, how they interact with aquifer materials, and how long it would take for them to be discharged to the river and contiguous wetlands. The investigation was done by Barbara Ryan of the Rhode Island Office and Kenneth L. Kipp, Jr., a solute-transport modeler with the National Research Center in Denver, Colo. Funds were provided by the Survey's Low-Level Radioactive Waste Program.

Results obtained from a simplified solute-transport model of the site indicated that reduction of strontium-90 concentration to the drinking-water criterion would take as long as 2 decades. Publications resulting from the study include a data report (OFR 84–725) and four interpretive reports—two in WSP 2270 and two in private scientific journals. In addition to Ryan and Kipp, co-authors of one or more of the reports included Barlow, DeSaulniers, and Bristol of the Rhode Island Office and Denis Healy of the Connecticut Office.

Study of Methods to Predict Ground-Water Levels. In 1990, a study was begun in cooperation with RIDEM to develop a technique for predicting high ground-water levels at building sites where septic systems were to be installed. The study and report (WRIR 94–4138) resulted in development of equations that can be used to estimate high, median, and low water levels and graphs of probable long-term annual water-level range. The study was done by Roy S. Socolow, Michael Frimpter, and Michael Turtora of the Massachusetts Office and by Richard W. Bell of the Rhode Island Office. The number of observation wells in the USGS cooperative ground-water data program was increased from 21 to 40 as a consequence of this study.

Investigations of Contributing Areas to Aquifers and Supply Wells. Concern in the early 1980's about potential contamination of the State's principal aquifers led to an investigation that resulted in three map reports in which recharge areas to selected aquifers were classified and delineated. These were prepared by Trench and Barlow of the Rhode Island Office and by Dan Morrissey of the Maine Office. The studies were cooperatively supported and were to be published by RIDEM in a State series. By 1994, one report had been published.

RIDEM also supported an investigation done by Morrissey in which he evaluated methods of estimating the sizes and shapes of contributing areas to supply wells located in unconfined glacial aquifers in stream valleys. In his report (WRIR 86–543), he described the advantages and disadvantages of using analytical, two-dimensional, and three-dimensional models to arrive at estimates of contributing areas. He used a hypothetical stream-valley aquifer to provide examples.

Block Island Ground-Water Investigation. A hydrogeologic study of Block Island, which lies 10 miles off the coast of Rhode Island, was begun in 1988. The island is composed of glacial sediments, and its residents rely primarily on wells for drinking water. A group of homeowners, concerned about future development of the island's finite supply of freshwater, voluntarily contributed funds to the town to support the first year of the four-year study. Illness and subsequent resignation of the project chief, and inability to find a replacement, delayed completion of the report (WRIR 94–4096). It was finally completed through the joint efforts of Anne Veeger, a professor at the University of Rhode Island who was employed intermittently as a hydrologist, and Herb Johnston, following his retirement. A section on geology done by Byron Stone of the Geologic Division of the USGS was incorporated into the report as an aid to understanding the complex geohydrologic framework. He was assisted in this work by Professor L.A. Sirkin of Adelphi University. Data for the project were compiled in a data report (OFR 92–155) by Emily Burns.

Water-Use Investigations

Statewide collection and computer storage and retrieval of comprehensive water-use data by State agencies was in the planning and development stage late in the reporting period. Estimates of comprehensive water-use data for Rhode Island were available mainly through the USGS water-use program, which has supported collection and publication of comprehensive water-use data for each State at 5-year intervals between 1950 and 1990. During 1988–89, a plan for developing a water-use data program for Rhode Island (WRIR 90–4207) was prepared in cooperation with GOHEIR. The plan was prepared by Marylee Horn of the New Hampshire office and Pat Craft of the Rhode Island office. This was followed by a water-use study of a single Rhode Island town, in cooperation with GOHEIR and RIDEM, to provide an example of how such a data-collection and retrieval system would work. The second study was prepared by Horn, Craft, and Lisa Bratton of the Massachusetts Office.

Other Studies

In the early 1990's, Elaine Trench prepared a report that provides a comprehensive summary of Rhode Island's ground-water resources (OFR 91–199). This was followed by a report that listed sources of geologic and hydrologic information pertinent to ground-water resources in Rhode Island (OFR 93–464). Statewide summaries of selected water-resources topics were also prepared between 1984 and 1990 for publication in National Water Summary reports. These included summaries of Rhode Island ground-water resources (Johnston), surface-water resources (Johnston), water supply and use (Johnston and Baer), ground-water quality (Johnston and Barlow), stream-water quality (Bell), and floods and droughts (Patrick Walker [USGS retired] and R.E. Lauzenheiser [New England Climate Service]).

Epilogue

The Federal-State cooperative program, which has been continuously funded by Rhode Island agencies for more than 50 years, has provided Rhode Island agencies with much of the information needed to develop, protect, and manage its ground-water and surface-water resources. Numerical models of many of the State's principal stream-aquifer systems, in particular, have provided tools that could eventually be used to manage withdrawals of ground water and the effect of these withdrawals on streamflow depletion. By 1994 many of the map products of USGS investigations had been incorporated into the Rhode Island Geographic Information System. This system enabled rapid production of a diverse set of map products that show the relationship of Rhode Island's water resource to a wide array of other physical features.

VIRGINIA

By Gary S. Anderson and Byron J. Prugh, Jr., including information provided by Sandra A. Nichols-Edwards, Don C. Hayes, and Gary K. Sperian

INTRODUCTION

As the 1979–94 period began, the Virginia District consisted of a District Office in Richmond, Subdistrict Offices in Fairfax and Marion, and a Field Headquarters in Charlottesville. In early 1983, Virginia was merged into a new Mid-Atlantic District along with Maryland and Delaware and became a State Office. In 1991, the Virginia Office was reorganized as an independent District.

In 1979, the District was staffed by approximately 34 permanent employees that included 5 hydrologists, 1 chemist, 13 hydrologic technicians, and 5 administrative clerical persons. During the period of 1979 through 1981, increased Federal funding for coal-mining-related studies in southwestern Virginia and the Atlantic Coastal Plain Regional Aquifer-System Analysis (RASA) study accelerated the program.

By the end of 1981, the District budget had doubled. Nine hydrologists were added to the staff both by recruitment and by transfer. This infusion of new talent provided the base to build a larger, more diverse program of water-data collection, hydrologic investigations, and water information services.

The District/State Office continued growth through this period and ended with a threefold increase in budget from 1978 and 46 permanent employees.

District Headquarters, Richmond

Office of the District Chief. In 1979, the District was located at 200 West Grace Street. In 1985, the office was relocated to 3600 West Broad Street. William E. Forrest, the second Virginia District Chief, served until late 1982, when he retired. Gary S. Anderson was designated Acting District Chief until the Virginia District merged with the Mid-Atlantic District; Anderson continued as State Office Chief until 1991 when the District Chief position was reestablished. Anderson retired in April 1994 and was replaced by Pixie A. Hamilton, who transferred from the National Water-Quality Assessment (NAWQA) National Synthesis Team.

Sandra A. Nichols-Edwards was the first Administrative Officer when the District organized in 1967 and continued in that position through the period. Others who served in the Administrative Section: Tom B. Bolles, Marshall D. Brooks, F.R. Brown, Marquis M. Chambliss, Loretta F. DePaul, J.L. Farlow, C.E. Hill, K.A. Holbrook, Angel A. Johnston, C. (Bobby) Lewis, E.A. Martin, Anita C. McGaha, Bonnie P. Pfaff, and Pam S. Whitaker.

Computer Services Unit

The Computer Services Unit was established in 1985. Todd W. Augenstein was Unit Chief throughout the period. Mary B. (Sue) Fussell was the site administrator throughout the period. Sue started as Clerk Steno in the Hydrologic Data Unit processing water data through dedicated lines to off-site computers. From there, she administered all in-house computer systems throughout the period. Others served in the Computer Units:

Carmine R. Baxter, Mat L. Boon, M.R. Chappell, A.O. Cherry, Lee M. Crowder, Steve T. Farrington, Alfrado C. Frauenfelder, Kevin C. Hansan, Sodana Heng, John F. Manzer, T Nguyen, Silvia Terziotti, G.I. Tsein, and Nelson Williams.

The Virginia District did not have a designated Reports Unit until the creation of the Mid-Atlantic District. Water data reports were processed within the Hydrologic Data Section (discussed later) and interpretive reports were processed in the Hydrologic Studies Section. Herb T. Hopkins was Reports Specialist until 1981, when Chet Zenone assumed the duties through 1982. Charles Blankenship was Senior Cartographic Technician through the period. Others involved in interpretive report processing: Robert B. Banks, Marcus D. Bond, Natalie Carrington, Judy McFarland, Ted Samsel, M.W. Scott, and Diane E. Williams.

Hydrologic Data Section

The Hydrologic Data Section provided overall coordination of statewide water-data collection and compilation for annual water-resources data release. The Section also conducted studies related to extreme hydrologic events, surface-water hydrologic analysis, and characteristics of surface-water-quality loads.

Section Chiefs during the period were Prentis M. Frye, until he retired in 1980, and Byron J. Prugh, Jr., who remained through the period. In 1993, the Richmond Field Unit was upgraded to a Field Headquarters with Roger K. White as Hydrologic Technician-in- Charge. Others involved in the Hydrologic Data Section in Richmond: Rick J. Ahlin, Donna L. Belval, Jim A. Bisese, Jean P. Campbell, Wayne A. Clingenpeel, William V. Daniels, Jr., Fritz E. Drummond, Karl M. Dykak, E.D. Gillispie, Joel R. Guyer, Don C. Hayes, Larry Huffman, C.A. Keller, Patricia A. Kingrey, William G. Langley, Virginia C. Lawrence, Dennis D. Lynch, John F. Magnotti III, S.D. Moore, Barry E. Moses, Edward H. Nuckels, Charles D. Nunn, D.K. Oliver, Jeff S. Putnam, Stanley M. Rogers, Benjamin Simerl, G.J. Thomas, Craig A. Thomas, Mary L. Thomas, Rebecca E. Vandermeid, Carlton D. Wood and Michael D. Woodside.

Hydrologic Studies Section

The Hydrologic Studies Section was responsible for single and multidiscipline hydrologic studies (including surface water, ground water, and water quality) and research on hydrologic processes.

The Section Chief position was vacant during the early part of the period and executive duties assumed by Gary Anderson, first as Assistant District Chief and later as District/Office Chief. In later years, Chiefs were William B. Scott 1985–86, Gary K. Speiran 1987–92, and James B. Campbell beginning in 1992.

Others who served in the Hydrologic Studies Section: J. Meade Anderson, Clifton F. Bell, Tom B. Bolles, Allen R. Brockman, Natalie R. Carrington, C.A. Chambliss, Dan R. Conrad, Robert E. Cooper, M. Crowley, S.D. Davis, Patricia L. Delbridge, J.J.

Fitzgerald, Michael J. Facazio, Robert Hale-Cooper, Jr., Pixie A. Hamilton, Emily C. Hammond, George E. Harlow, Jr., M.S. Harris, John F. Harsh, Amy J. Harshman, Charles F. Harvey, W.K. Hollis, Penny J. Hom, Herbert T. Hopkins, Peter W. Hufschmidt, Thomas K. Kull, Randy J. Laczniak, A.R. Lail, Jerry D. Larson, Cheryl R. Lipscomb, Greg J. Mangus, Randy E. McFarland, Drew A. Meng III, Nancy R. Mensch, Susan E. Mortell, M.P. Mulherin, David Nelms, Christa D. Peters, John R. Pilling, J.R. Ponton, Jr., John D. Powell, T.C. Redd, Donna L. Richardson, M.W. Scott, Amy G. Scruggs, Barry S. Smith, Danita L. Threadgill, Cindy L. Toenniessen, F.E. Tucker, Kevin L. Tweety, Nelson E. Williams, R.L.Winland and Winfield G. Wright.

The Field Offices

As the period began, there were two Subdistricts and one Field Headquarters. The Subdistricts were responsible for both data collection and hydrologic studies.

Fairfax Subdistrict was located at 9673 Lee Highway. Ewell H. (Sonny) Muhler, Jr., served as Subdistrict Chief from 1975 to 1980, and Chester Zenone served as Acting Subdistrict Chief through 1981. Following the completion of the urban flood studies in Fairfax County and Fairfax County and Culpepper Basin land investigations and analysis (LIA) studies, the office was closed in 1982.

Others who served in the office were Joe M. Abe, Steve F. Blanchard, M.W. Gwynn, Gary F. Hagan. K.A. Holbrook, John F. Magnotti III, E.A. Martin, Sarah A. Morsches, Alex Posner, Mike P. Shackelford, and Jerry D. Larson.

Marion Subdistrict

The office was located at 1021 Terrace Drive throughout the period. In late 1976, W. Eugene Hendrick became Hydrologic Technician-in-Charge. Terrance W. Danielson transferred to Marion as Subdistrict Chief in 1981, to coordinate coal-hydrology data collection and investigation in southwestern Virginia. Following the completion of the coal-hydrology investigation in1984, Danielson transferred from the District and Hendrich resumed the position of Hydrologic Technician-in-Charge and served until his retirement in 1989. Howard D. Williams served in the position through the remainder of the period. The office handled field operations and records preparation for sites throughout southwestern Virginia and the upper parts of the James and Roanoke River Basins.

Others who served in the office were Dennis W. Adams, Curtis W. Barrett, Robert M. Briggs, M.T. Cline, Patsy S. Francisco, James M. Gemmell, Harold G. Henderlite, William G. Langley, Gary D. LeCain, Peggy H. Sayer, Robert B. Wells, Stephen L. Wheeler, and Winfield G. Wright.

Charlottesville Field Headquarters

The office was located at 1036 Arlington Boulevard, sharing a building with the Virginia State Water Control Board (SWCB) Surface Water Data Unit, later the Virginia Department of Environmental Quality (VDEQ). At the beginning of the period, Roger N. Pollard served as Hydrologic Technician–in–Charge until 1988, when he retired. He was followed by Floyd L. Snow who served through the remainder of the period. The office was responsible for field work and records preparation for sites in central and northern Virginia and for the preparation of the District's annual data report including the records collected by the SWCB. Clairiece G. Humphrey was responsible for processing all District annual data reports throughout the period. Others who served in the office were S.L. Barnes, P.J. Elmore, Gary N. Matelli, Roger M. Moberg, Karen C. Rice, Karl L. Steider, Gianni Venturi, Warner C. Wood, Stephen L. Wheeler, and Richard J. Ziller, Jr.

Funding and Cooperation

As indicated in the table of funds, the Federal-State Cooperative (Coop) program more than doubled during the period. The Federal (Fed) program peaked in 1981, but with the completion of Land Information and Analysis (LIA) studies in the Fairfax office in 1982, the completion of the Surface Mining Control and Reclamation Act, and data collection and investigations in southwestern Virginia in 1984, the Federal program fell in 1985 to its lowest level of funding for the period. Through the remaining time of the period it grew gradually with new RASA and NAWQA projects. Other Federal agency funding was generally declining at the beginning of the period but accelerated in 1983–86 as a result of environmental work for the

Virginia District funds, fiscal years 1980–94

Funds in thousands of dollars]

Fund source	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	684	626	686	845	1,013	1,214	1,157	1,181	1,324	1,311	1,472	1,757	1,554	1,399	1,592
OFA	580	467	336	391	789	928	982	687	500	614	724	482	994	1,707	1,417
Federal	764	1,040	772	706	470	280	343	345	326	369	410	405	634	652	759
Total	2,028	2,133	1,794	1,942	2,272	2,422	2,482	2,213	2,150	2,294	2,606	2,644	3,182	3,758	3,768

Source: District program documents for 1980–94

Department of Defense and again from 1991 through the end of period.

Other Federal agencies contributing through the period were the U.S. Army Corps of Engineers (Baltimore, Huntington, Norfolk, and Willington Districts), U.S. Fish and Wildlife Service, National Park Service (NPS), Tennessee Valley Authority (TVA), and various power companies under the auspices of the Federal Energy Regulatory Commission (FERC), and Soil Conservation Service.

The principal State cooperation through the period was with the Virginia State Water Control Board, later reorganized as the Virginia Department of Environmental Quality. Up to one-half of the State's share was in the form of evaluated (direct) services including collection of basic records and drilling.

The Virginia Department of Highways and Transportation (VDH&T, later VDOT) cooperated throughout the period in the collection and analysis of flood data, bridge scour, and quantity of highway runoff.

Other local cooperators contributing to the data program through the period were James City, Orange and Prince William Counties, Northern Virginia Regional Planning Commission, West Piedmont PDC, Washington County and Southeast Virginia Public Service Authority, the University of Virginia, and the cities of Alexandria, Danville, Newport News, Norfolk, Roanoke, and Staunton.

Beginning in 1983, the Coop program accelerated with a series of investigations of ground-water availability and surface-water quality mostly on the coastal plain of York James Peninsula, Southeastern Virginia and the Eastern Shore. Almost every county or city provided financial support either directly or through the Richmond, Southeastern Virginia, or Eastern Shore Planning Districts

Hydrologic-Data Collection

Virginia's data-collection activities during this period were somewhat unique in that the Virginia State Water Control Board (SWCB) operated a complementary network of surface-water stations (varying annually from 79 to 103 stations) and ground-water observation wells (varying annually from 16 to 216 wells). Data were collected using USGS methods and procedures and were published jointly in WRD annual water-data reports. This unique cooperative effort started decades earlier when a single manager supervised both agencies' programs in Virginia. Responsibility for specific stations and observation wells were occasionally transferred between the agencies to accommodate project needs, funding levels, and personnel availability. The goal was the best possible hydrologic network for the State.

Monthly observations from a dozen water-table aquifer wells and about 20 telemetered surface-water stations were used to prepare the Virginia Water Resources Summary on the status of current hydrologic conditions in the State. The report was circulated to numerous local, State, and Federal agencies as well as the news media.

Streamflow Stations

The Virginia District operated 110 continuous-record stations in 1979. This number increased to 116 in 1981 before financial cutbacks by the TVA, various Corps of Engineer Districts, and other Federal programs; also, increased emphasis on current management rather than future needs resulted in a decline to about 90 stations in 1984. This number remained fairly constant through the next decade. Funding became more creative during the period, and as many as four cooperative users would share funding for a particular station. The reduction in stations

resulted in the surviving network being weighted toward large drainage-area sites on regulated streams. The importance of those stations operated by the SWCB on smaller, unregulated streams, providing a balanced picture of the State's hydrology, cannot be overestimated.

This period showed a progression in field data-recording equipment from analog recorders to ADR's to electronic data loggers. Older equipment was often left operational to serve as backup, and overall data record loss was less than 2 percent during the period. The use of telemetry increased as TVA, Corps, NPS, and FERC cooperators as well as USGS found increased need for real-time data.

The District also operated stage-only and partial-record sites for several Corps Districts as funds available for continuous-record stations became more difficult to obtain. Ratings for these sites were maintained for the high-flow end of the flow spectrum only.

The Data Section continued operation of a network of partial-record stations on smaller streams for VDOT as a followup to an earlier flood-frequency study. In 1979 there were 64 such sites. This number increased to about 100 during the end of the period (1990–94) as discontinued continuous-record stations were added to the network.

Miscellaneous measurements of flow were made by both USGS and SWCB and published in annual data reports. The number varied, depending upon flow conditions and project activities, but averaged about 135 annually with a maximum in 1981 of 311 sites during the peak of coal-hydrology studies in southwestern Virginia and a minimum of 18 in 1986.

There was an increased emphasis on low-flow measurements at smaller drainage-area sites to complement data from the basic data stations as part of a SWCB-sponsored study to improve techniques of low-flow estimation. This work was done on a rotating regional basis to accommodate personnel limitations. From 6 to 10 measurements were eventually made at each site. The total number of measurements increased from 67 in 1980 to a peak of 220 in 1983. Field aspects of this project ended in 1985.

Special Data Collection

Special data-collection projects were undertaken for U.S. Fish and Wildlife Service to assess inflows and outflows to the Great Dismal Swamp (1979–81) and National Park Service at Prince William Forest Park (1983–85) to characterize the surface-water hydrology of the park for planning purposes.

Water-Quality Stations

The District operated a network of more than 16 stations in support of Federal and State programs including the NASQAN program. In later years, five of these stations became part of a network monitoring inflows to Chesapeake Bay. The number of stations was reduced by seven in 1987, one in 1989, and one in 1994 due to funding constraints. One Hydrologic Benchmark Network station on Holiday Creek near Andersonville (begun in 1968) was active throughout the period.

Water-quality sampling was done as part of studies in Prince William County and Quantico Marine Corps Base beginning in 1994. Data Section personnel provided field support for studies on Diascund Reservoir and the Chickahominy River Basin as well as three NAWQA study areas headquartered in adjacent States.

The number of surface-water sites sampled annually during the period, both for basic data and project studies, averaged about 90 with a high of 218 in 1981 and a low of 40 in 1993.

Fluvial-Sediment Stations

Daily sediment loads were calculated for three stations for the Corps of Engineers through 1981 as part of inflow studies for Fishtrap and Kerr Reservoirs. A long-term index station was operated from 1951 to 1993 on the Rappahannock River at Remington. This site had one of the longest periods of sediment record on the East Coast before closing due to fiscal cutbacks.

Two sediment stations were operated for the U.S. Fish and Wildlife Service in the Great Dismal Swamp (1979–81) and the Soil Conservation Service (1980–81) in the upper Appomattox River Basin, four for the NPS in Prince William Forest Park (1983–85), six for Diascund and Chickahominy River studies for the city of Newport News (1989–91), three for Quantico Marine Corps Base (beginning in 1994), and two for Prince William County (also beginning in 1994).

Ground-Water Observation

In a manner similar to the surface-water network, SWCB also operated a network of observa-

tion wells. The joint network consisted of a few dozen mostly water-table aquifer wells distributed spatially across the State and a much larger number of wells in various aquifers in the Coastal Plain plus additional wells associated with short-term studies. One observation well at Reston served as a demonstration well for visitors to the USGS National Center.

The number of USGS wells varied from around 40 from 1979 to 1986, then increased to 150–186 from 1989 to 1994 as project wells were drilled and activated. The network was periodically reviewed and reconfigured to provide optimal spatial as well as aquifer-specific coverage. Feedback from various modeling studies proved helpful in the assessment process. The Virginia District was among the first to include ground-water-level hydrographs for all observation wells in the annual data report. This helped potential data users to quickly scan for trends and helped in-house reviewers check for extraneous data.

Water-Use Records

With the establishment of the National Water Use program in 1979, Virginia was one of two States to start pilot programs. In Virginia, a task force was formed that included Virginia representatives from the State Water Control Board, Division of Health, Council on the Environment, and Division of Taxation. Hopkins was the first Project Chief and represented the USGS on the task force. Through a reverse-flow funding agreement, the SWCB provided a full-time project coordinator to compile water-use records acquired through State permitting processes.

The Division of Taxation was contracted to write the code for the original Site-Specific Water Use Data System (SSWUDS). Augenstein, who was first employed by the Virginia Division of Taxation to develop the code, was hired by the District in 1985 and replaced Hopkins as Project Chief in 1987. Augenstein continued through the period working on State and national water-use programs. Data were used for national reports on use of water in the United States and updated model calibration for Coastal Plain ground-water investigations.

Interpretive Studies

Flood Investigations

The Flood Investigations program, in cooperation with the Virginia Department of Highways and Transportation, continued through the period. Prugh, Nuckels, and Humphrey updated the annual maximum stages and discharges of selected streams in Virginia through 1990 (OFR 90–587). Bisese developed new methods for estimating peak discharges of rural, unregulated streams (WRI 94–4148).

At the beginning of the period the District was cooperating with the Federal Emergency Management Agency (FEMA) to complete Type 15 flood reports. Between 1984 and 1986, Danielson resumed work with FEMA to do Limited Detailed Studies for the counties of Caroline, Floyd, Bland, Madison, Craig, and Grayson. Additional work by Prugh for the Soil Conservation Service was done on peak flows for selected areas in central and southwestern Virginia (1985–86) due to a shortage of technical personnel in their local office.

Low Flow

At the beginning of the period, Prugh was completing a planning study to determine the adequacy of the existing statewide data base for low-flow predictions. A network of several hundred low-flow sites was established (1980–85) to fill gaps in the existing CBR and ongoing project coverage. At the peak of the field data-collection phase of the project in 1983, there were 220 active partial-record sites. In 1985, Hayes replaced Prugh as Project Chief and developed methods for estimating low-flow in Virginia (WSP 2374). Another project initially begun as part of the study was a compilation of surface-water and water-quality data-collection sites in Virginia (OFR 93–462) by Prugh and Humphrey. Additional low-flow measurements were made in Orange County (1990–91).

Bridge Scour

Hayes led the Delaware, Maryland, and Virginia Highway Bridge Scour project (1990–94), in cooperation with the Maryland State Highway Administration and the Virginia Department of Highways and Transportation. Measurements at 15 bridges during storm runoff were conducted. Data were used for verification of existing equations and the results were presented in WRI 96–4089. Also, Drummond and Hayes evaluated

selected techniques for monitoring riverbed scour (WRI 94–4146).

Land Information and Analysis

The Environmental Hydrologic Mapping of Fairfax County was nearing completion at the start of the period. Studies completed in 1980–81 included a low-flow analysis (Mohler and Hagan) and a summary of ground-water resources (Zenone and Larson).

Following the completion of the Fairfax County study, Zenone headed a similar investigation of the Culpepper Basin. Products of this study included a description of chemical quality of ground water (Posner and Zenone), low-flow characteristics, chemical quality of streams (Lynch, Nuckels and Zenone), and a ground-water-resources analysis including a digital model (Laczniak and Zenone).

A unique land-analysis project was started in 1992 with a joint effort between the Geologic, National Mapping, and Water Resources Divisions. Todd Augenstein was the WRD team member. The area of study was the Elizabeth River Basin of southeastern Virginia. A large set of digital environmental data was drawn together into an Arc/INFO informational system. Applications were presented at symposia and other meetings. In addition, many "live" demonstrations were presented to Federal, State, and local agencies by using a portable computer.

Regional Aquifer-System Analysis (RASA)

Coastal Plain of Virginia

Work on the coastal plain of Virginia was carried out by a team led by Harsh. This team coordinated with the regional team led by Harold Meisler. Results of this study greatly improved knowledge of the geologic, hydrologic, and freshwater/saltwater characteristics of the multilayer aquifer system. Results were written in reports by Meng and Harsh PP 1404–C (Hydrogeologic Framework), Harsh and Laczniak PP 1404–F (Analysis of Ground-Water Flow System), and Kull and Laczniak WRI 87–4049 (Historic Ground-water Withdrawals).

Appalachian Valley and Ridge—Piedmont

With the financial support from the Regional RASA project office, Nelms, Harlow, and Hayes characterized the varied aquifer systems with the north Piedmont part of the Appalachian Valley and Ridge and Piedmont RASA area. The approach was to determine effective recharge rates for gaged sites and determine relations and ranking of hydrogeologic units. Results were published in WSP 2457.

Cooperative Ground-Water Investigation

At the beginning of the period, Harsh was completing the James City County study (OFR 80-961) and Larson was completing a study on the distribution of the Coastal Plain aquifer (OFR 81–1013).

Following the completion of the Coastal Plain RASA study, the District embarked on a series of Coastal Plain studies with local and State cooperation. The approach was to construct test holes to fill in hydrologic data gaps and develop local ground-water models for analysis and management. The localities provided their best estimate of ground-water requirements, which were used in the withdrawal scenarios.

The first of the series of studies starting in 1983, was the York–James Peninsula with Laczniak as the team leader. The project study results were published by Laczniak and Meng in WRI 88–4054.

In 1984, Harsh started the study in southeastern Virginia and was replaced by Hamilton in 1985. The study was completed in 1987 with the results reported by Hamilton and Larson in WRI 87–4240.

In 1986, Laczniak started the Eastern Shore Peninsula Study and was replaced by Richardson in 1989. This study was different from previous Coastal Plain studies in that saltwater was located within 200 feet of land surface and a new model had to be used that analyzed the movement of this saltwater interface. The Eastern Shore study was reported by Richardson in WSP 2401.

The Eastern Shore cooperative test drilling with the State Water Control Board and Geologic Division near Cape Charles discovered fused quartz shards that suggested a meteorite impact in the vicinity of the present-day Chesapeake Bay. The discovery of these shards resulted in a major reconceptualization of the Coastal Plain geohydrologic framework.

In 1989, Richardson teamed with Brakeman for a study of the shallow ground-water resources of eastern York County. Previous Coastal Plain studies proved little definition of the shallow ground-water system. Coastal counties like York County depend on this shallow system for modest but necessary supplies of water. Richardson (water quality) and Brakeman (hydrological) teamed up to characterize the ground-water resources of York County (WRI 92–4090).

From the late 1980's throughout the period there was a series of studies to update, compile, document, and disseminate ground-water information for the entire Coastal Plain. Focalize, Spearing, and Rowan summarized the quality of ground water (WRI 92–4175). Focalize and Seamless documented the geographic information system (GIS) coverage and data-input files used for analysis of the geohydrology (WRI 93–4159), and Hammond, McFarland, and Focazio mapped the 1993 potentiometric surface of the Brightseat–Upper Potomac aquifer (OFR 94–370) the middle Potomac aquifer (OFR 94–372) and the lower Potomac aquifer (OFR 94–373).

In 1993, an INGRESS data base was developed to store, manipulate, and retrieve ground-water use data in the Coastal Plain. Richardson determined ground-water discharge from the Coastal Plain by relating effective-recharge rates of gaged sites to GIS coverages of surficial geology and landform characteristics (WRI 93–4191).

Near the end of the period, the Virginia Coastal Plain model became fully automated and user friendly. Some model weaknesses were identified to be hydraulic properties near the fall zone, such as saltwater intrusion and interactions between the water table and the confined aquifer system. In 1994, McFarland began a study to refine the hydrogeologic framework and characterize hydrologic processes in the fall zone.

In addition to the regional Coastal Plain ground-water studies, two studies were in progress describing biogeochemical processes in selected geomorphic areas. Speiran studied the biochemical processes of nitrate-rich ground water from upland agricultural areas along the flow path under woodlands to the discharge areas of wooded wetlands, saltwater marsh, or estuary (WSP 2479).

Focazio headed a study to determine if upland runoff was reaching a wetlands conservation preserve containing rare or endangered species of plants and animals.

Cooperative ground-water investigation in areas other than the coastal plain totaled seven. In cooperation with the State Water Control Board, Powell also completed a ground-water quality study of the Piedmont (WRI 85–4235). In cooperation with Virginia Tech, Larson summarized the water resources of the Powell River Basin in Wise County (OFR 85–186). Wright described the ground-water resources of Clarke County (WRI 90–4134).

Nelms was Project Chief for two studies in Prince William County. The first was a description of the geohydrology and the occurrence of volatile organic compounds co-authored with Richardson (WRI 90–4032). This project was followed by a more comprehensive study in the rates and direction of ground water within the county (Nelms and Brockman, WRI 97–4009).

In 1985, Danielson started a cooperative study with the Virginia Division of Mined Land Reclamation to determine aquifer characteristics in the coal fields of southwest Virginia. LeCain replaced Danielson as Project Chief in 1986. The study results were summarized by Harlow and LeCain in WSP 2388.

Cooperative Surface-Water-Quality Investigations

During 1981–85, Lynch, in cooperation with the University of Virginia, started a study to determine the sensitivity of streams in Shenandoah National Park. In association with Nancy B. Dise (graduate student), the study results were published in WRI 87–4131. During the period 1982–85, the scope of study was expanding in cooperation with National Park Service to provide a broad understanding of the park's hydrologic cycle (WRI 87–4131).

Beginning in 1983, Lynch led a project, in cooperation with the City of Newport News, to determine the limnological characteristics of Diascund Creek and of Little Creek Reservoir, which receive water pumped from the Chickahominy River (WRI 92–4034). Cooperation with the City of Newport News continued in 1989. Woodside conducted a stream-sediment sample study throughout the Chickahominy drainage basin and identified areas of trace-metals concentration. Five subbasins were selected for peak runoff sampling. Focazio and Cooper summarized these results (WRI 94–4225).

In 1989, Woodside began the cooperative study with the City of Virginia Beach to characterize water quality of Pea Hill Arm of Lake Gaston, which was to become a source of water for the tidewater area. Results of the study were summarized by Woodside in WRI 94–4150.

Cooper started a project in 1993, in cooperation with the Virginia Department of Highways and Transportation, for the assessment of the effectiveness of a stormwater-management facility in reducing urban highway runoff loads. The project was continuing at the end of the period.

National Water-Quality Assessment Studies

The Virginia office provided support to adjoining Districts on three NAWQA Studies. Hamilton was on the Delmarva study team and later on the National Synthesis team; Woodside was on the Albermarle-Pamlico team; and the Charlottesville office assisted with the Potomac study data collection.

Federal Coal Hydrology Studies

At the beginning of the period, the District was conducting water monitoring in Virginia coal-mining areas for Public Law 95–87. Approximately 200 partial-record sites were visited at least annually in 1979–81. In 1980, Larson started a study of hydrologic interactions between the ground-water and surface-water systems in coal mining areas of southwestern Virginia (Larson and Powell, WRI 85–4238).

Also in 1980, Hufschmidt started a study of geochemical processes controlling mine drainage in southwest Virginia. Upon Hufschmidt's untimely death, Powell replaced him as Project Chief. Results of the study were published by Powell and Larson in WSP 2274.

In 1981, Danielson headed the efforts to gather sufficient information from two small drainage basins to be used as calibration data for the USGS rainfall-runoff model. In 1982, Wright started the study of the variability of aquifer characteristics (WRI 85–4061).

Department of Defense

In 1984, the Virginia District, with Powell as team leader, started its first Department of Defense contaminant hydrology study at the Defense General Supply Center in Richmond. The objective of the study was to develop a hydrogeologic framework and to determine the extent, concentration, and rate of movement of a contaminant plume. Results of the study were reported by Wright and Powell (WRI 90–4091); and Powell, Wright, Nelms, and Ahlin (WRI 90–4113).

In the late 1980's, Powell coordinated a Virginia team investigation to characterize soil and ground-water contamination at selected sites on Boling Air Force Base (Washington, D.C.) and Andrews Air Force Base (Maryland).

An investigation to describe the hydrogeologic framework and the interaction of ground water and surface water at Langley Air Force Base in Virginia was started in 1992. Brockman led the ground-water effort and Cooper led the surface-water effort. The project was suspended in 1994 before completion but resumed again in 1995.

An investigation to describe the hydrogeologic framework and ground-water flow system of the shallow aquifer system at the Weapon Warfare Center, Dahlgren Laboratory, was started by Harlow in 1992. A hydrologic and water-quality data report was completed by Bell, Bolles, and Harlow (OFR 94–301), and interpretive analysis continued after the period.

WEST VIRGINIA

By David H. Appel *and reviewed by* Eugene A. Friel, William A. Hobba, and David Brown

INTRODUCTION

The West Virginia District was difficult to manage during the period because of its small program and staff size, the poor State economy, and the influx of short-term large-dollar programs. In terms of percentages, a thrust program such as the Coal Hydrology Program has a much greater program impact on a small District than a large one. Total District funds increased nearly 100 percent in 2 years, from $1.1 million in 1978 to $2.1 million in 1980. The upside of this new money was that the District was able to do new work that otherwise could not have been done. The downside of this was that Coal Hydrology funding was relatively short lived, and by 1990 total District funding was down to $1.4 million. By 1994, the District funding was back up to $2.25 million owing to new work at Canaan Valley, Ohio River, and the National Water-Quality Assessment (NAWQA) Program. During the period 1979–94 the wide fluctuations in program size caused equivalent swings in numbers of personnel and the juggling of staff positions. The District entered the period with 36 full-time equivalent (FTE) positions in 1979 and was at 46 in 1982, during the peak of the Coal Hydrology Program; but FTE's dropped back to a low of 18 in 1992.

DISTRICT ORGANIZATION

Generally, the District organization consisted of the District Office, Hydrologic Studies Section, and

Charleston Subdistrict, located in Charleston, and the Morgantown Subdistrict located about 11 miles east of Morgantown. However, as programs and staff changed, the organization was changed to fit the needs. The organization is discussed in more detail in the following sections.

District Office

The District Office was located in the Charleston Federal Building from 1979 to 1982 and then relocated into privately leased space on Morris Street in 1983. The District Office consisted of the District Chief's Office, the Administrative Services Unit, and the Automated Data Processing (ADP) Unit. District Chiefs during the period were David H. Appel (1976–90) and David P. Brown (1991–95). Assistant District Chiefs were Celso Puente (1980–86) and David P. Brown (1986–90). The District did not fill the Assistant District Chief position when Brown became District Chief. Theodore Ehlke was the District Water Quality Specialist during the period 1980–86. The Office Secretary was Marilyn Fridley (1980–87) followed by Sherry Cabell (1988–90).

The Administrative Unit was staffed by the Administrative Officer and, generally, two or three support staff. Administrative Officers during the period were Carmine Scudero (1974–83) and Sandra Moles (1984–90). Georganne Gillespie, Administrative Operations Assistant, was the senior administrative staff person in the District office for the remainder of this period (1991–94). The ADP Unit consisted of 1–3 people and was supervised by Rungus Yerrid (1979–81), Colleen Cooper (1982–88), and Michael Cunningham (1989–94 and beyond). Other staff who spent about 2 or more years in the District office were Elizabeth Hanna, Michelle Kibbe, Karen Bragg, and Deborah Knopp.

HYDROLOGIC STUDIES (INVESTIGATIONS) SECTION

This Section was physically located in the same space as the District Office and was supervised by the Assistant District Chief. Staffing varied between 14 in 1980 to 3 in 1992. Generally, there were about seven hydrologists in the Section through 1989, but this number declined to only three in 1992. As the District was reorganized to accommodate new programs started in 1992–95, and due to the closing of the Field Headquarters, staffing for this Section was increasing at the end of the period. A Kanawha/New River office for the National Water-Quality Assessment (NAWQA) Program was established in 1994 and staffed by its first Chief, James Eychaner.

Other senior hydrologists who served all or part of the period in this Section included John Bader, Sanford Downs, Gerald Runner, James Borchers, Marcus Waldron, William Embree, Melvin Mathes, Steven McAuley, Robert Shultz, Jeffrey Wiley, Stephen Ward, Robert Bragg, John Atkins, Gloria Ferrell, and Mark Kozar. Others not previously named who spent more than about 2 years in this Section were Orville Rose, Gilbert Engelmeier, William Berkley, Joel Johnson, Donald Simmons, Mark Nelson, Doug Chambers, Kimberly Miller, Terence Messinger, and John Kirby.

Charleston Subdistrict (Field Headquarters)

The Subdistrict office was located in the same space as the District office in the Federal Building through 1982. At that time the Subdistrict moved into West Virginia Department of Highways space on Smith Street as part of the Cooperative (Coop) program. The Subdistrict Chief was William Embree (1980–86) until the office was changed to a Field Headquarters and Stephen Ward moved from the Hydrologic Studies Section to become the new Chief (1987–94). Embree moved to the Hydrologic Studies Section, and Ward moved to the Hydrologic Surveillance and Analysis Section. Other staff not previously mentioned who served about 2 or more years in this Section were Gary Crosby, Robert Bragg, John Atkins, Orville Rose, Albert Tyre, Carl Faulkenburg, Bonnie Taylor, Gloria Ferrell, Jeff Wiley, John Preston, Dayton Payne, Charles Rhodes, Larry Rogers, and William Berkley.

Morgantown Subdistrict

The Morgantown Subdistrict was the only office or unit outside Charleston, and it was located at Mont Chateau on Cheat Lake 11 miles east of Morgantown. The West Virginia Geological and Economical Survey provided space for the office as part of the Coop program. The daily contact provided an excellent working environment for our two agencies. This Subdistrict conducted hydrologic studies as well as data collection and provided assistance to the Hydro-

logic Studies Section. Subdistrict Chiefs during this period were Eugene Friel (1979–86), William Hobba (1986–87), Jo Ann Macy (1987–89), and William Hobba again from 1989 to 1991. During this period, Subdistrict staff dropped from 10 or 11 employees in 1980–83 to 6 in 1990. The office was without a Chief from 1991 to 1993; Robert Shultz was the senior hydrologist. In 1994, the office was changed to a Field Headquarters with a staff of two, Harry Arnentrout and Marion Rosier. Others, not mentioned previously, who served in this office for about 2 years or more were Alvin Jack, Stephen Ward, Mark Kozar, Carl Campion, Freda Taylor, Scott Smith, Chandler Smith, Deborah Demaree, Kevin Whetzel, and Kimberly Suder.

Staffing Difficulties

West Virginia is not a "high-profile" State that automatically draws people, and the District is small. It is difficult to convince experienced WRD hydrologists to transfer to the District to assist in major new short-term thrust programs. More often, the District relied on new hires if they could be found—spending valuable time and resources to train inexperienced staff. To some extent this goes on in all Districts; however, the small District has little flexibility. When the Coal Hydrology Program began in West Virginia in 1979, it was viewed with mixed emotions. The new work and new funds were certainly welcome, but it caused major juggling of staff and their workload. Total District funding nearly doubled in 1 year as 350 new data-collection sites were added to the statewide network. District staff numbered about 30 in 1978, prior to this new project, but numbered about 45 within 2 years. Data collection ended after 3 years, and the Coal Hydrology Program effectively ended in 1983, leaving the District with a staff it could not fully support. Staff reduction began at the end of 1982; by 1987 the District was down to 31, and 18 by 1992 (see graph). This was just in time for the next big increases in funds and work. The cycle started again!

FUNDING AND COOPERATION

As indicated in the table showing District funds by type, the period (1979–94) was plagued by large fluctuations in funding, both total and type. The Coop and Federal matching side of the District program remained reasonably stable from 1979 through 1990, with a combined total of between about $700,000 and $950,000. There were insufficient Federal matching funds to match the total State funds in 1979–82 and then again in 1989–91. In 1990, the cooperative Canaan Valley studies began, and during the 5-year period 1991–95 average funding was about $210,000. Funding for the Ohio River studies averaged $290,000 during the period 1992–95. At the end of the period the District Coop program totaled about $1.1 million. Our long-term cooperative programs continued throughout the period with the West Virginia Geological and Economical Survey (WVG&ES), West Virginia Department of Natural Resources–Division of Water Resources (WVDNR–DWR), and the West Virginia Department of Highways. The WVDNR–DWR was reorganized in 1992 and became the Division of Environmental Protection–Office of Water Resources. Several other State and local agencies supported relatively short-term but sometimes high-profile projects.

The other Federal agencies (OFA) program began the period at $290,000, grew to about $500,000 by 1982, decreased to $391,000 in 1983, but then jumped to $779,000 in 1985 with the addition of the Flood Insurance Mapping work for Federal Emergency Management Agency (FEMA). Major OFA cooperators included U.S. Army Corps of Engineers and DODEC, Soil Conservation Service (now the

West Virginia District funds, fiscal years 1979–94

[Funds in thousands of dollars]

Fund source	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Federal	537	986	725	481	596	330	285	383	225	195	239	227	204	236	204	449
OFA	290	394	473	497	391	474	779	593	437	662	458	420	453	534	621	731
Coop	374	367	397	444	385	419	484	446	455	461	470	397	522	482	528	561
Fed matching	312	323	329	389	385	419	484	468	495	461	441	372	510	482	525	541
Total	1,513	2,070	1,924	1,811	1,757	1,642	2,032	1,890	1,612	1,779	1,608	1,416	1,689	1,734	1,878	2,264

Natural Resources Conservation Service), National Park Service, and FEMA.

The Federal program also went through wide fluctuations in funding. The largest Federal program impact was a result of the Coal Hydrology Program in 1979–83. Several coal projects were ongoing during this period, and District Federal funding went from less than $200,000 in 1978 to $986,000 in 1980. The program funding then decreased to $285,000 by 1985. From 1985 to 1993 Federal funding varied between $195,000 (1988) and $383,000 (1986). In 1994, the federally funded NAWQA Program began at a minimal organizational level but built to a significant level after 1995. A Water Fact Sheet by James Eychaner was published in 1994 describing the program in the Kanawha–New River Basin.

PRINCIPAL PROGRAMS AND TYPICAL PRODUCTS

Hydrologic Data Collection

Continuous record sites were primarily operated by the two Subdistricts/ Field Headquarters. Short-term project sites were usually a joint effort between Subdistrict and project staff. During this period the short-term project data collection was intensive and will be summarized in the individual project discussions. Subdistricts were operating about 130 continuous-record streamflow sites in 1979, but this declined gradually to about 73 in 1989, primarily as a result of reductions in OFA funding. A "cost effectiveness of the streamflow program" report was completed by Runner and others in 1987 and was used to assist in prioritizing gaging station importance. By 1995, the District was operating about 90 continuous-record sites of which 73 had satellite communication links and 65 also had telephone links. Rainfall data were being transmitted from 64 of those sites. Ground-water data were collected at about 30 sites to monitor overall system behavior. West Virginia Water Resources Data reports were prepared annually and compiled by the Charleston Subdistrict Chief.

Two reports summarizing the high-flow and low-flow characteristics of West Virginia streams were published in 1988–89 (Friel and others). Two noteworthy data summaries were prepared during the period.

INTERPRETIVE STUDIES

Coal Hydrology Studies

In 1978–79, the Federal Coal Hydrology Program began in the District. This single project nearly doubled the District budget in 2 years. An additional 350 data-collection sites were established throughout the State. Ehlke was the Project Chief, but everyone in the District was immersed in the program. This project culminated in West Virginia with seven "Hydrology of Area ___, Eastern Coal Province" reports. These reports cover all of the State's coal areas and parts of adjacent States. A summary of the Northern Appalachian Region–Eastern Coal Province program was published in USGS Professional Paper 1464, pages 31–37.

Seven other coal hydrology studies were conducted in the District during this period. Most were funded by Federal funds or in cooperation with the WVG&ES. Approximately 20 District coal hydrology reports summarizing work conducted by District staff were written during the period. Some of the significant topics not mentioned above were "Effects of Coal Mining on Hydrologic Environment (Borchers and others), "Coal Mines as Public Water Supplies" (Ferrell), "Effects of Mine Collapse on Hydrology" (Hobba), "Rainfall-Runoff Modeling in Mined and Unmined Areas" (Puente and Atkins), and "Effects of Longwall Mining" (Shultz).

Water Resources of River Basins

This series of water-resources projects covering all of the State by river basin began in the 1960's and was completed during the period of this history. It was funded through the Coop program along with the WVG&ES and the WVDNR–DWR. The final four basins completed during the period were the Coal, Guyandotte, Tug Fork, and Gauley. This report series was published by the WVG&ES. Three additional reports that had not been included in previous basin reports were written on the geology and ground water of the area bordering the Ohio and Kanawha Rivers (Bader, Mathes, and Shultz) and were published as USGS reports.

Ground-Water Atlases

The WVDNR–DWR was required by the U.S. Environmental Protection Agency (USEPA) to document ground-water conditions within the State as part of USEPA's Underground Injection Control Program. The District agreed to supply the cooperator with "one-sheet" hydrologic atlases, using existing data, defining ground-water characteristics by major river basin, including the areas adjacent to the Kanawha and Ohio Rivers. These 10 atlases by six different authors would be similar to the "Potomac River Ground-Water Atlas" completed in 1973 (Hobba and others). The atlases were printed and published by the cooperator, thereby avoiding the constraints of publishing large, single-sheet atlases by the USGS.

New River Gorge Studies

The New River Gorge National River was established in 1978. The District began working with the National Park Service in the gorge in 1981. The New River at Thurmond gaging station was installed with a telemeter making river stage available to the rafting and fishing public. This program grew through several stages, starting with "Flood-wave traveltimes" (Appel) and ending with "Simulated flow and solute transport" (Wiley). Primary subjects for the 11 reports summarizing New River Gorge work during the period were flood-wave traveltimes, dispersion and traveltime of solutes, river depths, hydraulic characteristics, and modeling flows and solute transport.

Canaan Valley Studies

The Canaan Valley, at over 3,000 feet in elevation, is the highest valley of its size east of the Rocky Mountains. The forest and wetlands support plants and animals that are unusual in West Virginia and the Eastern United States. The area has many permanent and seasonal residents and about 1.5 million annual visitors. In 1994, the Canaan Valley National Wildlife Refuge was established. The District began studying the water resources of the Canaan Valley in 1990 with the assistance of M.C. Waldron of Marshall University, who then joined the District staff in 1991. During the period 1991–94, the District was conducting three separate studies in the Canaan Valley, and average annual funding during the 5-year period was $105,000 each side. The cooperators were WVDNR–DWR and West Virginia Department of Commerce. Reports were written on "Water Quality and Processes Affecting Dissolved Oxygen" (Waldron and Wiley), "Physical, Chemical, and Biological Data for Four Wetland Habitats" (Chambers), and "Geohydrology and Ground-Water Quality" (Kozar).

Ohio River Studies

New hydroelectric generators are planned for several navigation dams on the Ohio, Monongahela, and Allegheny Rivers. Flows would be discharged from the turbines with less turbulence and air contact than currently occurs through the gates. This could reduce reaeration and, therefore, wasteload-assimilation capacity of the river. Dissolved-oxygen monitoring began in 1991 in two navigation pools through a cooperative program with the City of New Martinsville at a total cost of $102,000. The program was expanded in 1992 to nearly $290,000 per year for the period 1992–95. Extensive water-quality data were collected annually from June to October during this period from New Cumberland Dam to Pike Island Dam and from Willow Island Dam to Belleville Dam. Reports were authored by Miller and others, Waldron and others, and Chambers and others.

Some Additional Cooperative Studies

The potential for industrial spills in rivers in West Virginia remains high, and solute traveltime studies were conducted and reported on the South Branch Potomac River (Jack), Kanawha River (Appel, Wiley), and Ohio (Wiley). The eastern panhandle of West Virginia continues to develop as a bedroom community for the Washington, D.C., urban center, and water availability and movement primarily in the carbonate rock area may limit growth. Reports were prepared for Jefferson County (Kozar and others) and Berkeley County (Shultz and others). Three sediment-yield studies were completed during the period after several years of data collection. The Coal River/Trace Fork and Taylor Run/Shavers Fork studies compared sediment loads and yields from areas affected by highway construction to those in unaffected areas. The third study reported on the effects of a gas-well drilling operation on sediment loads. Senior author of the final reports was S.M. Ward. Drainage area reports for five major river basins were published during the period. Other noteworthy reports prepared

in the District were on the distribution of fluoride in ground water (Mathes and Waldron) and ground-water quality (Ferrell).

A special thanks to Georganne Gillespie, Mark Kozar, and Sandra Moles for their assistance in gathering information for this summary.

WISCONSIN

By Warren A. Gebert

INTRODUCTION

As the 1979–94 period began, the Wisconsin District Office was located at 1815 University Avenue, and Field Offices were in Madison, Merrill, Rice Lake, and Waukesha. In June 1987, the District Office moved to 6417 Normandy Lane in Madison.

The Wisconsin District maintained a well-balanced technical program, not only between hydrologic surveillance and interpretive studies but also among the surface-water, ground-water, and water-quality disciplines.

Major Events

Several significant administrative and programmatic events occurred in the Wisconsin District during the period from 1979 to 1994. These events started with the changes in the District Chief's office: Bill Mann, 1979–80; Vernon Norman,1980–90; and Warren Gebert, 1990–present.

There were changes in Sections and Section Chiefs as well. When Fred Dreher retired in 1982, the Water Environment Monitoring Section was combined with the Hydrologic Systems Section to form the Hydrologic Systems and Data Section with Warren Gebert as Section Chief and Assistant District Chief. In 1990, that Section was split into the Hydrologic Systems and Data Section and the Environmental Studies Section. Herbert S. Garn became Section Chief of the Hydrologic Systems and Data Section, and Peter Hughes became the Section Chief of the Environmental Studies Section.

Dale Cotter retired from the position of Section Chief of the Hydrologic Studies and Data Section in 1987. James T. Krohelski became Section Chief of the Hydrologic Studies and Data Section in 1989.

In 1984 the Subdistrict Office in Wales closed due to a large reduction in the District's program. As a result of the District's budget problems, a number of employees were transferred: Tom Ross to Headquarters in Reston, Va.; Dan Olson and Roger McFarlane to the Illinois District; Paul Boetcher to the Florida District; Lee Trotta to the Minnesota District; and James Kammer to the New Jersey District. Fred Warner took an early retirement.

The Northern Midwest Regional Aquifer-System Analysis Study was housed in the District Office from 1979 to 1987. The study was a large, multi-District ground-water modeling project. The study was attached to the Northeastern Region financially, as were the personnel.

In 1990, the Publishing Services Unit had outgrown its space needs at the District Office. Due to the increasing national projects and space limitations, the Unit became the Cartographic and Publications Program (CAPP), moved to 550 Science Drive in Madison, and was assigned to the Northeastern Region.

During the late 1980's, the Wisconsin Department of Natural Resources (WDNR) became aware that a surprising number of lakes in remote locations contained game fish with high levels of mercury. These observations resulted in the start of the District's Mercury Program. The Mercury in Temperate Lakes (MTL) project and Florida Everglades were the District's first mercury projects and were directly responsible for redefining what we know about mercury concentrations, sources, and effects on aquatic life. The Office of Water Quality provided funding to establish the Wisconsin District Mercury Research Laboratory (WDMRL) in 1994. The WDMRL immediately began offering low-level mercury analysis for all the USGS and initiated a large, multiagency mercury investigation in the Florida Everglades.

The National Water-Quality Assessment Program (NAWQA) was also implemented in 1990, and the Western Lake Michigan Drainage Study, which was one of 20 study units funded in the first phase, was assigned to the Wisconsin District. This program required 8–10 full-time people with funding of $1.5 million during the 3-year intensive phase that started in 1991 and was planned to last 30 years. James G. Setmire transferred to the District from California as Project Chief of the NAWQA study.

In 1992, the District initiated a Total Quality Management Program (TQM). This program had a significant effect on future District operations. A consultant, Jonathon Reed, was hired to train and assist the District in the implementation of the program. After the initial training was conducted, a Quality Improvement Council was selected that represented a cross section of employees and helped to implement TQM in the District. Process action teams were formed to address areas of concern that the District staff had identified as part of the process. By 1994, a number of process action teams had successfully completed their studies, and recommendations for improving the processes had been implemented. The first process action teams were on report illustrations, report processing, computation of streamflow records, and employee training. By the end of 1994, significant improvement had occurred as a result of work done by these teams.

Funding

Funding for the Wisconsin District during the 1979–94 period is shown in the table below. Funding increased from $2,196,000 in 1979 to $6,484,000, and most of the increase occurred after 1990. As shown, the funding increased substantially in all areas, with the largest increase occurring in Federal funds with the addition of the Western Lake Michigan Drainage NAWQA study and Mercury Program being started. The District's sizable increase in Federal matching funds and repay is the result of the District being very successful in the National Merit Study Competition and the National Research Enhancement Studies Competition. During the period of the competition, the District was awarded eight studies.

Cooperation

During the period 1979–94, the District continued to expand the type and number of projects and cooperators. In 1979, the District conducted 39 projects with 18 cooperators. The number of projects increased to 62 projects with 78 cooperators by 1994. The WDNR and the Wisconsin Geological and Natural History Survey (WGNHS) were the primary cooperators during the 1979–94 period.

Number of Employees

At the beginning of the 1979–94 period, the Wisconsin District had 68 employees (60 permanent and 8 students). In 1981, the number of District personnel reached a high point of 92 employees, with 60 permanent and 32 other than permanent.

DISTRICT STRUCTURE AND ORGANIZATIONAL CHANGES

The organization of the District in 1979 was fairly typical of most USGS Districts. There was a District Chief, an Assistant District Chief, and three Section Chiefs for hydrologic systems, water environment monitoring, and hydrogeologic studies. The Water Environment Monitoring Section was divided into four Field Headquarters: Merrill, Madison, Rice Lake, and Waukesha. The Field Headquarters in Waukesha was changed in 1980 to the Wales Subdistrict Office, and it operated until 1984 when it was closed due to funding problems in the District.

The four support units reported to the Office of the District Chief. They were the Computer Applications Services Unit, the Operations Services Unit, the Water Quality Services Unit, and the Publications Services Unit.

Wisconsin District funds, fiscal years 1979–94, in thousands of dollars

[OFA, other Federal agency]

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990*	1991	1992	1993	1994
Gross funding	2,196	2,595	2,881	2,782	2,663	2,887	3,181	3,153	3,505	3,596	4,030	3,645	4,384	5,151	5,907	6,484
Federal matching	762	818	887	1,009	1,022	1,071	1,069	1,009	1,045	1,170	1,214	1,231	1,356	1,479	1,675	1,597
Repay and direct	762	818	887	1,009	1,022	1,071	1,069	1,009	1,045	1,170	1,214	1,231	1,356	1,479	1,675	1,597
Unmatched	30	28	32	6	23	6	6	67	5	5	196	562	550	258	183	373
Federal	273	485	585	410	284	435	728	722	981	1,080	1,157	238	589	1,288	1,791	2,042
OFA	369	446	490	348	312	304	309	346	429	171	249	383	533	647	583	875

*Cartographic and Publications Program (CAPP) became its own cost center.

Personnel, number of employees, by type and year

Type	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Employees Total/Permanent	86/59	88/60	92/60	82/62	84/59	80/58	84/54	79/51	66/53	67/51	61/51	60/53	76/55	82/61	80/61	81/57
Hydrologists	18	21	20	21	21	17	18	19	21	18	19	19	22	31	30	29
Technicians	26	25	26	26	23	17	19	18	15	16	15	16	17	18	19	18
Administrative	5	4	5	5	5	5	5	4	6	6	6	6	6	6	6	4
Computer	3	3	3	4	4	5	5	3	4	4	4	4	3	3	3	3
Publications staff	7	7	6	6	6	7	7	7	7	7	7	8	2	3	3	8

DISTRICT ADMINISTRATION AND SERVICES

Office of the District Chief

At the beginning of the 1979–94 period, Bill Mann was the District Chief in Wisconsin. He transferred to Reston, Va., in 1980 to oversee the Water Use Program. That year, Vernon W. Norman became District Chief and remained with the Wisconsin District until he transferred to Denver, Colo., in early 1990, into the Central Region's Water-Quality Specialist position. Warren A. Gebert was selected as District Chief in December of 1990. Gebert remained District Chief throughout the remainder of this period.

In 1979, the District had four Assistant District Chiefs. They were Dale Cotter, who was also the Section Chief of the Hydrologic Studies Section; Fred Dreher, who was also the Section Chief for the Water Environment Monitoring Section; Warren Gebert, who was also the Section Chief for the Hydrologic Systems Section; and Jack Green, who was also the District Reports Specialist. Dale Cotter retired in 1986, Fred Dreher in 1981, and Jack Green in 1983. After Warren Gebert became District Chief, the "assistant" title was not attached to that of Section Chiefs.

During 1979–85, Betty Hamre was Secretary to the District Chief. In May of 1985, Diane Maertz (Weber) took over that position.

Administrative Services Unit

Richard L. Grover continued in the position of Administrative Officer. Others who served in various capacities in the Unit were Diana Cutright, Mary Crawmer, Kathleen Mayer, Rachel Lansing, Edith Gillitzer, Kaye Evans, and Julie Wolf (Urben).

Computer Applications Unit

During the 1979–94 period, the USGS and the Wisconsin District joined the computer revolution in a big way. The terminals then in use (essentially a card reader to send jobs to the mainframe in Headquarters) and microcomputers were replaced by a minicomputer in 1983. In 1984, the processing of gage-height records was moved to the minicomputer. In the next few years, all the USGS data bases were moved from the mainframe to the minicomputer. In 1991, servers and workstations were purchased. With local networking and wide-area networks, everyone had access to computing capabilities on his or her desk.

In 1987, Robert McLeod left the USGS and Robert B. Bodoh became the District Computer Specialist. Bodoh was assigned supervisory duties for the Unit. Others who worked in the Unit were Gary Gill, Jeannette Zahn, and Robert Purvis.

Publications Services Unit

The Publications Services Unit experienced significant growth during the 1980's, doing work for Headquarters on the National Water Summary and other national reports. Greg Allord was the Publications Unit Chief. Other personnel who worked in the Unit between 1979 and 1990 were Wendy Danchuk, Nancy Dudley, Suzanne Hamilton, Judith Lee, Elizabeth Enright, Christine Bebow, Steven Denowski, Ira Hubert, James Rounds, Phillip Redman, Jamaica Pettit, Lucille Strassman, Caryl Wipperfurth, Gregory Howe, John Watermolen, and Gina Barker.

After the departure of the CAPP Unit from the Wisconsin District, new publications personnel, Sue Jones and Karen Lonsdorf, were hired and were under the supervision of Phil A. Kammerer, Jr. In 1989, Krohelski took over the supervisory duties.

Other Units

Hydrogeologic Studies Section.—The Section Chief was Dale Cotter (1966–87) and then Jim Krohelski (1989–present). Other personnel who served in the Section were Bill Batten, Bernie Ellefson, Bob Erickson, Pat Emmons, Bob Devaul, Bob Lidwin, Chuck Dunning, John DeWild, Randy Hunt, Dave Krabbenhoft, Phil Kammerer, Gary Patterson, Lee Trotta, Terrence Conlon, Bart Manion, Jim Rauman, Ty Sabin, Jenny Schiller, and Elaine Boyd.

Hydrologic Systems and Data Section (HSDS).—The Section Chief was Warren Gebert (1975–90). This Section split into the Environmental Studies Section and Hydrologic Systems and Data Section in 1991. Personnel who were in HSDS during the period 1979–90, and left the District before the other Sections were formed, were Duane Conger, Roy Campbell, Carl Lawrence, Jane Hannukula, Leo House, Marv Duerk, Emery Henrich, and Jim Kammer.

Environmental Studies Section.—The Section Chief was Peter Hughes (1990 to present). Other personnel in the Section were Bill Krug, Jerry Goddard, Dave Graczyk, Nick Hanson, Dave Housner, John Walker, Leo House, Harry House, Jeff Steuer, Steve Corsi, Dave Owens, and Todd Stuntebeck.

Water Environmental Monitoring Section (1979–82) and Hydrologic Systems and Data Section.—The Section Chiefs were Fred Dreher (1966–82) and Herb Garn (1990–present). Other personnel in the Section were Barry Holmstrom, Steve Field, Pat Stark, Dan Olson, Bill Rose, and Elmer Zuehls.

The following people were in the Field Offices during this period: Madison Field Headquarters personnel were Joe Habale (Technician-in-Charge), Tom Wittwer, Ken Koenig, and Steve March; Rice Lake Field Headquarters personnel were Jack Freshwaters (Technician-in-Charge), Ken Hedmark, Tom Popowski, and Joe Schuler; Merrill Field Headquarters personnel were Jim George (Technician-in-Charge), Bob Biller, Brett Esser, and Jeff Hanig.

Southeast Wisconsin Subdistrict Office.—During the period the office was open, Tom Ross was Subdistrict Chief and Fred Warner was Lead Technician. Other personnel who worked only in that office during this period were Paul Boetcher, Roger McFarlane, and Betsy Cannon. The office was closed in 1984 as part of the District reduction in staff with the completion of the Milwaukee Harbor Project.

Northern Midwest Regional Aquifer-System Analysis Study (RASA).—During this period, the RASA study was housed in the District Office but was officially attached to the Northeastern Region. The study was completed in 1987. Harley Young and Walt Steinhilber were the Project Chiefs. Other personnel working on the project, within the District, were Rick Mandle, Alan MacKenzie, Angela Kontis, and George Saulnier.

SUMMARY OF PROGRAMS

Collection of Basic Records

The 1980's was a transition period for introducing computer technology into the processing of data and publication of the data report. The Director placed emphasis on getting the annual data report published. A goal was established in the late 1980's to have the report to the printer by March 31. In the late 1970's, the report was usually printed in the late summer. The District was successful in meeting these deadlines. In 1989, the data report went to the printer in May, and in 1992 and subsequent years, it went to the printer by the end of March.

Streamflow Stations

In 1979, the streamflow-gaging station network consisted of 127 gaging stations. This number declined to 87 by the early 1980's due to funding cutbacks by the WDNR and the USGS Federal program. Unfortunately, many of the stations that were lost were stations with records longer than 30 years and represented unregulated conditions. The number of gaging stations increased to 96 by 1994 due to increased emphasis on the program.

This period also marked a big change in equipment at the gaging stations. In the late 1970's, most stations were equipped with digital recorders and mercury manometers. By 1994, due to potential mercury contamination problems, mercury manometers were being replaced by pressure transducers and digital recorders were replaced by data loggers. Many of the data loggers were linked to the District's main computer by telephone lines for retrieving streamflow data. The District made the decision to use phone lines for communication instead of data-collec-

tion platforms (DCP's) like most Districts did, due to installation cost and maintenance problems with DCP's. In addition, phone lines provided two-way communication.

Ground-Water Observation Wells

In 1979, the ground-water-observation well network had 203 stations. The project was done in cooperation with the WGNHS. The number had increased to 213 by 1985, but by 1994 it had decreased to 203 stations. In 1994, 22 were equipped with digital recorders. Several digital recorders were replaced with data loggers. Most of the ground-water levels were obtained from local observers, many of whom were county resource agents.

Water-Quality Stations

The network had eight stations in 1979 as part of the National Stream Quality Accounting Network (NASQAN) program and one Hydrologic Benchmark station. By 1994, the network had seven NASQAN stations and one Hydrologic Benchmark station. Most of the water-quality monitoring stations were being operated as part of projects by 1994.

Sediment-Monitoring Stations

The sediment-monitoring program in 1979 consisted of five stations that collected daily suspended-sediment levels. Intermittent samples were obtained from 30 miscellaneous sampling sites during high flows and were used to determine annual sediment load. Funding was discontinued by 1984 for all sites except one station—Grant River at Burton—that continued to be operated through 1994. Sediment-monitoring activities continued for a number of nonpoint-pollution and lake projects during the period 1979–94. Although it was recognized that a long-term sediment-monitoring network was very important in the State, efforts to develop a comprehensive project were not successful.

Other Major Projects

In addition to the two major projects—collection of basic records at streamflow-gaging stations and ground-water observation wells—the following are other major studies that were conducted during this period.

Nonpoint-Pollution Studies.—A series of projects was instituted to collect streamflow and water-quality data at rural and urban sites to evaluate best management practices that had been implemented. The project was conducted with the WDNR with Roger Bannerman as the program coordinator. Most of the studies required intensive-event sampling for streamflow and water quality.

Ground-Water Quality of Wisconsin Aquifers.—A statewide project was started in 1979 to delineate and evaluate areas of known ground-water-quality problems and to define the quality of Wisconsin's ground water. The project started in 1979 and was completed by 1990. During this period, it was one of the District's largest ground-water projects and provided several very valuable reports describing the ground-water-quality conditions in the major aquifers in the State.

Effects of Acid Precipitation on Lakes in Northern Wisconsin.—In 1980, studies were started to determine the mechanisms and long-term change of acid loading to five lakes in northern Wisconsin. This involved several projects that were completed by 1992.

Low-Flow Studies.—Several large projects that determined the magnitude and frequency of low-flow characteristics at ungaged sites and sewage-treatment plants had begun in the late 1960's and were completed by 1987. Low-flow discharge measurements were made at more than 1,000 low-flow partial-record stations during this period. Regional low-flow frequency equations were determined using the low-flow characteristics at the low-flow partial record stations and basin characteristics. Reports were prepared for 10 of the 12 major river basins in the State by 1984. Due to WDNR budget problems, the project was essentially stopped in 1985 and the remaining two reports were not completed. The District continued to assist the State in providing site-specific requests for low-flow estimates at sewage-treatment plants and industrial outfall sites when requested.

Regional Flood Frequency Study for Rural and Urban Streams.—This was the longest running project in the District, outside of the Collection of Basic Records (CBR) projects, that was started in cooperation with the Wisconsin Department of Transportation in 1959. The project operated a network of 132 crest-stage gages to determine flood-frequency

estimates required for bridge and culvert design as well as flood-plain management. Reports from this project that provide regional regression equations for estimating flood-frequency characteristics at ungaged sites have been the most popular in the District over the years.

County Ground-Water Studies.—These studies were conducted to describe the geology and the availability, quality, and use of ground water within a county. This project was one of the primary projects conducted in the Ground-Water Section during this period. Eleven reports were published. The studies were done in cooperation with the WGNHS.

Assessment of the Hydrology, Water Quality, and Biology of Delavan Lake.—In 1983, the District started this major project to determine water and chemical budgets for the lake, including internal recycling of nutrients to assist in the rehabilitation of Delavan Lake, which was highly eutrophic. A number of rehabilitation measures to improve the lake were implemented by the WDNR, the U.S. Environmental Protection Agency (USEPA), and the Delavan Lake Sanitary District. It was the largest lake in the country that the USEPA funded for rehabilitation. The District continued to monitor the system to evaluate the effectiveness after the rehabilitation measures were implemented.

Lake Water Quality Monitoring.—The District started a lake program in 1983 with this study, which collected lake samples five times per year to evaluate the trophic status of the lakes. The study was done in cooperation with individual lake districts and provided the data on the eutrophic status of a lake that resulted in a large number of more detailed lake studies. In 1994, 36 lakes were being monitored. The success of this study resulted in the District having the largest lake program in the USGS.

Ground-Water Flow Model for the Area of the Proposed Crandon Mine.—The District started this complex study in 1983 in cooperation with the WDNR and WGNHS. The development and use of the model were used to help evaluate the impact of mining on the hydrology of the area. While the District had conducted previous ground-water system appraisals by ground-water modeling, this project helped raise the District's expertise in the State because of the importance and exposure of the Crandon mine. District use of ground-water models in projects increased significantly after this project.

Milwaukee Harbor Study.—The District conducted a large, intensive study with the Southeastern Wisconsin Regional Planning Commission during the period 1982–85. The study consisted of collecting discharge and sediment data at 7 stations and water-quality data at 16 stations. The project also developed an estuary streamflow model. The project was operated from the Waukesha Subdistrict Office and later the Wales Subdistrict Office. Unfortunately, with the completion of the project, the District had significant funding problems and closed the Wales Subdistrict Office.

Flood Insurance Studies.—This was a major surface-water program in the District during this period. Hydrologic and hydraulic analyses to delineate the flood boundaries for the 100-year flood were done, thereby providing data to the WDNR and the Federal Emergency Management Agency (FEMA) for establishing the flood plain for zoning and insurance rates. This required extensive surveying of stream cross sections and water-surface profiles to conduct the analysis. Many District surface-water hydrologists and hydrologic technicians worked on this project. During this period, the District completed 37 (through 1984) reports.

Superfund Remedial Response Support, USEPA Region 5.—The District began this project in 1988 and worked at a number of Superfund sites in Illinois, Indiana, Michigan, Ohio, and Wisconsin. The service provided included drilling, monitoring-well installation, and packer tests. To provide this service, the District enhanced its capabilities with purchase of a new drill rig, packer rig, and geoprobe.

REPORTS

During the 1979–94 period, the District was very productive in publishing reports. The following are the number of reports published by type: 9 Water-Supply Papers, 62 Water-Resources Investigations Reports, 3 Hydrologic Atlases, 4 Professional Papers, 11 WGNHS information circulars and maps, 5 Open-File maps, 27 Open-File Reports, 1 Administrative Report, and 29 journal articles.

SOUTHEASTERN REGION

By Jeffrey T. Armbruster

INTRODUCTION

The Southeastern Region boundaries changed several times during this history period. From 1979 to 1982, the Region was composed of eight Southeastern States (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee) plus the Caribbean District. The Caribbean District included the Commonwealth of Puerto Rico and the U.S. Virgin Islands, with the District Office located in San Juan, Puerto Rico. In 1982, however, the States of Arkansas and Louisiana were added to the Region. Both States had previously been part of the Central Region. During the early 1990's, another realignment took place as part of a WRD reorganization. At that time, Kentucky was transferred to the Northeastern Region, leaving nine States and the Caribbean District. Each State constituted an individual District.

The Office of the Regional Research Hydrologist, at the beginning of this period of history, also was under the direction of the Southeastern Region and was located at the Gulf Coast Hydroscience Center, NSTL Station, Mississippi. That office existed as a separate entity from 1979 to 1982, when the position was abolished. The Gulf Coast Hydroscience Center was renamed the Hydrologic Instrumentation Facility (HIF) but remained under the direction of the Southeastern Region to the end of the period and beyond. While the Office of Surface Water had responsibility for the oversight of the technical work done at the HIF, day-to-day management of the Division facility was under the Regional Hydrologist, Southeastern Region.

At the beginning of this period, the Southeastern Region Office housed the staff of the Southeastern Limestone Aquifer Project, one of the Regional Aquifer-System Analysis Program (RASA) projects. The project staff remained collocated with the Regional Office until 1982 when the project was completed. Richard Johnson was Project Chief of the Limestone RASA project throughout it duration. Staff working on the project included James Miller, Craig Sprinkle, and Peter Bush.

In 1980, another RASA project, the Southeastern Coastal Plain Aquifer Project, was initiated and collocated in the Regional Office. That project remained with the Region until its completion in 1987. Harlan Counts was the initial Project Chief for the Southeastern Coastal Plain RASA study but was replaced by Robert Wait in 1981. In 1984, James Miller assumed the Project Chief responsibility and held that position until the completion of the project. Staff working on the project included Rene' Barker, Roger Lee, Robert Renken, Virginia Stricker, Gary Mahon, Maribeth (Molly) Pernick, and Gary Davis.

The National Ground Water Atlas project was established in 1988 under the direction of James Miller. The project staff was housed with the Southeastern Region throughout its duration, through the end of the period of this history and beyond. Working with Miller on the project were Perry Olcott and Robert Renken. Martha Smith provided support.

Southeastern Region Office and Staff

The Southeastern Region was headquartered in metropolitan Atlanta, Georgia, during this time and physically located in three different locations. During the first few years of the period, the office was located in a neighborhood called Pershing Point, at 145 Peachtree Street, in Atlanta, Georgia. In 1981, the office moved to the Richard B. Russell Building in downtown Atlanta where it remained until 1991. In 1991, the office moved to its location on Holcomb Bridge Road in the Atlanta suburb community of Norcross, Georgia, where it remained to the end of this history period.

Robert Dingman was Regional Hydrologist until early 1981 when he retired. James L. Cook replaced Dingman in 1981 and served in that position for the remainder of this period of history. Cook had been Assistant Regional Hydrologist prior to assuming the Regional Hydrologist role. After Cook vacated the Assistant Regional Hydrologist position, the position remained vacant for about a year, at which time it was filled by Phillip Greeson, who transferred to the Region from a position at WRD Headquarters in Reston, Va. Greeson served as Jim's assistant for the remainder of the period of this history. Lee Holt was the Regional Program Officer until the end of late 1980 when he retired. He was replaced by John George who transferred in from the Georgia District where he served as District Chief. George served as the Program Officer until 1986 when he assumed a similar position with the Central Region. He was replaced by Richard Bloyd who transferred to Atlanta from Wyoming where he served as District Chief.

Bloyd filled the responsibilities of the position until 1990 when he retired. For the remained of the period of this history, the Regional Program Officer position was officially vacant.

Jerry Pascale was serving as the Assistant Regional Program Officer at the beginning of the period and did so until late 1980 at which time he moved to Alabama as District Chief. The position remained vacant until 1982 at which time Larry Hayes was selected for the position from his Project Chief position in the Georgia District. Hayes served in this position for about a year and a half when he was selected as District Chief in Tennessee. Wanda Meeks replaced Hayes in 1983 and continued in the position for about 3 years. Meeks moved to the Region from the North Carolina District. She was selected to be Subdistrict Chief in Orlando, Florida, in 1985, at which time she was replaced on the Regional Staff by Michael Yurewicz, who transferred in from Tallahassee, Florida. He served until 1988 when he transferred to the Office of Water Quality. The position was vacant again for about a year when it was filled in 1989 by Bob Lidwin who transferred from the Wisconsin District. Lidwin was on the Regional staff for 2 years and then was replaced by Paul Hampson in 1991. Although Hampson was the Assistant Program Officer for the remainder of the period of this history, he actually served as Acting Program officer for that entire time. Bob Lidwin transferred to the Texas District, and Hampson transferred into the Regional office from the Orlando Subdistrict Office.

Management positions titled "Area Hydrologist" were created in 1991 and were filled by Wanda Meeks, Irwin Kantrowitz, and Michael Gaydos. These positions were subsequently abolished in 1996.

In 1990, the National Water-Quality Assessment Program was established, and with the implementation of the program, a new position was established on the Regional staff to manage the program in the Region. Jeffrey T. Armbruster served as the NAWQA manager from the inception of the program in 1990 through the end of the period of this history and beyond. Charles Demas served as Staff Biologist for this program during 1991 and was replaced by Cliff Hupp, a member of the National Research Program who served in that role to the end of this history. Jerry O'Neal provided biological liaison with the U.S. Fish and Wildlife Service from 1992 through the end of the period of this history.

The discipline specialists during this period were: Ground Water, James Daniel, 1979–80; Harlan Counts, 1981–82; Richard Johnson, 1983–84; Robert E. Faye, 1985–1988; Eve Kuniansky, 1989 to the end of this history and beyond. Water Quality, Robert Krieger, 1979–80; Gary Pederson, 1981 through the end of this history and beyond. Surface Water, Vernon Sauer, 1979–1988; Harold Golden, 1988–90; Darrell Carlson, 1991–through the end of the history and beyond. The technical specialists left the Region for a variety of reasons. Daniel was selected District Chief in New Mexico; Counts, Johnson, Faye, Kreiger, Sauer, Golden, and Carlson all retired.

A Staff Hydrologist position was established in 1990 with responsibilities for providing liaison with numerous other Federal agencies (OFA's). Briane Adams transferred to the Regional staff from the Alabama District to serve in that position. One of the more significant OFA activities, in partnership with the States of Georgia, North Carolina, and Tennessee was the *Southern Appalachian Man and the Biosphere Program*. That program was established in the early 1990's and was active through the end of this period of history and beyond.

Report review was done by Donald Jordan, 1979–85; Perry Olcott, 1985–89; Andrew Lamonds, 1989 through the end of the history and beyond. Jordon and Olcott retired.

Computer Specialists were James Bergman, 1979–90; and James Bettandorff, 1991 to the end of the history and beyond. Bergmann retired.

Administrative Officer for the entire period of this history and beyond was Robert Hudson. Others involved in administrative duties included Brenda Scott, Jo Nell Stancil (Pendley), Stella Collins, Jill Edwards, Vivian Putnam (Olcott), Patricia Clark, Elizabeth Pinitsch, Eric Hensel, and Jane Cunningham.

The Secretary to the Regional Hydrologist was Betty Bates until 1990. Betty was replaced by Mary Dunn who served in that position until the end of this history and beyond. Bates retired. Other secretarial support was provided during the period by Patricia Bentley, Marian Boykin, Veronica Oliver, Edy Shealy (Barker), Nancy Owens, Donna Petty, Martha Smith, Carmen Torrens, and Dawanna Terry.

Human Resources activities were handled by Ann Beam, 1979–81; Wanda Meeks, 1981–82; William Shampine, 1983–84; and Connie Smith, 1985 through the end of the period of this history and beyond.

Safety issues were handled as a collateral duty by various members of the Southeastern Region staff.

Programs and Funding

Total program funding for the Districts in the Southeastern Region during the fiscal years 1979–94, with appropriate adjustments for changes in the number of Districts comprising the Region rose steadily throughout the period and did so with program increases from all sources. The significant growth and development in the Southeastern United States that began in earnest during the mid-1970's and continued throughout the period of this history placed significant new demands on the water resources of the Region. Major increases in demand for water supplies in many parts of the Region, particularly in Florida, Georgia, and coastal South Carolina, were particularly significant factors driving program growth. Increased development brought water-quality issues to the forefront of program development as well.

The program mainstay of the Southeastern Region has been and continues to be the Federal-State Cooperative program. Several Districts, particularly Florida, had such demands placed on Coop offerings, that the District was unable to match all offerings, so State and local cooperators began providing funding unmatched. That trend has grown in the Region during the last 10 or so years of this history and beyond.

Direct appropriation of funds to the WRD for Federal program activities increased significantly during this period. The RASA program projects were a major contributor of Federal funds during the early 1980's, but as that program came to a close, the National Water-Quality Assessment Program infused significant funding that more than offset the phase out of the RASA program. In addition, several federally funded projects in Georgia and Florida also contributed significantly to the increase in Federal funds to the Region. The Toxics Program funded work in both Georgia and Florida, and the National Atmospheric Deposition Program provided funding for biogeochemical processes research at Panola Mountain in Georgia.

From 1979 to 1994, there were substantial changes in program and distribution of programs in the Southeastern Region. For example, South Carolina's data-collection programs pioneered the widespread use of satellite telemetry for collecting water-resources data and for providing near-real-time data for use by water-management officials for making timely decisions. Georgia's mathematical modeling and research program grew substantially throughout the period of this history. Particularly important to the growth of the modeling program were significant demand for ground-water resources along the coast for municipal and industrial use and in the southwest part of the State to meet rapidly increasing needs for irrigation. Florida's involvement in providing massive amounts of water resources data for use by the water management districts grew in importance, particularly in response to explosive growth in urban areas of the State. The Tennessee District developed a strong mathematical modeling program that addressed the increasing stresses on water resources there.

The NAWQA Program began its operational phase in October 1990, and the Southeastern Region initiated four major projects called study units—the Appalachicola-Chattahoochee-Flint Basin, the Albemarle-Pamlico system, the Georgia-Florida Coastal Plain, and the Ozarks Plateau. Each of these study units' funding ramped up and reached their peak funding at about the end of this history. A second suite of study units began their initial planning in 1994: the Santee, Southern Florida, Mississippi Embayment, and Upper Tennessee. Each project was staffed by experienced scientists already working with USGS and with about two to four new people added for each project, to round out critical technical needs for the work required. The local liaison committees established as a part of each study generated a generally favorable level of new relations with those interested in water quality, often groups or agencies with whom USGS seldom had interactions. Funding for the NAWQA studies, while insufficient to study water quality in detail, did provide the resources to generate a significant increase in the understanding of human activities on water quality. The program continues well beyond the period of this history.

Management and Personnel Issues

Under the leadership of Regional Hydrologist Jim Cook, from 1981 to the end of the period of this history, the Southeastern Region was characterized by an unprecedented level of cooperation and collaboration between and among the Districts. Likewise, Cook was progressive in encouraging the recruiting, training, and development of staff and sought advice

and recommendations for improvements from those doing the work.

For example, in the early 1980's, Cook established a pool of experts within the Southeastern Region for the purpose of ensuring that when a District or a District scientist in the Region was in need of a particular expertise, and that expertise did not exist in their District, they could engage talented staff from other Districts within the Region. District Chiefs were fully supportive and energetically promoted the use of expertise from that pool. The list of specialties included everything from sophisticated modeling of hydrologic processes to expertise in specialized field data-collection techniques. One significant benefit of the sharing was a genuine sense of collaboration among the Districts and among scientists in the Districts.

Similarly, early in the 1980's, a Hydrologic Technician advisory group was established by Jim Cook to assist him in understanding the full suite of issues and problems faced by those most closely connected to the field. Cook began his career as a Hydrologic Technician and spent many years in the data program; he, probably more than most, understood the value of getting advice on field issues by those actually doing the work. That advisory group met regularly for the remainder of the period of this history and beyond, assisting senior Regional managers to remain well informed about the changing nature and technologies of current field work.

Several Districts in the Southeastern Region were plagued with funding issues during this period, but only one situation called for extraordinary measures to protect the staff and Division's presence in the District. In 1987, the Louisiana District had a reduction in local Coop offerings equivalent to nearly one-half of its Coop funding—a blow that could have been a disaster had Regional managers and the managers of Southeastern Region Districts not provided a much-needed safety net. The District was required to significantly reduce expenses. More than a dozen people transferred to other Districts (all in the Southeastern Region), and about that many more were detailed to work in other Districts (most, but not all in the Southeastern Region) for extended assignments so that the District could remain viable. Throughout that ordeal, the District Chief relied heavily on the rest of the Region, and he was not disappointed.

In another situation during the mid-1980's, after a great deal of study and evaluation, the Doraville Central Water Quality Laboratory closed its doors. While the laboratory was not actually a part of the Southeastern Region, the Regional Hydrologist encouraged Districts in the Region to provide opportunities to as many people as they could. Some of the laboratory staff chose to resign or retire, others accepted transfers to the laboratory in Denver, and others accepted positions with several different Districts around the Division. The Southeastern Region Districts provided opportunities for more than a dozen technicians, chemists, and administrative staff.

But beyond sharing expertise, the period of the 1980's was one of significant building of a scientific talent pool in the Southeastern Region, particularly in the fields of hydrologic and geochemical modeling. The Southeastern Region became a real center of excellence in ground-water modeling. As a result of the building of the talent pool, a wide range of programs were developed that used modeling as a major analytical tool. Also, during the 1980's a major effort to recruit women, particularly into the Hydrologist series, was successful. Many female hydrologists were hired—many with advanced degrees in engineering, geochemistry, geology, and chemistry.

In the mid-1980's, the Research Grade Evaluation Guide (RGEG) process was expanded beyond the National Research Program to scientists working in the field. While there was not a huge rush of scientists in the Southeastern Region to enter RGEG, several chose to do so from the outset, including scientists assigned to the Georgia, Florida, South Carolina, and Caribbean Districts. Others joined the ranks of RGEG in subsequent years from these and other Districts in the Region, and most benefited through promotions to higher grades as a result of the quality of their research. The quality of research products from the RGEG scientists assigned to Districts in the Southeastern Region has been excellent.

The Southeastern Region, at the start of this period of the Water Resources Division's history, was heavily vested in data-collection programs with some hydrologic studies and research being done. By the end of the period, however, the Region's scientific programs and staff were second to none in the Division. This period in the Region was significant in virtually every positive aspect.

ALABAMA

By John Scott

INTRODUCTION

Alabama experienced hurricanes, droughts, and floods during the period 1979–94, and the Alabama District of the WRD contributed significantly to documentation and analysis of these hydrologic events.

Hurricane Frederick came ashore near the Alabama-Mississippi boundary in September 1979, devastating the coastal resorts of Dauphin Island and Gulf Shores in Mobile and Baldwin Counties. The Alabama and Florida Districts and the U.S. Army Corps of Engineers (the Corps) mapped the areas inundated by the hurricane and measured the height of storm surges caused by the storm tide. The results of this investigation were published in a series of hydrologic atlases.

The drought years of 1981, 1986, and 1988 in Alabama and Georgia were the most severe since the droughts of the 1950's. The Alabama District increased the monitoring of streamflow and ground-water levels to document these droughts. A significant result of these drought years was that the City of Atlanta applied to the Corps for permission to increase withdrawals from the Chattahoochee, Coosa, and Tallapoosa Rivers. Realizing that these increased withdrawals would affect the water resources of Alabama, the State of Alabama threatened to bring suit against Atlanta, the State of Georgia, and the Corps. The State of Florida also objected to the proposed increased withdrawals because of effects on the Apalachicola River and Bay. These proposals led to the interstate controversy that was referred to by the news media as the "Water Wars." The U.S. Congress allocated funds to the Corps to make an intensive study of the water resources of the Apalachicola-Chattahoochee-Flint and the Alabama-Coosa-Tallapoosa River Basins in Alabama, Florida, and Georgia to assist in finding equitable solutions to the controversy. The Alabama, Florida, and Georgia Districts of the WRD participated in the analysis of hydrologic data related to the controversy.

Floods occurred in south Alabama in 1990 and 1994. The most severe flooding was on the Pea and Choctawhatchee Rivers. The 1990 flood on the Pea River at the city of Elba and on the Choctawhatchee River at the city of Geneva was the most severe flood since the 1929 flood. After the flood of 1929, the Corps constructed dikes around the inner cities of Elba and Geneva to prevent future flooding. The floods of 1990 and 1994 breached these dikes, inundating the inner-city areas. By 1995 the Alabama District, WRD, and the Corps were making plans to establish an early warning system on the rivers to assist city managers and residents in preparing for future floods.

The 1979–94 period was a period of great change for the Alabama District. The computer age arrived in the District, and ground-water and surface-water modeling was used to assist in the development of water resources and the design of bridges. Streamflow and water-level records could be processed within the District as they were collected from the field. Formerly, data were processed using a mainframe computer in Reston, Va. During the latter part of the period, a Geographic Information System (GIS) was established in the Alabama District, bringing a significant innovation to mapping in Alabama.

Water-data collection stations were equipped with satellite telemetry so data could be transmitted instantly from the station to a WRD office. With the occurrence of major floods and severe droughts within a few years of each other, the importance of realtime data became vital to major cooperators such as the Corps, Alabama Power Company, Alabama Department of Environmental Management (ADEM), and Jefferson County Environmental Services. Surface-water gaging stations and ground-water monitoring sites were equipped with recorders that stored data on paper tape or strip charts, which had to be collected periodically by a hydrologic technician. This method began to change as water-data collection stations were equipped with telemetry so current data could be used for the daily management of the State's water resources. As satellite telemetry improved, telephone modems were exchanged for data-collection platforms (DCP's) equipped with satellite transmitters. By 1995 most streamflow stations and ground-water sites in the Alabama District were equipped with satellite telemetry.

ORGANIZATION AND MANAGEMENT

The Alabama District in 1979 consisted of the District Office at Tuscaloosa, Subdistrict Offices at Montgomery and Tuscaloosa, and a Field Office at Cullman. The District Office was established at Tuscaloosa when the Ground-Water, Surface-Water, and

Water-Quality Branches were integrated in the 1960's. The Montgomery Subdistrict Office replaced the District Office of the Surface-Water Branch, which had been headquartered at Montgomery since the 1930's. The Cullman Office, which was a Subdistrict Office in the 1960's, was a Field Office responsible mainly for collection of water-resources data in the northern part of Alabama.

During 1979–80, W. J. (Bill) Powell was District Chief and Hillary Jeffcoat was Assistant District Chief. James R. Avrett was in charge of the Subdistrict Office at Tuscaloosa, and James E. Bowie was in charge of the Subdistrict Office at Montgomery. Paul W. Cole was in charge of the Field Office at Cullman. Joe R. Harkins in the District Office and Charles O. Ming in the Subdistrict Office at Montgomery supervised surface-water activities in Alabama.

Powell and Bowie retired during 1980–81, leaving vacancies at positions of District Chief and Subdistrict Chief at Montgomery. C.A. (Jerry) Pascale was selected as Alabama District Chief in 1981, and Roy B. Stone was selected as Chief of the Montgomery Subdistrict Office. The Subdistrict Office at Tuscaloosa was closed soon after Pascale came to the Alabama District. The District Office, which had been in the building with the Geological Survey of Alabama since the 1960's, was moved to a building in the center of the Tuscaloosa Business District. Personnel who had been at the Tuscaloosa Subdistrict Office were transferred to the new District Office.

Pascale reorganized the District by designating Hydrologists in Charge of Basic-Data Operations, Water-Resources Investigations, and Water-Quality functions. Harry C. Rollins transferred to the Alabama District Office as Hydrologist in Charge of Basic Data, and Michael Planert transferred to the Alabama District as Hydrologist in Charge of Water-Resources Investigations. Avrett, who had been Water-Quality Specialist for many years, retained that title. At the Montgomery Subdistrict Office, Charles O. Ming was Surface-Water Specialist and E.G. (Grady) Ming was in charge of basic-data operations.

Avrett retired during 1983, and Roy Stone and Grady Ming retired in 1985. Jerry Pascale transferred to the Colorado District Office in 1986 and J.L. (Leroy) Pearman transferred to the Montgomery Subdistrict Office as Hydrologist in Charge of surface-water activities. John C. Scott was designated Acting Subdistrict Chief at Montgomery after Stone's retirement.

D.B. (Briane) Adams was selected as Alabama District Chief in 1987. Adams retained the organization of the District much the same as the Pascale organization. Charles Ming retired in 1988, and Harry Rollins transferred to the Kentucky District in 1989. Adams was transferred to the Southeastern Region Office at Atlanta in 1990. Hillary Jeffcoat was selected as Alabama District Chief and John Scott was designated Subdistrict Chief of the Montgomery Office. Jeffcoat assigned J.L. Pearman as Chief of Surface-Water Activities and R.E. Kidd as Ground-Water Studies Chief. Jeffcoat also brought on several cooperative education students who were to later become important personnel in the Alabama District.

Other hydrologists and hydrologic technicians who worked in the Alabama District during the 1979–94 period were D.L. Berlin, B.G. Byrd, F.D. Byrd, R. Cobb, W.A. Hard, S.L. King, F.C. Sedberry, J.W. Tucker, I.A. Giles, D.D. Bateman, T.R. Duval, C.R. Bossong, D.A. Olin, W.S. Mooty, W.L. Psinakis, V.E. Stricklin, M.E. Davis, J.S. Williams, G.H. Nelson, R.S. Moreland, Daryll Lambeth, Celeste Journey, J.B. Atkins, R.D. Castleberry, T.S. Hedgecock, and Joanne Richardson.

A.J. (Jean) Roberts was Administrative Officer for the District until she retired in 1994. She was assisted in the District Office by Sandra Simpson, Judi Harbin, and Pam Griffin. Elizabeth Meadows was Reports Specialist for the District and prepared all reports for publication during the period. Jacqueline (Jackie) Freeman was in charge of administrative functions at the Montgomery Subdistrict Office in addition to many other stenographic and clerical duties. Reba McHenry served in the same capacity as Jackie at the Cullman Field Office. Debra Tracy transferred to Montgomery in the latter part of 1994 as Administrative Officer of the Alabama District.

FUNDING

During the 1970's and early 1980's, the major projects in the Alabama District were Coal Hydrology Studies funded by the Bureau of Land Management and completion of a series of water-availability studies that were funded cooperatively by WRD and the Geological Survey of Alabama. There were also cooperative projects between the WRD and the Alabama Highway Department to analyze the hydraulics of

Table 1. Funding for the Alabama District, 1979–94 (in dollars)

Fiscal year	Federal	Other Federal agencies	State	Federal matching	Total
1979	498,452	687,195	628,451	597,074	2,411,172
1980	626,047	986,097	564,317	569,870	2,746,331
1981	658,260	747,777	626,202	647,673	2,679,912
1982	506,037	1,114,694	568,184	579,181	2,768,096
1983	344,630	546,047	433,387	441,637	1,765,701
1984	369,852	497,943	481,706	357,111	1,706,612
1985	212,381	290,603	666,232	364,618	1,533,834
1986	215,700	540,240	815,000	815,000	2,385,940
1987	252,510	451,640	830,000	830,000	2,364,150
1988	253,620	879,495	916,500	750,000	2,799,615
1989	270,670	849,220	535,890	520,890	2,176,670
1990	256,760	690,320	640,800	625,000	2,212,880
1991	137,860	628,140	691,000	675,200	2,132,200
1992	166,221	779,571	713,420	696,000	2,355,212
1993	147,485	1,283,886	712,220	700,000	2,843,591
1994	140,210	1,011,290	903,800	706,000	2,761,300

Note: These numbers may not be absolute but accurately show the funding trends through the period.

bridge openings at proposed construction sites and hydrogeologic studies to aid the Highway Department with geologic and ground-water problems related to highway construction.

Funding for the coal hydrology project and the county water-availability studies dwindled soon after C.A. Pascale transferred to Alabama as District Chief (see table 1). Consequently, Pascale had to "beat the bushes" to find cooperators for funding water-resources investigations in Alabama. During Pascale's service in Alabama, the Alabama Department of Environmental Management (ADEM) requested the Alabama District to name, classify, and delineate the major aquifers in Alabama and to characterize their susceptibility to contamination from the land surface. This investigation resulted in hydrogeologic reports for Alabama that are the foundation for ADEM's classification of aquifers and the wellhead-protection program for Alabama.

HYDROLOGIC BASIC DATA PROGRAMS

The surface-water data-collection program was fairly constant through the 1979–94 period. The program was supervised in the early years by James Avrett at the District Office, Grady and Charles Ming at the Montgomery Subdistrict Office, and Paul Cole at the Cullman Field Office. Later in the period, supervision consisted of Harry Rollins at the District Office and Leroy Pearman at the Montgomery Subdistrict Office. After Rollins' transfer to the Kentucky District and Grady Ming's retirement, the program was supervised mainly by Pearman at the Montgomery Office and Victor Stricklin at the District Office. The collection of surface-water data consisted of about 85 to 105 full-range gaging stations, streamflow and water-quality data for about 100 partial-record or ungaged sites, stage and contents for 13 major reservoirs, and flood-hydrograph or peak-stage data for about 70 sites.

In 1980 the District maintained a network of about 46 water-level recorders in wells throughout the State. During Briane Adams' years as Alabama District Chief, practically all of the ground-water data-collection stations were given to the Geological Survey of Alabama to operate. Cooperative ground-water investigations during the 1980's and early 1990's resulted in the collection of periodic water-level measurements in 50 to 100 wells, primarily during the course of the respective studies. In 1994 the District maintained one federally funded observation well and two cooperatively funded observation wells.

Periodic (mainly semiannual) water-level measurements were made in about 55 wells in the State.

HYDROLOGIC INVESTIGATIONS

Hydrologic investigations during the 1979–94 period included ground-water, surface-water, and water-quality projects. Ground-water investigations during the period were made in cooperation with Butler and Calhoun Counties and the cities of Alabaster, Jacksonville, Montgomery, Prattville, and Sylacauga.

A significant ground-water study during the period was a ground-water modeling project at Dauphin Island in Mobile County. Dauphin Island is a resort barrier island off the Mobile County mainland in the Gulf of Mexico. The island's water supply historically consisted of two wells developed in rock units of Pliocene-Miocene age. Increased demand for water on the island resulted in lowering of the water surface in the aquifer and saltwater encroachment into the aquifer. Modeling of the shallow dune-sand aquifer on the island resulted in development of an auxiliary water supply. This investigation was funded cooperatively by WRD and the Dauphin Island Water Authority.

Ground-water investigations funded by other Federal agencies (OFA) included a study at Fort Rucker Aviation Center in southeast Alabama funded by the U.S. Department of Defense and a statewide aquifer-classification and aquifer-susceptibility study funded by the U.S. Environmental Protection Agency (USEPA) through the Alabama Department of Environmental Management.

Investigations that included surface water and ground water were the coal-hydrology studies and the "Water Wars" studies. The coal-hydrology studies consisted of documenting the effects of strip-mining of coal on ground water and surface water. This project was funded by the Bureau of Land Management. The "Water Wars" project consisted of describing the relationships between ground water and surface water in the Alabama-Coosa-Tallapoosa and Apalachicola-Chattahoochee-Flint River Basins. These studies were funded by the U.S. Congress through the U.S. Army Corps of Engineers, Mobile District.

Surface-water investigations during the period include sedimentation-erosion studies along the Tennessee-Tombigbee Waterway, time-of-travel studies along various streams in Alabama to aid in pollution studies, and water-quality and sedimentation studies for Lake Tuscaloosa in Tuscaloosa County and Big Creek Lake in Mobile County. The Tennessee-Tombigbee project was funded by the Corps. The Lake Tuscaloosa project was in cooperation with the Tuscaloosa Water Department. The Big Creek project was in cooperation with the Mobile Waterworks Department. The time-of-travel studies were in cooperation with the ADEM. Other surface-water and water-quality studies were in cooperation with the cities of Birmingham, Huntsville, Montgomery, and Tuscaloosa and with Autauga, Coffee, and Jefferson Counties.

A significant increase in OFA funding occurred during fiscal years 1993 and 1994 (see funding table). This increase was primarily due to the extensive involvement of the Alabama District in stormwater sampling and delineation at military bases in Alabama. The USEPA required permits for stormwater discharges into streams from military bases. These investigations included Redstone Arsenal, Fort McClellan, Fort Rucker, and four Army Reserve Centers. Each military base has as many as nine sites to be sampled, based on land-use characteristics. This funding helped to keep the District solvent during some lean years prior to National Water-Quality Assessment studies in Alabama.

HYDROLOGIC EVENTS

The 1979–94 period began with Hurricane Frederick hitting the Alabama Coast near the Alabama-Mississippi boundary in September 1979. The storm demolished the coastal resorts of Dauphin Island and Gulf Shores and resulted in significant damage as much as 50 miles inland and as far east along the coast as the city of Navarre in northwest Florida. The Alabama and Florida Districts, in cooperation with the Corps, mapped areas inundated by floodwater from the storm and measured and documented the height of storm-tide surges caused by the storm.

The Southeastern States had deficient rainfall in the early 1980's, and by 1986 the most severe drought since the 1950's affected Alabama and Georgia. Water managers in the southeastern part of the United States had historically believed that water in the Southeast was abundant and inexhaustible. However, the 1986 drought ended this belief. The Atlanta area was booming and demanding more water. Lake Lanier on the Chattahoochee River was Atlanta's primary source

of water supply. The 1986 drought prompted the Atlanta Waterworks to apply to the Corps for permission to increase withdrawals from Lake Lanier and reservoirs on the Coosa River in northeastern Georgia. The Corps tentatively agreed to the request, resulting in the threat of a lawsuit by the State of Alabama to stop the proposal. These actions resulted in a controversy that was given the name of "Water Wars" by the news media. The U.S. Congress appropriated funds through the Corps to conduct a study to ascertain water availability in the Apalachicola-Chattahoochee-Flint and Alabama-Coosa-Tallapoosa River Basins in Alabama, Florida, and Georgia so equitable decisions could be made on allocations. The Alabama, Florida, and Georgia Districts of WRD were assigned the ground-water element of this study. The three WRD Districts worked closely together because of the interstate nature of the study. The task of WRD was to describe the relationships among rainfall, runoff, streamflow, and ground-water storage and movement in these river basins.

SIGNIFICANT PUBLICATIONS

The flood-inundation/storm-surge study for Hurricane Frederick was summarized in 21 hydrologic atlases authored by hydrologists in the Alabama and Florida Districts. Storm-surge data contained in these reports resulted in the U.S. Department of Housing and Urban Development (HUD) requiring all homes along the coast of Alabama and northwest Florida insured by HUD to have their lowest floors at least 17 feet above mean low tide.

The coal-hydrology studies in Alabama resulted in 10 reports documenting the effects of strip mining of coal on ground water and surface water.

Thirteen reports describing and delineating major aquifers in Alabama and their susceptibility to contamination from the surface served as a framework for the classification of aquifers and the wellhead-protection program administered by the ADEM.

Reports produced from studies describing the relationships among rainfall, runoff, streamflow, and ground-water storage and movement were in process. When published, these reports would be essential in making equitable allocations of water in Alabama, Florida, and Georgia.

Other significant reports resulting from work performed during the 1979–94 period summarized ground-water availability, ground-water modeling studies, hydrologic framework studies, time-of-travel studies for streams in Alabama, and reports summarizing sedimentation and water-quality studies for lakes and reservoirs used for public water supplies in Alabama.

Reports updating low-flow and flow-duration data and flood-frequency data for Alabama were also published during the 1979–94 period.

ARKANSAS

By Charles T. Bryant with contributions from E.E. Gann and active Arkansas District staff members, John E. Terry and Tony Schrader. Reviewed by Ed Morris and Dave Freiwald.

INTRODUCTION

The period 1979 through 1994 began with some uncertainties for the Arkansas District. The District Chief, who had served in that position since the District was reorganized, retired 2 years into the period. The retiring District Chief had built a strong program with State cooperators, and it remained to see how the cooperators would accept a new Chief. In addition, the Arkansas District was transferred from the Central Region to the Southeastern Region, so the District was under the gun to please new management.

The new District Chief proved up to the challenge. The District made great progress. New programs were added, programs with existing and new cooperators increased, and the District had more employees than any time in its history.

ORGANIZATION AND PERSONNEL

District Headquarters remained in Little Rock for the period. A two-man Field Office was located in Fort Smith, near the border of Arkansas and Oklahoma, and continued in operation for the duration of the period. A Project Office was established in Fayetteville in 1991 in cooperation with the University of Arkansas Water Resources Research Center and continued throughout the remainder of the period. In 1979 there were 43 employees in the Arkansas District. By 1993 that number reached 62, the largest number of employees in the history of the District.

District Headquarters, Little Rock

Office of the District Chief.—The District office was located in the Dwight D. Eisenhower Federal Building at 700 West Capitol Avenue. Richard T. (Dick) Sniegocki, who was the original District Chief at the time of reorganization in 1964, continued as District Chief until his retirement in January 1981. John Hubbell, who had served as Program Officer for a number of years, served as interim District Chief from January 1981 until August 1981 when he retired. E.E. (Gene) Gann, in charge of the Fort Worth Subdistrict, was selected by the Southeastern Region to serve as District Chief for the Arkansas District. Gann was appointed in September 1981 and served as District Chief for the remainder of the period.

Assistant District Chiefs during the period were Chiefs of the two major Sections. These were Marion Hines from 1979 until his retirement in 1980; Louis Ducret from 1979 until his transfer to the Miami Subdistrict in 1981; Charles Bryant from 1981 until retirement in 1987; Terry Lamb from 1982 until his transfer to National Headquarters in 1993; Ed Morris from 1993 until the end of the period; and Richard Taylor from 1988 until the end of the period.

Bobbie Vines was Chief of the Administrative Services Section from the beginning of the period until her retirement in 1987. Her successor was Paula Herrin who served as Chief of the Section for the remainder of the period. Others serving in the Section were Diane Johnson, Suzanne Townsend, Roxanne Childers, Sharon Dyer, Toni Stella, Julia Alford, Sharon Touschner, Bonnie Taylor, Sandra Dolls, and Patricia Cornish.

Hydrologic Surveillance (Data) Section.—This Section comprised the stream-gaging personnel, ground-water data-collection personnel, the water-quality Field Service Unit, and a two-man Field Office in Fort Smith. The Field Service Unit was located in the basement of the U.S. Post Office building at 600 West Capitol until 1987 when it moved into the Federal Building. The Field Service Unit became a separate Unit in 1992 and was renamed the Water Quality Services Unit.

Louis Ducret served as Chief of this Section from 1979 to 1982 when he transferred to the Miami Subdistrict Office. Terry Lamb was Section Chief from 1982 until he transferred to Headquarters in 1993. Ed Morris then served as Section Chief of the Hydrologic Surveillance Section for the remainder of the period while also serving as Chief of the Hydrologic Investigations Section.

Hydrologists assigned to this Section during the period were A.H. (Gus) Ludwig, Richard Hunrichs, Rodney Southard, Scott Hodge, and Maria Plafcan. Other scientists were Earth Scientist Alan Hall and Civil Engineer Shane Barks.

Hydrologic Technicians included Elton Porter, Joe Edds, Jerry Garrett, Ronald Knott, Martha Moore, Autry Meeker, Kenneth Rollins, James Spencer, Leonard Thompson, Terry Holland, Troy Brossett, Benjamin Krone, Alan Lasker, Karen Young, Janelle Jones, Charles Heavener, Phillip Stephens, and Christopher King.

Others assigned to the Section were Pansye Jones, Walter Freeman, Mark Pruit, Gregory Winter, Rocky Pressley, Sharon Touschner, Matthew Moix, Rene Freret, and Mark Fredericks.

Field Headquarters - Fort Smith.—The Fort Smith Field Headquarters was assigned to the Hydrologic Surveillance Section. This was a two-man office with the primary responsibility of stream gaging in the mountainous western part of the State. Johnnie Cottingham supervised this office through 1989 when he moved to the Miami, Fla., Subdistrict Office. Chris O'Dell was in charge of the Fort Smith office until 1991 when Autry Meeker transferred from the Little Rock office. Meeker was in charge for the remainder of the period.

Field Operations Unit.—The Field Operations Unit was made a separate Unit of the Hydrologic Surveillance Section in 1991 and was primarily responsible for much of the statewide stream-gaging program. Ron Knott supervised this Unit from its beginning through the remainder of the period. Others serving in this Unit were James Spencer, Thomas Porter, Troy Brossett, Rene Freret, Karl Henson (student trainee), Mark Fredericks (student trainee), and Jaysson Funkhouser (student trainee).

Field Service Unit.—The Field Service Unit was assigned to the Hydrologic Surveillance Section and was primarily responsible for water-quality data collection and storage, and preparation of data for publication in the annual report for the District. Hydrologic Technician Frank Lambert supervised this Unit from 1979 until his retirement in 1991. After Lambert's retirement the Unit was renamed the Water Quality Services Unit and was assigned to the Office of the District Chief. Ed Morris was named Chief of this Unit. Others serving in the Field Service

Unit were Dennis Evans, Charles Heavener, Alan Hall, Robert Childers, Karen Young, Phillip Stephens, Janelle Jones, Patrick Edelmann, Larry Remsing, Paul Westerfield, Thomas Porter, William Shelton, and James Petersen.

Water Quality Services Unit.—This Unit was formed in 1991 from the Field Service Unit and was assigned to the Office of the District Chief. Ed Morris, Hydrologist, served as Chief of this Unit from 1991 until 1994 when he became Chief of the Hydrologic Surveillance Section. Dennis Evans replaced Morris as Chief of the Water Quality Services Unit.

In addition to those who served in the Field Service Unit, the following served in the new Unit: Alan Lasker, Christopher King, Robert Joseph, Faron Usrey, and Michael Hoggard.

Hydrologic Investigations Section.—This Section was known as the Areal Investigations Section until 1982. Marion Hines was Chief of the Section from 1979 until his retirement in 1980. Forest Lyford served in 1980 and 1981, and Charles Bryant was Section Chief from 1981 until his retirement in 1987. Richard Taylor transferred in and served until 1994. Ed Morris served the remainder of the period.

Hydrologists assigned to this Section during the period were Gus Ludwig, Roy Gilstrap, Terry Lamb, Matt Broom, John Terry, Braxtel Neely, Dan Ackerman, Dan Fitzpatrick, Elizabeth Cole, Dave Freiwald, Jess Weaver, John Kilpatrick, Maria Plafcan, Johnny Courtney, Valerie Leidy, James Petersen, Gary Mahon, William Green, Gerald Gonthier, and Phillip Hays.

Hydrologic Technicians were John Yanchosek, Kenneth Stafford, Larry Remsing, Todd Fugitt, Elizabeth Tweedle, and Steve Bearden. Computer Technicians included Mark Farmer, John Owen, and Jim Monical. Margaret Gurley served as Editorial Assistant from 1979 until she retired in 1982.

Reports Unit.—The Reports Unit was begun in 1982 as part of the Hydrologic Investigations Section to type and track reports in progress. Matt Broom supervised this Unit until 1984. Jim Petersen supervised the Unit until 1988. Bobbie Louthian began as an Editorial Clerk part time in 1982, was promoted to Editorial Assistant in 1983, and to Writer/Editor in 1988. Louthian served in that capacity for the remainder of the period. Diane Johnson and Steve Bearden were Cartographic Technicians who provided illustrations for publications as needed. The Unit was dissolved in 1988 and the personnel remained in the Hydrologic Investigations Section, providing the same services as they did in the Reports Unit.

Technical Services Section.—This Section provided computer and drafting services to the District. Charles Bryant supervised the Section until he was appointed chief of the Hydrologic Investigations Section in 1981. Others serving in the Section were Ed Morris, Guy Bearden, John Stephens, John Owen, and Diane Johnson. The Section was dissolved in 1981. Bearden and Stephens retired. Ed Morris moved to the Hydrologic Investigations Section. John Owen became a part of the Computer Unit, and Diane Johnson moved to the new Reports Section.

Computer Unit.—The Computer Unit began in 1982 as part of the Hydrologic Investigations Section to provide computer services to District personnel. Those serving in this Unit were John Owen, Mark Farmer, and Barry Lile. The Unit was changed in 1984 to the Computer Applications Section.

Computer Applications Section.—The Computer Applications Section was expanded from the Computer Unit and took on much more responsibility including computer modeling. John Terry was chosen as supervisor of the Section. Mark Farmer, John Owen, and Jim Monical remained as staff members. In 1988, this Unit's responsibilities were again expanded; the Unit became the Information Management Section and remained under the supervision of John Terry.

NWIS-II Coding Team.—Staffing for this team began in 1991 at the request of the National Water Information System (NWIS) Program Office. This team was selected by and operated under the general oversight of John Terry as a Unit under the Computer Applications Section. The NWIS-II Team was supervised by Mark Farmer from its inception through the remainder of the period. Others serving in this Unit were Roland Bryant, David Beeler, Randal Cole, Scott Davidson, Patrick Rael, Michael O'Conner, Clark Wierda, Gerald Purifoy, and Robert Hoover. The people staffing the team were classified as Computer Specialists.

Information Management Section.—In 1992 the existing Computer Applications Section was broadened in scope to include additional functions and was renamed the Information Management Section. The additional functions included custom computer programming for other Districts and Headquarters offices and oversight of selected other projects in the Arkansas District. Notable among these was the

Water-Use Cooperative project that by 1994 was receiving national recognition. John Terry supervised this Section from its beginning through the remainder of the period. Also serving in this Section, in addition to the ones who served in the Computer Applications Section, were Nancy Baker, Terry Holland, Carmen Baxter, Elizabeth Beavers, David Poynter, and Jimmie Handley.

Project Office - Fayetteville.—The Project Office was established in 1991 in cooperation with the University of Arkansas, Water Resources Research Center, to perform research on the hydrology of the karst area in northwestern Arkansas. Van Brahana, Research Hydrologist, headed this office from 1991 throughout the remainder of the period. Others serving in the Project Office were Grace Ford, Hydrologist, and Matthew Moix, student trainee.

National Water-Quality Assessment Program Office.—The NAWQA Program Office was established in 1991 as a part of the National Water-Quality Assessment. The Arkansas District was to perform a water-quality assessment of the Ozark Plateaus. David Freiwald supervised the office from its beginning through the remainder of the period. Others serving in the office were Jim Petersen, Jim Adamski, Richard Bell, Aaron Pugh, and Bob Joseph.

Office of the Regional Hydrologist - Area Hydrologist.—Beginning in 1992 the Area Hydrologist for Lower Mississippi Programs (Arkansas, Louisiana, Mississippi, and Missouri) shared office space with the Arkansas District. Wanda Meeks was Area Hydrologist and served through the remainder of the period.

FUNDING AND COOPERATION

As shown by the table, total funding for the District increased almost threefold during the period. Direct Federal funding showed the largest increase over the period, growing from $232 thousand in 1979 to more than $1.8 million at the end of the period. Other Federal agency (OFA) funding increased more than four times during the period. Cooperative (Coop) funding remained somewhat static except for a "downturn" in the period 1982–85.

The Arkansas Geological Commission (AGC) remained as a cooperator throughout the period. The AGC has been a cooperator with the Arkansas District since 1958. The Arkansas Soil & Water Conservation Commission (ASWCC) was the principal cooperator during the period. Other State agencies providing direct and cooperative funding included the following:

Arkansas District funds, fiscal years 1979–94

[In thousands of dollars]

Fiscal year	Federal	OFA	Coop	Total
1979	232	365	1,155	1,752
1980	288	474	1,103	1,865
1981	305	512	1,214	2,031
1982	391	611	995	1,997
1983	371	467	783	1,621
1984	267	561	690	1,518
1985	245	504	766	1,521
1986	289	1,122	1,105	2,515
1987	397	867	1,363	1,627
1988	476	1,232	1,488	3,196
1989	387	1,775	1,174	3,336
1990	344	1,269	1,421	3,034
1991	614	966	1,610	3,190
1992	1,177	1,181	1,566	3,924
1993	1,942	1,155	1,448	4,545
1994	1,842	1,537	1,481	4,860

- Arkansas Department of Health
- Arkansas Department of Parks and Tourism
- Arkansas Department of Pollution Control and Ecology
- Arkansas Game and Fish Commission
- Arkansas-Oklahoma Arkansas River Compact Commission
- Arkansas State Highway and Transportation Department
- University of Arkansas-Fayetteville
- University of Arkansas-Little Rock

Federal agencies providing funding included the following:

- U.S. Department of Agriculture, Soil Conservation Service
- U.S. Department of the Army
  - Corps of Engineers
    - Little Rock District
    - Memphis District
    - Tulsa District
    - Vicksburg District
    - Waterways Experiment Station
- U.S. Department of Commerce
  - National Weather Service
- U.S. Department of Energy

U.S. Department of the Interior
National Park Service
U.S. Environmental Protection Agency

Local agencies providing funding included the following:

Arkansas Power and Light Company
City of Fort Smith
City of Little Rock
City of Rogers
Independence County
Little Rock Municipal Water Works
Saline County Rural Development Authority

SUMMARY OF PROGRAMS

Hydrologic-Data Collection

The data-collection workload changed little during the period. The District completed its annual data reports either on time or before the deadline. The reports were completed under the supervision of Lou Ducret, Terry Lamb, and Ed Morris. Several Hydrologic Surveillance Section personnel worked on the reports. These included Elton Porter, Martha Moore, Joe Edds, Frank Lambert, and Dennis Evans.

Streamflow stations.—In 1979, the Hydrologic Surveillance Section operated 69 continuous-record daily-discharge gaging stations, 18 of which were equipped with Satellite Telemetry Data Collection Platforms (DCPs), and 125 crest-stage partial-record stations. In addition, stage and content were measured for four lakes and reservoirs.

In 1987, the District, after statistical analysis, decreased the number of continuous-record gaging stations to 50. Of these, 13 were equipped with DCPs. The number of crest-stage partial-record stations decreased from 125 to 58.

In 1994, the District operated 61 daily gaging stations; 41 were automated. There were 108 peak-discharge partial record stations. Discharge measurements were made at four daily sediment stations.

Water-quality stations.—In 1979, the District operated 95 water-quality sites. These included 13 National Stream Quality Accounting Network (NASQAN) stations, 1 Benchmark Network station, 6 cooperative stations, and 73 sites on 12 Corps of Engineers lakes.

In 1987, the District operated 119 water-quality sites. Of these, 70 sites were on 13 Corps of Engineers reservoirs. There were 13 NASQAN stations, 2 hydrologic benchmark stations, and 1 radiochemical station.

In 1994, the District operated 128 water-quality stations. There were 74 lake sites on 13 lakes. The District operated five NASQAN stations, two hydrologic benchmark stations, and one national tritium station.

Fluvial-sediment station.—During the period, the Arkansas District operated sediment stations in the St. Francis River Basin of eastern Arkansas for the Memphis District Corps of Engineers. In 1979, there were 13 sediment stations in operation. The number remained the same in 1987 but increased to 16 in 1994.

Ground-water observation wells.—Ground-water-level measurements continued to be very important for the State of Arkansas during this period. This was especially true for the alluvial and Sparta Sand aquifers where water levels continued to decline in places of heavy withdrawal and continued high use for agricultural, industrial, and municipal purposes. In 1979, water-level measurements were made in 595 wells. In 1987, 701 wells were measured, but in 1994 the number of wells measured decreased to 369.

Water-use data.—This program, which began in April 1979, has provided much useful information for those making management decisions concerning water use in the State. During the period, the Arkansas District published a manual on techniques of collection and management of water-use data for the Southeastern Region. Terry Holland, who headed the water-use program, authored WRIR 92–4028, "Water-Use Data Collection Techniques in the Southeastern United States, Puerto Rico and the U.S. Virgin Islands."

Hydrologic Surveillance Section Publications.—The Hydrologic Surveillance Section published 93 reports during the period. There were 15 annual data reports. There were 35 water-level reports including 12 potentiometric-surface maps. The water-use group published 29 water-use reports, including 22 county reports. In addition, the Section published 12 reports on the "Annual Yield and Selected Hydrologic Data for the Arkansas River Basin Compact, Arkansas-Oklahoma."

Hydrologic Investigations

Cooperative ground-water investigations.—Ground-water problems in Arkansas were delineated by Bryant and others in 1985. The two major aquifers

in the State, providing most of the ground water for agricultural, municipal, and industrial uses, are the alluvial and the Sparta Sand aquifers in eastern Arkansas. Heavy withdrawals from the alluvial aquifer for agricultural use and from the Sparta Sand aquifer for industrial and municipal uses created large cones of depression in these aquifers. In some cases, saltwater concentrations were increasing with pumpage. Broom and Lyford (1981) reported on the alluvial aquifer of the Cache and St. Francis River Basins in northeastern Arkansas. Broom and others (1984) performed a reconnaissance study of saltwater contamination in the El Dorado (Sparta Sand) aquifer, Union County. Fitzpatrick (1985) reported on the occurrence of saltwater in the alluvial aquifer in the Boeuf-Tensas Basin. Morris and Bush (Arkansas Geological Commission, 1986) studied the extent and source of saltwater in the alluvial aquifer near Brinkley. Fitzpatrick and others (1990) defined geohydrologic characteristics and used a flow model to determine aquifer response to pumping stresses in the Sparta Sand in east-central Arkansas. Mahon and Ludwig (1990) modeled ground-water flow in the Mississippi River Valley alluvial aquifer in eastern Arkansas. Fitzpatrick(1990) did a preliminary assessment of the potential for artificial recharge in eastern Arkansas. Kilpatrick (1992) modeled simulated response to future pumping in the Sparta aquifer in Union County. Mahon and Poynter (1993) developed, calibrated, and tested ground-water flow models for the Mississippi River Valley alluvial aquifer in eastern Arkansas using 1-square-mile cells. Gonthier and Mahon (1993) reported on the thickness of the Mississippi River Valley confining units in eastern Arkansas.

There were several cooperative projects unrelated to the alluvial and Sparta Sand aquifers. Bryant and others (1983) reported on the hydrology of Area 42, Western Region, Interior Coal Province. Petersen and others (1985) described the geohydrologic units of the Gulf Coastal Plain in Arkansas. Morris (1987) defined ground-water quality for Arkansas. Fitzpatrick and Ludwig reported on the ground-water resources in the upper White River (1990) and in the Arkansas River Basin (1990). Leidy and Morris (1990) described the ground-water quality and assessed the potential for ground-water contamination beneath agricultural lands in central Lonoke County. Leidy and Morris (1991) also described the hydrology and quality of ground water in the Boone Formation and Cotter Dolomite in Boone County. Leidy and Taylor (1992) performed an overview of susceptibility of aquifers to contamination in Union County.

Regional Aquifer-System Analysis (RASA) program.—Dan Ackerman headed the RASA program in Arkansas. During this period five reports were published: Generalized potentiometric surface of the aquifers in the Cockfield Formation, southeastern Arkansas (1980); Hydrology of the Mississippi River Valley alluvial aquifer, south-central United States—A preliminary assessment of the regional flow system (1987); Potentiometric surfaces of the Mississippi River Valley alluvial aquifer, eastern Arkansas, spring 1972 and 1980 (1988); Generalized potentiometric surface of the Sparta-Memphis aquifer, eastern Arkansas, spring 1980 (1988); and Hydrology of the Mississippi River Valley alluvial aquifer, south-central United States (1990).

National Water-Quality Assessment (NAWQA) Program.—David Freiwald headed the Ozark Plateaus Study Unit of this national project, which began in water year 1992 and continued throughout the period. Reports generated during the period included a description of the NAWQA Program as it related to the Ozark Plateaus, a ground-water study of the Ozark Plateaus by Pugh and Adamski (1993), and a surface-water study of this area by Femmer and Joseph (1994).

Surface-water studies.—Yanchosek and Hines (1979) delineated drainage areas of streams in the Ouachita River Basin in Arkansas. Lamb (1983) performed time of travel of selected streams in Arkansas. Hunrichs (1983) identified and classified perennial streams in Arkansas. Darling and Lamb (1984) did a cost-effectiveness study of the U.S. Geological Survey stream-gaging program in Arkansas. Freiwald (1985) reported on the annual precipitation and runoff for Arkansas from 1951 through 1980. Neely (1985) published surface-water profiles along Bayou Meto and Rocky Branch near Jacksonville for the Environmental Protection Agency. Freiwald (1987) did a streamflow gain-and-loss study of selected streams in northern Arkansas. Grosz and others (1988) reported on the hydrology of the lower Little Red River and a procedure for estimating available streamflow. Ludwig (1992) defined flow duration and low- flow characteristics of selected Arkansas streams. Ludwig and Tasker (1993) regionalized low-flow characteristics for Arkansas streams.

Flood studies.—Neely (1985) reported on the flood of 1982 and the 100- and 500-year floods on the

Buffalo River. Gilstrap and Neely (1986) reported on floodflow characteristics of Current River at Arkansas State Highway 328 near Reyno. Neely (1987) determined the magnitude and frequency of floods in Arkansas. Neely (1987) defined flood characteristics of the Buffalo River at Tyler Bend. Neely (1989) reported on estimating flood hydrographs for Arkansas streams. Neely (1987) published annual peak discharges and stages through 1984 for gaging stations in Arkansas. Neely (1989) reported on the flood of December 1987 in central and eastern Arkansas.

Surface-water-quality studies.—James Petersen performed water-quality reconnaissance studies of several watersheds that included Patton Lake in Jefferson County (1981); Larkin Creek in Lee and St. Francis Counties (1981); Harding Creek in Lawrence County (1981); and a reconnaissance of stormwater-runoff quality of the Big Piney Creek segment of the Cedar- Piney Creeks watershed in Yell County (1982). Terry and others (1982) performed a water-quality assessment of the White River between Lake Sequoyah and Beaver Reservoir in Washington County. Terry and others (1984) performed a water-quality assessment of the Illinois River Basin. Petersen and Morris (1984) compiled data collected in 1980 and 1981 for the purpose of water-quality modeling of the lower Ouachita River and selected tributaries in south-central Arkansas. Cole and Morris (1986) described the quality of water resources in the Ouachita National Forest. Potts (Arkansas Tech University) (1987) determined water quality and quantity in abandoned underground coal mines in west-central Arkansas for the Arkansas District. Petersen (1990) described trends and comparison of water quality and bottom material of northeastern Arkansas streams, 1974–85, and effects of planned diversions. Petersen also (1992) described trends in stream-water-quality data in Arkansas during several time periods between 1975 and 1989. Joseph and Morris (1993) performed a bacterial survey of Nimrod Lake in the spring and summer of 1992. Green (1994) completed a water-quality assessment of Maumelle and Winona reservoir systems in central Arkansas May 1989 to October 1992. Joseph and Green (1994) performed a water-quality reconnaissance and streamflow gain and loss of Yocum Creek Basin, Carroll County.

Miscellaneous investigative studies.—Fitzpatrick and Westerfield (1990) published hydrologic data collected in the vicinity of the proposed gamma-ray and neutrino detector site in Hot Springs County. Louthian and Gann (1991) reported on water-resources activities in Arkansas. Ford and Brahana (1992) published soil-gas data for the underground hydrocarbon contamination site in the Highland Avenue area in Fayetteville. Monical (1992) published a user's guide to the Arkansas rural water-delivery network of Geographic Information System (GIS) software. Southard (1992) reported on scour around bridge piers on streams in Arkansas.

CARIBBEAN DISTRICT

By Allen Zack

OVERVIEW

During the period 1979 to 1994, the Caribbean District, representing Puerto Rico and the U.S. Virgin Islands (USVI), evolved from a small data-collection and area-studies organization into a mainstream USGS District Office. The period began with a staff of 28 and a budget of $1,100,000; the period ended in 1994 with 80 employees and a budget of $5,800,000

The scientific renaissance of the Caribbean District began in 1981 with a more diverse program and greater participation by cooperators. Also, automatic data processing and satellite communication became a reality. A period of more complex investigative studies began to evolve between 1987 and 1994, during which time the scientific and research agendas of the Caribbean District were strengthened.

Caribbean District program will always be influenced by the passage of hurricanes and by political changes. Documentation of the environmental effects of flooding, landslides, and sinkhole collapse caused by hurricanes and heavy rainfall can result in increased District program. Political changes tend to cast temporary uncertainty on program funding and shift program emphasis, which can lead to District reorganization. For example, up until 1984, the Puerto Rico Department of Agriculture cooperated heavily with the Caribbean District. After 1984, and a change in local administration, program priority shifted to the Puerto Rico Industrial Development Company, and the agricultural programs were discontinued. Again, after 1992 and another political change in Puerto Rico, programs traditionally conducted by the USGS were gradually distributed to local consulting engineering firms by cooperators, resulting in USGS staff reduc-

tions and a staff composed of more temporary positions.

The nationality of Caribbean District professional staff during the period 1979 to 1994 changed from that of stateside engineers, geologists, and chemists (before 1979) to principally Puerto Rican professionals. Beginning in 1981, a concerted effort was made to recruit talented local engineers and hydrologists from the University of Puerto Rico. Through the period, local professionals gradually replaced transferred personnel from the United States mainland. This course of action encouraged greater retention of employees.

The bimonthly bulletin, "Water Resources in Puerto Rico and the U.S. Virgin Islands—A Review" began circulation in November 1981 and continued throughout the period. This important periodical provided general water-resources information for the Caribbean Region and kept subscribers informed as to current water-related events and activities of the Caribbean District. The first Caribbean District publication in Spanish was released in 1986.

The American Federation of Government Employees was certified in 1993 for nonmanagement staff of the Caribbean District.

District Headquarters, San Juan

The Caribbean District Office was located in San Juan, Puerto Rico, at the General Services Administration Center, Building 652, until November 1993 when a move was made within the same facility to Building 651.

Year	District Chief	Number of employees	Funding
1979	Craig B. Bentley	28	$1,100.000
1980			1,200,000
1981	Ferdinand Quiñones	20	1,400,000
1982		33	1,600,000
1983		43	1,800,000
1984		52	(?)
1985		49	2,800,000
1986		60	3,200,000
1987	Allen Zack	69	3,700,000
1988		69	4,600,000
1989		79	4,900,000
1990		107	6,100,000
1991		113	6,000,000
1992		105	6,000,000
1993		102	5,300,000
1994		80	5,800,000

Office of the District Chief

Craig Bentley was the Caribbean District Chief in 1979 and 1980, Ferdinand Quiñones 1981 to 1986, and Allen Zack 1987 to 1994. Henry McCoy was Assistant District Chief 1979–80, followed by Allen Zack (1982–86), Arturo Torrés (1987–93), Russell Curtis (1987–92), Zelda Bailey (1990–92), and Patrick Tucci (1991–92). Maria Irrizarry was Associate District Chief in 1994.

Hydrologic Records Section (including Computer/GIS Unit)

Patrick McKinley was the Data Chief in 1979–81, Russell Curtis in 1982–85, Eloy Colón-Dieppa in 1986–87, Russell Curtis in 1988–92, and Pedro Díaz in 1993–94. Others who served in the Hydrologic Records Section were Hector Colón-Ramos, Rafael Dacosta, Pedro Vázquez, Angel Class-Cacho, Juan Ortíz-Medina, Ivonne Colón, Rafael Peña-Cortes, Felipe Hernández, Philip González, Luis Santiago, Gladys Lenway, Eric Lugo, Zaida Aquino, Senen Guzmán, Bruce Green, Agustín Sepúlveda, Rene García, Antonio Delgado, Radames González, Michael Aponte, Iris Zayas, George Arroyo, Mary Sánchez, Carlos Martínez, Nilda Echevarria-Figueroa, Eliezer Bermúdez, José Colón, Marisol López, Iris Concepción, Luis Rivera, Ileana Arroyo, Ana Sánchez, Luis De Jesus, José Agis, José Torrés, Enrique Rivera-González, Manuel Amador, Juan Jirau, Manuel Ramírez, José Vázquez, Luis Soler, Ricardo Vachier, Lourdes Rolón, Luis Vega, Alexie Cruz, Angel Ferrer, Thomas Espinal-Domínguez, José Sánchez, Ahmed Valencia, Sandra Hernández, Daniel Maldonado-Mercado, Allen Gellis, Francisco Pérez-Blair, Sandra Lagares, Ronald Richards, Miguel Rodríguez, Ernesto Mangual, Jorge Ortiz, Wilfredo García-García, Israel Cruz-García, Anthony Pabon, Abel Quiles-Figueroa, James Torrés-García, Michael Torrés-Pastor, Carlos Santos, Marilyn Santiago, Luis Vallejo, José A. Rodríguez, Rafael Rodríguez, Mario Fuentes, Evelyn Guevara-González, Eduardo Figueroa-Gibson, William Wolfe, Wilfredo Rivera, Francisco Pérez, Carlos Nervaez, Antonio Pagan-Gavino, Miguel Soto, Jesus Burgos, José González, Robert Fitzhugh, Antonio González, Xevier Maldonado, Carlos Rodríguez, Pedro Galindo,

Dianne López-Trujillo, Felix Elias, Julio Rodríguez, Livia Montalvo, and Luis Torrés.

Hydrologic Investigations Section (including Reports Unit)

The Project Chief was James Heisel in 1979 and 1980, followed by Craig Bentley (1981), Allen Zack (1982–87), Arturo Torrés (1988–90), Patrick Tucci (1991–92), Arturo Torrés 1993, and Robert Graves 1994. Others who served in the projects section from 1979 to 1994 were José Díaz, Fernando Gómez-Gómez, Eloy Colón-Dieppa, Karl Johnson, José González, José Alicea-Ortiz, Ralph González, Arturo Tórres, Ramon Carrasquillo, Vicente Quiñones-Aponte, José Merced, Miguel Orona, Stuart Gibbings, Sigfredo Tórres-González, Heriberto Tórres, Adriana Cruz, Ramon Ramos, Gilberto Peña-Cruz, Angel Román-Mas, Richard Wolansky, Juan Deliz, Gustavo Rodríguez, Nelly Tirado, Hector Guardiola, Edgardo Lozano, Douglas Whitesides, Dennis O'Connell, Victor Hernández, Angel Ortiz, Ken Reid, Jesus Rodríguez, Juan Puig, Ada Aviles, Carlos Figueroa-Alamo, Javier García, Orlando Rámos-Gines, Carlos Bonnet-Vargas, Francisco Folch, Viviam Puig, Elba Rivera, Felix Rodríguez, Wilfredo Lozano-Feó, Carlos Conde, Teresita Rodríguez, José Rodríguez, Joseph Troester, Matthew Larsen, María Cherena, Julio Oms, Nicasio Sepúlveda, Thalia Veve, Ingrid Padilla, Wanda Molina-Rivera, Angel Tórres-Sánchez, Teresa Dopaso, Juan Rámos, Gilberto Rodríguez, Alfredo Santiago, Lionel Kaufman, Luis Menoyo, Rafael Medina, Francisco Maldonado, Edna Alvarez, Dyhalma Malave, Enrique Aviles, Jerry Ortiz, Paul Collar, Gregory Cherry, Elizabeth Powell, Myrna Martinez, Richard Webb, Hector Rivera, Wilfred Montano, Orlando Robles, Bruce Taggart, and María del Carmen Alvarez.

Before 1987, the District had neither the program nor the personnel to participate in the National Research Program. However, as applied research gradually became part of Caribbean District programs, Nicasio Sepúlveda and Joseph Troester became RGE accredited in 1988, Matthew Larsen in 1991, and Bruce Taggart in 1992.

Administrative Services Section

The period began with Georgina de Pineiro as Administrative Officer. She served in the position until replaced by Ana Nieves in 1990 through 1994. Others who served in the Administrative Section were Jane Montgomery, Mirtelina Colón, Rita López-Camacho, Carmen García, Iris Picart, Silma Gautier, Zaida Díaz, Ruth Guzman, Carmen Torrens, Maribel Lazu, Virgen Negron, Jesus Rivera, Katherine Nieves, Efrain Lorenzo, Michelle Henríquez, Camille Loubriel, and Brenda López.

Field Office, St. Croix, U.S. Virgin Islands

Located at the USDA Agricultural Research Station, the Caribbean District opened a two-person Field Office in St. Croix in 1988, administered by Bruce Green. Allen Heakin and David Peyton arrived in 1991, Gregory Cherry in 1993. The office was closed in 1994.

Field Office, St. Thomas, U.S. Virgin Islands

Located at Nisky Center, the Caribbean District opened a two-person Field Office in St. Thomas in 1989, administered by Judy Steiger. The staff grew to four in 1992 and 1993 and included Richard Kessler, Keith Overton, and John Parks. The office was closed in 1994.

FUNDING AND COOPERATION

The period began with the following cooperators: The Puerto Rico Department of Natural Resources (PRDNR), Puerto Rico Environmental Quality Board (PREQB), Puerto Rico Aqueduct and Sewer Authority (PRASA), the Puerto Rico Department of Transportation and Public Works (PRDTPW), and the Puerto Rico Industrial Development Company (PRIDCO). Between 1986 and 1988, agreements were made with 17 local and Federal agencies in Puerto Rico and the USVI. By 1994 the number of cooperators had increased to 21.

During the entire period, the Caribbean District Data Program was financed equally between the USGS and a consortium of Commonwealth agencies, coordinated by PREQB. Through the period, the composition of the consortium varied but invariably included PREQB, PRDNR, PRASA, PRIDCO, PRDTPW, the Puerto Rico Department of Health (PRDOH), the Puerto Rico Department of Agriculture (PRDOA), the Puerto Rico Electric Power Authority (PREPA), and, after 1983, the Puerto Rico Planning Board (PRPB).

In 1982, basic streamflow-gaging-station and ground-water-level networks were initiated in the USVI with matching funds from the Virgin Islands Department of Public Works.

Funding of programs by other Federal agencies in Puerto Rico and the USVI has always been limited. However, the U.S. Army Corps of Engineers (Corps) began cooperating with the Caribbean District in 1982 with the activation of a daily sediment-discharge station, and soon after, with the increased funding of surface-water studies. Also, the U.S. Environmental Protection Agency (USEPA), U.S. Fish and Wildlife Service, and the U.S. Forest Service supported modest programs with the Caribbean District.

Beginning in 1984, a large portion of the operating budget of the Caribbean District was composed of unmatched local funds. During the period 1988 to 1994, the percentage of unmatched funds provided to the Caribbean District was the largest in the Nation and supported projects for which no Federal matching funds were available.

SUMMARY OF PROGRAMS

Hydrologic-Data Collection

At the request of cooperators, the collection of basic hydrologic information increased through the period. Construction of Data-Collection Platforms (DCP's) began in 1984, increased to 12 in 1986, 18 in 1987, and 29 in 1988. Five DCP's were located on water-supply reservoirs, and all were equipped with real-time rainfall recorders. These stations supported flood-alert programs operated by the National Weather Service and various Commonwealth agencies. The scientific mission of the Caribbean District was markedly enhanced in May 1989 with the acquisition of a direct-readout ground station and uninterruptible power supply. These facilities signaled the beginning of comprehensive real-time data collection and distribution in the Caribbean District, without depending on transmission links to the U.S. mainland.

An inventory update of water wells throughout Puerto Rico was initiated in 1984, in cooperation with PRDNR. The previous inventory was conducted in 1959–61. By the end of the period, 5,700 wells and springs throughout Puerto Rico and the USVI had been entered into the fully computerized Caribbean District ground-water site inventory. A reinventory of water wells throughout the USVI was conducted in 1991–93.

Projects conducted under the Data Studies Chief included frequency and magnitude of minimum flows, flood studies, storm-surge, and bridge-site analyses (up until 1988). With PRASA and PREPA as principal cooperators, many reservoirs used for water supply and hydropower generation were measured periodically for sediment accumulation (bathymetry) and chemistry. The first Caribbean District rainfall/runoff simulation was conducted for Rio Grande de Loíza at Quebrada Arenas, Puerto Rico, in 1984.

Streamflow Stations

The period began with 35 gaging stations (sites with continuous stream-gage recorders). In 1982, the network was upgraded to 40 stations. In 1987 the network was composed of 41 stations and in 1988 the number was increased to 52 continuous streamflow-gaging stations and five continuous stage records for lakes. By the end of the period, the Caribbean District maintained 74 real-time reporting streamflow-gaging stations and 11 stage-only stations. Daily sediment records were collected at 21 of the sites. Also, the District maintained 112 partial-record stations and stage for 9 reservoirs.

Four recording and two partial streamflow stations were established in the U.S. Virgin Islands in 1982, in cooperation with the Virgin Islands Department of Public Works (VIDPW). These same stations remained throughout the period.

Water-Quality Stations

The period began with 74 water-quality sampling stations on streams. By 1982, this number decreased to 62 stream sites and 7 lake sites due to a request from PREQB. By 1988, there were 61 stream sites, 11 lake sites, 1 lagoon, and 1 bay site. At the end of the period, the network was composed of 57 stream sites, 14 lake sites, 8 lagoon sites, and 1 bay site.

Beginning in 1981, 57 wells were sampled for water-quality analysis. In 1982, emphasis was given to the measurement of synthetic organic compounds, and contamination was detected in 19 water-supply wells. Elevated levels of trichloroethylene resulted in the closing of several well fields in Puerto Rico; this was the beginning of intense U.S. Environmental Protection Agency (USEPA) oversight of drinking-water

supplies in Puerto Rico and the beginning of Superfund-site designations for the island. A similar program was initiated in 1984 for St. Croix, where ground water provides 15 percent of the water supply. Twenty wells were sampled for inorganic and organic constituents.

In cooperation with the PRDOH and PRASA, 350 public-supply wells were sampled for 29 volatile organic compounds, heavy metals, and inorganics during 1985. As a result of the sampling program, eight wells were closed by PRDOH owing to high concentrations of trichloroethylene and tetrachloroethylene. At PRASA's request, the Caribbean District initiated an appraisal of trihalomethane (THL) concentration in finished drinking water at 50 PRASA filtration plants. The study revealed that THL's were exceeded at key plants serving the San Juan metropolitan area.

Sediment-Discharge Stations

Only two sediment-discharge stations were operational in Puerto Rico in 1982. Automatic sediment samplers were installed at the stations in 1985. In cooperation with PRDNR, PRASA, and the Corps, a program to quantify suspended-sediment transport to Lago Loíza was begun in 1983. These 10 streamflow/sediment stations consisted of two daily and eight partial-record stations. Depth-integrated samplers were installed at six of the stations.

At the request and funding of the U.S. Forest Service, three streamflow, rainfall, and suspended-sediment stations were established in St. Lucia (1984–87), St. Vincent (1984–86), and Dominica (1984–90). The sediment program was supported by the Caribbean District sediment laboratory, which determined suspended-sediment concentrations in collected samples.

Ground-Water Observation Wells

The period began with 58 observation wells throughout Puerto Rico, consisting of 19 sites having water-level recorders and 38 periodic water-level measurements. The network was evaluated in January 1985, and the number of recording wells was reduced to 11. By 1988, 65 wells made up the ground-water-level network. At the end of the period, the ground-water network in Puerto Rico consisted of 53 recorder-equipped wells and 60 wells for which periodic measurements were made.

In 1984, 27 observation wells were completed in the three USVI, in cooperation with the VIDPW. In 1985, continuous ground-water-level recorders were installed in seven of the wells. These same wells continued operation through the end of the period.

Water-Use Data

The Caribbean District water-use program advanced significantly through the period, with the application of computer technology and more precise data collection and interpretation. Computerized storage of water-use data began in 1983. A comprehensive water-use inventory was conducted on St. Thomas during 1983 and 1984. The inventory was extended to St. Croix in 1985.

By 1991, the water-use program included seven cooperating Commonwealth of Puerto Rico agencies and reflected state-of-the-art standards for data collection, quality control, dissemination, and publication. By 1994, the program identified 11 water-use categories applicable to Puerto Rico and the USVI. All data were stored in a computerized storage-retrieval system called State Water-Use Data System.

Interpretive Studies

Before 1979, the assessment of water resources throughout Puerto Rico and the USVI amounted to about one-fourth of the District budget. As the need for advanced hydrologic analysis became apparent, interpretive studies became more important in the overall functions of the Caribbean District. In 1982, two-thirds of the District budget was dedicated to area studies. Beginning about 1986, applied research gradually evolved within the District, providing support to Research-Grade hydrologists. By 1988, 29 interpretive studies were being conducted in the Caribbean District.

Studies relating to suspended-sediment transport in the upper Río Grande de Loíza Basin were initiated in 1983 and expanded significantly in 1989. Sedimentation of Lago Loíza (Carraizo Reservoir) affects the sustainability of drinking water from this principal water supply for metropolitan San Juan. The Caribbean District began intense studies beginning in 1990 to determine the effect of land-use changes on sedimentation in Lago Loíza and alternatives for

sediment control. These studies included the effect of river discharge on the vitality of coral reefs.

At the request of PRASA, the Caribbean District entered into a cooperative agreement to make marine environmental assessments in the vicinity of the Mayaguëz ocean outfall operated by PRASA.

Cooperative Ground-Water Investigations

In the early 1980's, interpretive studies included approximately 10 studies, ranging from complex two-dimensional ground-water flow models to water-resources reconnaissance at various locations in Puerto Rico and the USVI. Up until 1984, particular emphasis was given to water-for-agriculture programs supported by the PRDOA; with a change in administration, emphasis shifted to water-for-industry programs. By 1983, ground-water flow modeling was a component of most interpretive aquifer studies. Particularly significant ground-water projects of the period included the comprehensive appraisal of the ground-water resources of the north-coast limestone aquifers of Puerto Rico (1984), atlas of aquifers in Puerto Rico and USVI (1985), geohydrology of potential hazardous-waste sites in Puerto Rico (1986), inter-aquifer movement within the limestone aquifer, north coast of Puerto Rico (1987), vertical continuum of aquifer compressibility and its relation to specific storage (1988), quantitative assessment of landslide susceptibility (1987), and a well system to recover usable water from a freshwater/saltwater aquifer in Puerto Rico (1987).

Caribbean District Response to Hydrologic Emergencies (selected examples)

In September 1982, the shallow aquifer in Barceloneta was contaminated by an accidental spill of 15,000 gallons of carbon tetrachloride. The Caribbean District assisted the USEPA in sampling support and analysis. This accident became the focal point of USGS environmental programs in Puerto Rico, from the perspectives of scientific evaluation and informed data collection. The USGS assumed a leadership position, providing scientific oversight to all aspects of data collection, hydrologic evaluation, and aquifer-recovery monitoring.

The first significant flood during the period 1979–94 occurred on St. Thomas on April 18, 1983. Ten Caribbean District hydrologists and technicians documented the extent of flooding, tagged high-water marks, and estimated peak flows for principal arroyos.

Intense, prolonged rainfall, principally along the south-central coast of Puerto Rico on October 6–7, 1985, caused severe flooding, bridge collapses, and landsliding and resulted in the deaths of more than 200 persons. Historical peak flows were recorded at many south-coast stations, surpassing the 100-year recurrence interval. The most significant landslide occurred at Barrio Mameyes, Ponce, where 200,000 cubic meters of mud buried more than 200 people. The USGS, WRD, participated in the scientific assessment of Mameyes, cooperating with the USGS, Geologic Division, in Reston, Va. This event signaled the beginning of landslide-susceptibility studies by the Caribbean District, the first two being "Quantitative Assessment of Landslide Hazard in the Río Blanco, Río Cibuco, and Río Coamo Basins, Puerto Rico" (1987) and "A Rainfall Intensity-Duration Threshold Relation for Landslide Occurrence in the Humid Tropical Environment of Puerto Rico" (1992).

Heavy rainfall during April 11–13, 1987, caused flooding and the formation of collapse sinkholes in the Vega Baja–Manatí area. Damage to homes, pipelines, and roads was documented by Caribbean District hydrologists, and potential preventive measures were suggested to avoid future sinkhole development.

Several times during the period, the Caribbean District responded to requests from cooperating Commonwealth agencies to evaluate environmental conditions favoring waterborne and water-related disease such as gastroenteritis, bilharzias (schistosomiasis), and dengue fever. An outbreak of gastroenteritis in the town of Florida in August 1985 was assessed by a task force, including the USGS. Coliform analyses were performed and preventive measures promulgated. The transmission mechanics of dengue fever were intensely studied during 1994, in cooperation with the National Centers for Disease Control, using the geographic information system for statistical analyses.

The Caribbean District was requested by the USEPA and the Territorial Government of the USVI to assess contamination to hydrologic systems related to leakage from gasoline-storage tanks in Tutu, St. Thomas, USVI, in July 1987.

On September 17 and 18, 1989, Puerto Rico and the USVI sustained a direct assault from Hurricane Hugo. Whereas there were few human casualties,

economic losses were in the billions of dollars. The USGS Field Office in St. Croix was totally destroyed, the roof having blown off during the storm. USGS hydrologists participated in every aspect of scientific data collection related to the hurricane and its environmental/hydrologic consequences. In the aftermath of Hurricane Hugo, the Caribbean District hosted the Secretary, U.S. Department of the Interior (DOI), Manuel Lujan. The Caribbean District Chief was designated Caribbean-area DOI representative for environmental relief. Restoration programs were drafted with U.S. Fish and Wildlife Service, USGS Geologic and Water-Resources Divisions, and the National Park Service. Federal funds were solicited and received from the Department of the Interior in Washington. This infusion of dollars substantially helped reestablish damaged hydrologic-collection installations and supported hydrologic programs related to the passage of Hurricane Hugo.

Regional-Aquifer Studies

Initiated in 1984, the Caribbean Islands Regional Aquifer-System Analysis (CIA–RASA) addressed aquifer characterization along the south coast of Puerto Rico and the Kingshill aquifer in St. Croix. After the reconnaissance phase of the program, geochemical modeling commenced in 1985, followed by ground-water flow modeling and the publication of numerous reports.

WEBB Projects

Global climate-change research began in the Caribbean District with the initiation of the Water, Energy, and Biogeochemical Budgets (WEBB) program in 1991. The program focused its research efforts on part of the Luquillo National Experimental Forest and the Río Grande de Loíza Basin. Many research publications were produced by this program.

Technological Support to Caribbean District Programs

Early during the period (1982), the Caribbean District acquired the technology for measuring the geophysical characteristics of aquifers. Truck-mounted geophysical-logging equipment was leased from the Colorado District, and seismic and other surface geophysical equipment was rented. In 1983 a mud-rotary drilling rig was purchased and rig operators hired. In 1985, the District upgraded its geophysical-logging capabilities with 5,700 feet of cable, sonic-velocity measurements, and combined probes to become more time-efficient. These technologies supported numerous interpretive studies including test drilling in Vieques, the North Coast Limestone Study, USEPA Superfund programs, test drilling in the USVI, and numerous area studies. Contracting these services would have incurred prohibitive costs to the District and its cooperators.

During the course of the North Coast Limestone Study, begun in 1984, a contract was obtained for dual-tube drilling—with continuous cores to depths of 3,000 feet—into the North Coast artesian aquifer system. This comprehensive drilling program greatly advanced the knowledge of the geology and geohydrology of the north coast of Puerto Rico, including the existence of strongly artesian conditions in the Dorado, Hatillo, and Isabella areas.

Surface geophysical prospecting was conducted for most comprehensive area studies to augment borehole geophysical data. Geophysical methods included terrain conductivity, electromagnetic profiling, transient electromagnetic soundings, direct-current resistivity, and seismic-refraction surveys.

The Geographic Information System (GIS), introduced in 1988, was rapidly integrated into the data and studies sections, enhancing the quality and reliability of the hydrologic information provided to the public and to cooperating Commonwealth and Federal agencies. Cooperating Commonwealth agencies, led by PREQB, actively participated in GIS development and funding. The GIS was extended to the USVI in 1990.

Computer Development

Computer enhancement began in earnest in 1981 and continued through the period. Computer data-base development began in early 1983 with the acquisition of a minicomputer. In 1984, the system was upgraded to 2 megabytes memory, national communication link, and computer connections to cooperators (PREQB, PRDNR, and PRASA). Beginning in 1985, workstations gradually began replacing the minicomputer. With the installation of a demodulator and receiver, real-time flow data were received (through the South Carolina District) from remote transmitters located at five streamflow-gaging stations, within Puerto Rico.

During 1988, the District minicomputer was enhanced with an upgrade from 1-MIPS (million instructions per second) unit to a 5-MIPS; this allowed much faster processing of hydrologic data. The old 630-megabyte and 300-megabyte disk drives were interchanged with three 773-megabyte disks, making the system three times more efficient in access time. This equipment, combined with digitizers, graphic terminals, and plotters supported the GIS.

During May 1989, the Caribbean District began using a direct-readout ground station (DRGS) capable of receiving remotely collected hydrologic data from the GOES satellite. The system was supported by an uninterruptible power supply.

FLORIDA

By John Vecchioli

INTRODUCTION

A notable event early in this period was the retirement in February 1980 of Clyde Conover, Florida's first District Chief. The latter part of the period was marked by Hurricane Andrew's devastation of extreme South Florida in August 1992. In between, the period was marked by a major downsizing of the District Office staff, which was accomplished by assigning the duties and responsibilities of positions vacated by retirement to remaining staff members. Following the lead of WRD, the District changed from a top-down mode of operation to a more distributed style of management during this period.

ORGANIZATION AND MANAGEMENT

At the start of the period, the Florida District consisted of the District Office in Tallahassee and major Subdistrict Offices in Miami, Tallahassee, Tampa, and Orlando. The area of operation of the Subdistrict Offices coincided more or less with the boundaries of the Florida Water Management Districts, except for the East-Central Subdistrict (Orlando), which took in parts of Southwest Florida Water Management District and South Florida Water Management District in addition to the territory of the St. Johns River Water Management District. Attached to the District Office were a Field Unit in Tallahassee staffed by retired research hydrologist Hilton H. Cooper, a Field Headquarters in Jacksonville, and a Quality of Water Service Unit in Ocala. The South Florida Subdistrict Office in Miami oversaw two Field Offices, one in Ft. Myers and the other in Jupiter (later Stuart). Attached to the Southwest Florida Subdistrict (Tampa) was a Field Office in Sarasota; a Field Office in Ocala served as part of the East-Central Florida Subdistrict in Orlando.

By 1994, several major organizational changes had been made. The North Florida Subdistrict Office (Tallahassee) was consolidated with the District Office soon after the two groups moved from separate buildings on the north end of Tallahassee to a new pseudo-Federal building downtown in 1983. The Jacksonville Field Office became a Subdistrict in 1983 and later, in 1984, reverted to a Field Headquarters, but under the Orlando Subdistrict Office instead of the District Office. In 1988, the Orlando Subdistrict Office moved to Altamonte Springs, and in 1983 the Miami Subdistrict Office moved from southwest Miami to northwest Miami, into a fortified building of the Federal Reserve.

At the start of this period, the District program was under the direction of Clyde S. Conover, District Chief, and Rufus H. Musgrove and Clarence B. Sherwood as Assistant District Chiefs. The South Florida Subdistrict Office was led by Albert M. LaSala, Jr., Subdistrict Chief, and Steven L. Johnson, Assistant Subdistrict Chief. William B. Mann IV, Subdistrict Chief, and Jack C. Rosenau, Assistant Subdistrict Chief, headed the North Florida Subdistrict. Robert L. Knutilla was Chief of the Southwest Florida Subdistrict and Joe W. Stewart was Assistant Subdistrict Chief. Joel O. Kimrey, Subdistrict Chief, directed the East-Central Florida Subdistrict Office with Harry C. Rodis as Assistant Subdistrict Chief. Field Offices were headed by Gilbert W. Leve, Jacksonville; Durward H. Boggess, Ft. Myers; George W. Hill, Stuart; Horace Sutcliffe, Sarasota; and Richard Hedges, Ocala. The Quality of Water Service Unit in Ocala was under the direction of Robert T. Kirkland. In 1979, Bill Mann transferred to Wisconsin to become District Chief, and Glen L. Faulkner became Subdistrict Chief of the North Florida Subdistrict.

The year 1980 marked the retirements of Conover and Musgrove, who were replaced later that year by Irwin H. Kantrowitz as District Chief and Ann C. Beam as Assistant District Chief. In 1981, LaSala was replaced by Alfred L. Knight as Subdistrict Chief in Miami. In 1982, Knight transferred to Kentucky to become District Chief and was replaced by G. Louis Ducret as Subdistrict Chief of the Miami Subdistrict

with Aaron L. Higer as Assistant Subdistrict Chief. William A. Long replaced George Hill as Field Office Chief in Jupiter at about the same time. In 1985, the Tallahassee Subdistrict Office was combined with the District Office upon transfer of Glen Faulkner to Headquarters and the retirement of Jack Rosenau. Henry R. LaRose replaced Frank Watkins as Ft. Myers Field Office Chief upon Watkins' retirement, and Eugene C. Hayes took over as Chief of the Jacksonville Field Office, which had formerly been a Subdistrict, upon Warren Leve's retirement in 1983.

Knutilla transferred to become District Chief of New Mexico in 1984, and Thomas H. Yorke became Chief of the Tampa Subdistrict at that time. Stewart's retirement resulted in the abolishment of the Assistant Subdistrict Chief position there. Sherwood's retirement as Assistant District Chief resulted in the abolishment of that position, and in 1987, the other Assistant District Chief position was left unfilled upon the retirement of Ann Beam.

The transfer of Kimrey to an International Hydrology Program assignment in 1988 brought Wanda C. Meeks in as Chief of the Orlando Subdistrict, and John E. Coffin replaced Eugene Hayes as Jacksonville Field Office Chief upon Hayes' transfer in 1989

In 1990, Wesley L. Miller became Chief of the Stuart Field Office. Yorke transferred to Headquarters and Walter C. Aucott became Subdistrict Chief of the Tampa Office. In 1991, Wanda Meeks became District Chief in Arkansas and Charles H. Tibbals replaced her as Orlando Subdistrict Chief. Also that year, Ducret's transfer to Denver brought in William C. Scott as Subdistrict Chief in Miami. Coffin's transfer to Tampa left the Jacksonville Field Office Chief position vacant; James E. Sohm filled it the following year.

John Vecchioli replaced Irwin Kantrowitz as District Chief in 1992 when Kantrowitz was reassigned as Area Hydrologist for Florida-Caribbean programs. The following year, Thomas E. Richards replaced Miller as Field Office Chief in Stuart.

At the end of this period, the Florida managerial staff had been pared considerably with the abolishment of the Assistant Chief positions, both at the District level and the Subdistrict level. The number of Subdistricts began the period at four, grew later to five with the addition of Jacksonville, and closed the period at three as Jacksonville reverted to a Field Office and the Tallahassee Subdistrict was consolidated with the District Office.

FUNDING AND COOPERATION

Most of the funds for the District programs during this period (table 1) were from the Federal-State Cooperative (Coop) program, following the pattern of many years. However, unlike past years when the Coop program was cost-shared equally between Federal funds and funds contributed by State and local agencies, this period had a growing imbalance in cost sharing, with the local offerings exceeding the Federal match by more than $2 million in 1994. The District program grew from just under $9 million in 1979 to more than $17.6 million in 1994. Of the total program in 1994, the Coop program furnished more than 75 percent of the funds. Varying amounts ranging from 11 percent to 25 percent of the total program were furnished by the Federal Program during this period. The large increase in total program over this period was due to the large growth in Florida's population, the consequent increase in water demand, and a growing awareness of environmental issues.

In 1979, the Florida District Program included some 60 State, county, and city agencies in the Coop program, including the statewide agencies of Florida Department of Environmental Regulation (FDER), the Florida Department of Natural Resources (FDNR), the Florida Department of Transportation (FDOT), and the five regional Water Management Districts. Federal agencies helping to fund the program were the National Park Service (NPS), U.S. Air Force (USAF), Bureau of Land Management (BLM), U.S. Civil Service Commission (USCSC), U.S. Army Corps of Engineers (Corps), U.S. Department of Housing and Urban Development (HUD), U.S. Environmental Protection Agency (USEPA), and the Bureau of Mines (BOM). The number of cooperators in the Florida

Table 1. Florida District funds, fiscal years 1979, 1986, and 1994

(in thousands of dollars)

Funding source	1979	1986	1994
Cooperator	3,768.6	4,612.6	7,556.8
Federal matching	3,520.1	4,210.1	5,224.0
OFA	858.8	759.8	2,241.4
Federal	843.7	1,000.2	2,578.6
TOTAL	8,991.2	10,582.7	17,600.8

program numbered some 60 to 70 throughout the 1979–94 period, although new agencies replaced preexisting ones from time to time. By far, the major participants in the program throughout this period were the five Florida Water Management Districts.

Federal Program funds varied considerably during this period from a low of less than $600,000 in 1984 and 1985 to about $2.5 million in 1993 and 1994. The large increase in the later years coincided with the start of the National Water-Quality Assessment (NAWQA) Program. Funds from other Federal agencies (OFA) also fluctuated considerably from year to year, ranging from under $200,000 in 1985 and 1987 to more than $2.2 million in 1994. The large increase in the later years was largely a result of work with the U.S. Air Force and the U.S. Navy.

At the start of the period, the program was divided 70 percent investigations and 30 percent hydrologic records. However, the program gradually moved toward a more balanced status and at the end of the period was about evenly divided between investigations and hydrologic records.

STATEWIDE AND NORTH FLORIDA PROGRAMS

The need for water-supply development and management brought about by the growing population resulted in a substantial increase in the water-resources Coop program during this period. State population increased from 9.8 million in 1980 to about 14 million in 1994, whereas freshwater use increased from 6.6 billion gallons per day in 1980 to 7.2 billion gallons per day in 1995 (table 2). The comparatively small increase in freshwater use relative to the population increase was largely a result of relocation of power-generation plants to the coast and major recycling of processed water by the phosphate industry. However, public-supply use showed a sharp increase from 1.3 billion gallons per day in 1980 to about 2 billion gallons per day in 1995, in accord with the large population increase. Ground water was the principal source of public supply during this period. In addition to the concern of adequate water supply, the continuing growth in population and the attendant mounting waste-disposal impacts on water quality resulted in a greater emphasis on surface- and ground-water-quality studies.

Table 2. Freshwater withdrawals in Florida, by source, 1980–95

[All values are in million gallons per day; source, R.L. Marella (1999, WRIR 99–4002)]

Year	Population (in millions)	Freshwater withdrawn, by source		
		Ground water	Surface water	Total
1980	9.75	3,677.2	2,937.3	6,614.5
1985	11.32	4,047.7	2,236.6	6,284.3
1990	12.94	4,664.7	2,867.1	7,531.8
1995	14.15	4,335.6	2,879.4	7,215.0

The Regional Aquifer-System Analysis (RASA) Federal program studies were a major focus of the early part of this period. Started under the name "Southeast Limestone Aquifer System" analysis, the study was formally changed to the Floridan Aquifer System at about this time. Subregional studies were done by Paul Ryder at Tampa for the aquifer system in west-central Florida, by Charles Tibbals at Orlando for the aquifer system in east-central Florida, and by Fred Meyer at Miami for the aquifer system in south Florida. Objective of the RASA studies was to develop an improved understanding of the hydrology of major aquifer systems throughout the Nation, using numerical models as tools. These studies on the Floridan Aquifer System culminated in a series of chapters in Professional Paper 1403.

Florida continued its annual assessment of water use throughout this period. At the start of the period, Stan Leach was designated as the District Project Coordinator, but from 1988 on, the project has been under the direction of Richard Marella. The Water Use assessment was funded through the Federal-State Coop program with the Florida Department of Environmental Regulation, and it compiles, interprets, and publishes regularly at 5-year intervals reports on the "Source, Use and Disposition of Water in Florida." The program relies heavily on data collected and furnished by the five Florida Water Management Districts. A number of reports in the Open-File, Water-Resources Investigations, and Florida Atlas Series have been published by this continuing water-use effort. The Florida District has led the WRD in maintaining a continuous and vigorous program of water-use data compilation and assessment.

Subsurface waste injection continued to grow in use as a wastewater disposal method, particularly in southeast Florida. Research on the hydrogeology and

geochemical effects of waste injection also continued as part of a federally funded study headed at the start by John Vecchioli and later by Jack Hickey, and through Coop program studies done by Fred Meyer, Mike Merritt, Hickey, Bob Hull, Edward German, and Ann Bradner. Much attention was directed toward assessing the impact of drainage wells in central Florida on the quality of water in the Upper Floridan aquifer by German and Bradner in Orlando. A considerable body of literature was produced by this research during this period and was published as journal articles, Water-Supply Papers, Water-Resources Investigations Reports, and Open-File Reports.

Major surface-water-quality studies at the start of this period included the Federal Program/Apalachicola River Quality Assessment study headed by Hal Mattraw and including John Elder and Helen Leitman as principal investigators. Several Water-Supply Papers were produced from this study. Tony Irwin directed an intensive water-quality survey of rivers and estuaries, and Bernie Franks performed a statewide assessment of the impact of land application of treated domestic wastewater on ground-water quality; both studies were part of the Coop program with FDER. More specific research on effects of land application of domestic wastewater on ground-water quality in Tallahassee was done first by Mike Yurewicz, followed by Hull, Elder, Janet Pruitt, and Marian Berndt. This research was done cooperatively with the City of Tallahassee and resulted in several WRIR's. David Troutman did a study of the effect of industrial wastewater impoundments on ground-water quality under the Coop program with FDER in the early 1980's. Toward the mid-1980's, Franks led a federally funded Toxics Program Study of organic contaminants in ground water from a wood-treatment operation in Pensacola.

Establishment of a ground-water-quality monitoring network became a major priority of the FDER in the early 1980's and help in designing a network was provided to them by Paul Seaber. Later, Brian Katz assumed this role, and he also provided geochemical evaluation of the data that had been acquired from the network. Brian Katz together with Anne Choquette, Marian Berndt, and Mary Jo Radell described the geochemistry of Florida's major aquifer systems.

In the later 1980's, Berndt, in cooperation with the City of Tallahassee, performed geochemical evaluation of ground water in the vicinity of the closed landfill at the Tallahassee Airport. Also in the later 1980's, the effect of dairy feedlots on surface- and ground-water quality was studied by Bill Andrews in cooperation with FDER. A similar study involving swine and poultry was done by Hilda Hatzell, who also evaluated chemical constituents in crab-scrap compost and their effect on ground-water quality.

The start of the 1990's saw the initiation of the South Georgia–North Florida NAWQA study, headed by Ed Oaksford with help from Clyde Asbury, Berndt, Hatzell, Christy Crandall, and Lori Peed. J.B. Martin was the Lead Technician on the team. The intensive phase of the NAWQA study was concluded in the late 1990's with the publication of several reports.

Flood studies during this period included HUD Type 15 studies headed by Stan Leach at the start of the period and later by Wayne Bridges; small-basin flood assessments by Wayne Bridges in cooperation with FDOT; and runoff from urban watersheds by Marvin Franklin in cooperation with Leon County. In the later 1980's and early 1990's, Roger Rumenik evaluated the low-flow characteristics of Florida streams statewide, and in the early 1990's, together with Jack W. (Trey) Grubbs, did a more in-depth study of north Florida streams in cooperation with the SRWMD and FDEP.

A water-budget study of a seepage lake in the Panhandle was begun by Jim Oliveros and Walter Aucott. Upon Oliveros' resignation, Choquette became the principal investigator. Trey Grubbs completed the study in the early 1990's.

Ground-water protection issues were addressed by David Hunn, Vecchioli, and Aucott in their evaluation of protection-zone delineation around public-supply wells in west-central Florida in cooperation with FDER in the late 1980's. The resulting WRIR caused a rethinking of the USGS role in studies of well-head protection. Delineation of recharge areas in three geographically distributed counties in Florida was done by John Vecchioli, Charles Tibbals, Craig Hutchinson, and Dan Duerr in the late 1980's. In the early 1990's, Trey Grubbs continued the effort in Escambia and Santa Rosa Counties. These studies resulted in reports published in the WRIR series.

In the late 1980's and early 1990's, Helen Light (formerly Leitman) and Melanie Darst conducted studies of fish ecology in wetland forests and also investigated biological indicators of blackwater streams. These studies were done for north Florida streams in cooperation with the Florida Game and

Freshwater Fish Commission for the former study, and with FDER for the latter study. Mary Jo Radell began a study of the Upper Floridan aquifer flow system in Leon County in 1990 in cooperation with FDER and the City of Tallahassee. The study was later completed by Hal Davis. Toward the end of the period, Hal Davis embarked on a long-term study with the U.S. Navy involving movement of contaminants in ground water at the Naval Air Station in Jacksonville. Also toward the end of the period, Light and Darst began a study of hydrologic conditions in the flood-plain of the Apalachicola River in cooperation with the Northwest Florida Water Management District. This study was completed in the late 1990's with publication of a Professional Paper.

Throughout the period, compilation of information on hydrology, water quality, and water use on a statewide basis was continued and published as maps in the Florida Water Atlas Series in cooperation with the FDER, later changed to FDEP. The maps were compiled by various District authors and were published upon completion by the Florida Geological Survey. The Atlas Series presents in map and graphical form a statewide synopsis of important water-resources information.

At the start of the period, stream-gaging sites in Florida numbered 597, and lake and reservoir sites were at 219 (table 3). Toward the end of the period, the former totaled 489 and the latter 148; the number of stream-gaging sites approached 600 in 1989, and again in 1991. Ground-water level continuous-record stations numbered 504 at the start of the period and closed the period at 442. Periodic ground-water-level sites varied considerably in number from year to year but were as many as 3,528 in 1979. Quality of water surface-water sites decreased during this period from 359 at the start to 121 at the end, whereas ground-water sites decreased from 923 to 319 during the period. The Hydrologic Records program was coordinated by Stan Leach at the start of the period, by Wayne Bridges after Leach's retirement in 1983, and by Marvin Franklin after Bridge's retirement in 1992.

Table 3. Water records monitoring network

Classification	Number of stations	
	1979	1994
Streams		
Continuous	272	320
Periodic discharge	86	11
Continuous or daily stage	90	120
Periodic stage	62	0
Peak discharge	73	19
Peak stage	14	19
TOTAL	597	489
Lakes		
Continuous or daily stage	113	74
Periodic stage	106	74
TOTAL	219	148
Wells		
Continuous water levels	504	442
Periodic water levels	3,528	716
TOTAL	4,032	1,158
Quality of water		
Surface water	359	121
Ground water	923	319
TOTAL	1,282	440

DISTRICT REPORTS SECTION

By Roz Czajkoski

After Warren G. Hodson, Reports Specialist for the Florida District, retired at the end of 1983, Irwin Kantrowitz, District Chief, formed an Editorial Board consisting of three hydrologic specialists: John Vecchioli, Ground Water; Tony Irwin, Water Quality; Wayne Bridges, Surface Water; and two members of the Scientific Publications Section: Roz Czajkoski, Chief of the Editorial Unit, and Don Tucker, Chief of the Cartographic Unit. The Board, chaired by Roz Czajkoski, met weekly to monitor the status of technical reports as they proceeded through the system, to coordinate technical review of the reports, to set priorities, and to discuss and stay apprised of report policies and all matters pertaining to publications. The activities of the Board helped to reduce the number of overdue reports in Florida.

During 1979–94, a yearly average of 55 publications were processed by the Florida District. In addition, the Florida District Office staff assisted a number of other Districts, Region, and Headquarters offices (sometimes on detail for a week or more) in the review, preparation, and production of reports, including nine publications of Proceedings of the Toxics Program Technical meetings, National Water Summary papers, RASA reports, NAWQA nationwide retrospective reports, Abstracts for the National Water Quality Symposium, Publications Guide articles, fact

sheets, news releases, bibliography reports for other States, and materials used for classroom training. For part of the period, Tony Irwin, Florida Water-Quality Specialist, also was acting Southeastern Regional Reports Specialist.

The Publications Section conducted training courses on editing techniques for the Southeastern Region for a number of years. Detailed course workbooks (parts of which were incorporated into a course on report writing for USGS authors that was conducted by a commercial company) were compiled in the Publications Section. Publications staff also conducted reports workshops in Subdistrict Offices in Florida and for individuals from other Regions who came to Florida for training.

Florida was selected as one of three Federal Reports Preparation Units to work with Headquarters in preparing complete camera-ready copy for publication in the USGS formal series. One of the early products was a Water-Supply Paper prepared totally in-house.

The Publications Section negotiated a contract with the Government Printing Office in the 1980's for sole source printing of publications from Florida and other offices in the Southeastern Region. After that, Florida had most of its reports printed rapidly.

Computerization of two comprehensive lists began in 1979. One, published in 1980, was a USGS bibliography of the water resources of Florida, 1886–1979 (Hoy, Simmons, and Czajkoski), and the second was a report distribution list of about 600 entries, reformatted in the Editorial Unit to arrange the list in organizational categories. The list was marked, ultimately, by the District Chief to indicate what distribution was to be made for each publication because mailings varied depending on the nature of the report.

QUALITY OF WATER SERVICE UNIT (QWSU)

By Irwin H. Kantrowitz

Despite the 1973 consolidation of all WRD District water-quality laboratories into two national laboratories (and later into one central laboratory), and primarily due to the efforts of former District Chief Conover, the Ocala-based QWSU continued (sometimes surreptitiously) to provide analytical services and other water-quality support to the Florida District in 1979 and beyond. Housed in the Federal Building in downtown Ocala, the QWSU, under the leadership of Bob Kirkland, had an experienced young staff of laboratory personnel. In 1979, the staff were Dan Stanley, Connie Geller, John McKenzie, Stan Ockosz, and Sue Sahagun. This staff was to stay largely intact and provide the core leadership required in the expanding role QWSU was to play during the 1979–94 period.

Like QWSU's in other Districts, the Ocala laboratory provided time-sensitive (largely nutrient) analyses in support of Florida projects. The staff also provided training for hydrologists and hydrologic technicians in all the Florida offices to ensure that geographically dispersed field personnel followed uniform District-wide procedures. Another function of the QWSU was to prepare reference samples (chloride and specific conductance) for use by the mini-labs in each of the Florida offices as part of the District's quality-assurance (QA) program. The staff's experience with reference samples, training, and QA would later result in the QWSU having major participation nationally in these programs.

The QWSU had somehow managed to retain analytical equipment that other District laboratories had been forced to send to the Central Laboratories and so was able to provide major-ion ("complete") analytical services to the Florida Subdistricts as well as perform some analytical work for other Districts in the Southeastern Region. This sometimes created conflict with Regional Water-Quality Specialists and particularly with personnel from the Central Laboratories. The Florida District always sent just enough samples to the Central Laboratories to keep them placated and thus avoid a major confrontation.

In time, the Central Laboratories came to appreciate the analytical capabilities of the QWSU and turned to Ocala for help in running the Blind Reference Sample Program. In this program, standard water samples were disguised as regular field samples and submitted to the Central Laboratories from all Districts. Ocala's involvement began in 1982 with just the shipping of previously prepared samples to the various Districts for reshipment to the Central Laboratories. By 1985 a commandeered room in the basement of the Federal Building housed the large water tanks necessary for the preparation of the samples. By completely removing all aspects of the preparation, shipping, and statistical analysis of the program from the Central Laboratories, QWSU ensured that the program remained truly "blind." By 1986, Ocala was responsible for all of WRD's reference-sample programs including field reference samples, precipita-

tion samples, the International Reference Sample Program, and the Blind Reference Sample Program.

In 1982, the Bio Section in the Atlanta Central Laboratory was closed down and, with the transfer of Bill Fife and the necessary equipment, the Ocala Laboratory became responsible for the preparation and shipment of the bio media kits needed by all Districts to perform *Escherichia coli* counts. Gradually, QWSU became responsible for running the national microbiologic QA program in addition to its major participation in inorganic QA programs.

Long involved in training Florida personnel in standardized field techniques, the Water-Quality Branch asked Kirkland to prepare a national training course for field techniques. The course was initially presented in 1984 by Kirkland and other QWSU staffers Connie Geller, Dan Stanley, and Stan Ockosz, as well as Edward Simonds (Orlando) and J.B. Martin (Tallahassee), to a cadre of future trainers who spread Florida's standardization procedures throughout the Division.

In 1985, the Atlanta Central Laboratory closed and the Denver Central Laboratory became the sole National Water Quality Laboratory. Hope Almond, an Atlanta chemist, transferred to Ocala, and with the addition of personnel as well as equipment, QWSU increased its analytical capability. Shortly after consolidation, the Denver laboratory requested help in handling analytical work for the Bureau of Reclamation and this work, consisting of several hundred samples per month, was assumed by QWSU in 1985.

Due to increasing space requirements and the addition of new analytical equipment that taxed the air conditioning and electrical systems, Kirkland began a campaign in 1987 to move the laboratory out of the Federal Building. While negotiations with General Services Administration (GSA) dragged on, the potential for a new program made it essential that the laboratory relocate. In mid-1989, exploratory discussions were held to move all supply-distribution responsibilities from the Denver laboratory to Ocala. Known as DENSUPPLY, this program purchased, stored, and distributed to the Districts all the consumable items involved in water-quality work, such as bottles and filters. The space needed to warehouse the supplies was considerable and dual-track negotiations with GSA and the Denver lab continued for some time. By mid-1990, the transfer of DENSUPPLY to Ocala was agreed to in principle. At this same time, and against all odds, Kirkland convinced GSA that a stand-alone, dedicated laboratory and warehouse were in the best interests of the government. Furthermore, all aspects of the siting, design, and construction of the new facility was to be under USGS direction. In early 1992, plans for the building were prepared and a suitable site was located. The District contracted with Dick Heath, who had retired in 1979, to interface with the contractors and relieve some of the daily pressure on the QWSU staff. The building was finally occupied in late 1993 at which time the DENSUPPLY program became OCALAMAN. The new facility, formally dedicated at an open house in January 1994, housed 24 employees including 6 of the original staff from 1979.

At this point it is fitting to discuss the extraordinary Bob Kirkland who, during this period, was the embodiment of the Ocala QWSU. A few credits short of a college degree, with no formal training in chemistry, Kirkland worked his way up the ranks and could more than hold his own in any discussion of analytical procedures or equipment. Suffering from a congenital bone disease and in later years with failing eyesight, his frailty was more than compensated by his quick and often acerbic wit and highly opinionated nature. His opinions were delivered in a rich, booming voice that was incongruous with his diminutive physical stature; earlier in his Survey career he moonlighted as a disk jockey for radio stations in Raleigh, N.C., and in Ocala. Bob Kirkland received the Department of the Interior Meritorious Service award in 1987 based on his accomplishments in Florida and throughout the WRD; he had transformed the Ocala QWSU from a near-clandestine operation to a key component of the national water-quality program. In 1990, after considerable effort by the District and Regional staffs, Kirkland's professionalism was formally recognized and he was converted to a Physical Scientist and promoted to GS–13. In early 2000, six years after its opening, the laboratory building in Ocala, the crowning achievement of his career, was lovingly renamed the Robert T. Kirkland, Jr., Building, in Bob's memory after his untimely and sudden death in 1999.

MIAMI SUBDISTRICT

By Barbara Howie

Introduction

The Miami Subdistrict, called the South Florida Subdistrict at the beginning of the period, was a

dynamic Subdistrict in terms of size, program emphasis, and personnel changes. At the beginning of the period, the Subdistrict had 59 people. The Studies Section employed hydrologists, the Data Section and a small Water Quality Unit employed mostly hydrotechs, and there was no Computer or Data Processing Section. The Subdistrict was at its smallest, 43 folks, in 1983 and 1988. At the end of the period the Subdistrict had 53 employees. Reflecting the increasing complexity of the work done in the Subdistrict, the Data Section employed hydrologists, and a separate Computer Section was staffed with computer professionals. During the 1979–94 period, the Subdistrict had four Subdistrict Chiefs: Al LaSala until 1981, Al Knight from 1981 to 1982, G. Louis (Lou) Ducret from 1982 to 1990, and William C. Scott from 1990. The Subdistrict was ably served by Aaron Higer, sitting in several times as Acting Subdistrict Chief. Of the 59 people in the Subdistrict at the beginning of the period, only Aaron Higer, Carolyn Price, Don McKenzie, Barbara Howie, Clint Lietz, Rhonda Howard, and Bill Scott (who left the Subdistrict and came back as Subdistrict Chief) remained at the end of the period.

The period saw the retirement of a number of long-term Survey employees. Among these were Howard Klein, Fred Meyer, John Warren, Ed Cordes, Ellis Donsky, Ed Hull, Wes Miller, Jim Schneider, Tony Jurado, Ted Miller, Rene Dasen, Art Schnarr, Doris Luethi, Durward Bogess, George Hill, Bill Long, Jim Hourihan, Mary Simmons, Frank Watkins, Sonny Wyant, Andrew Wooten, Bob Southwood, Judith Dickson, Jack Steinberg, Russ Curtis, and Bill Cogger.

Joe Voegtle, Drilling and Construction Supervisor, and Ed Koszalka, Studies Section Chief, passed away during the period.

The most significant natural event during the period was Hurricane Andrew, which struck south Dade County on August 24, 1992.

Areal Investigations

Appraisal of the Shallow Aquifers of the Lower East Coast—Project Chief: John Fish.

The objective of the study was to do a regional appraisal of the hydraulic, geologic, and water-quality characteristics of the shallow aquifer of the lower east coast. The study extended from fiscal year 1980 to fiscal year 1987 and was planned to include a phased-in approach that investigated Dade, Broward, and Palm Beach Counties simultaneously. This approach was changed to proceed county-by-county in order to have products available earlier in the study. The end date of the project was extended several times, and most of the work in Palm Beach was included in a later study by Leo Swayze and Wes Miller.

During the first phase of this study an extensive inventory of existing data from 2,200 wells was conducted and an annotated bibliography by Carmen Causaras was published in 1982. Reports documenting the availability of hydrologic, geologic, and chemical data for Broward, Dade, and Palm Beach Counties were authored by Roy Sonenshein and others and were published between 1982 and 1984.

The reports and results from this study proved to be some of the Subdistrict's most useful and in-demand products. These reports and an earlier reconnaissance by Parker (Parker and others, 1955) are the starting point for any study of hydrogeology in Dade and Broward Counties. This study was also the first to identify a potential aquifer, the Gray Limestone aquifer, that could be used for auxiliary supply.

Saltwater Intrusion—Throughout the period, the Subdistrict was deeply involved with the issue of saltwater intrusion on both the southeast and southwest coasts. The approaches to the problem included both numerical modeling and analysis of data from saltwater monitoring networks. In Dade County, Klein and Waller (1985) did a synopsis of saltwater intrusion through 1984, Sonenshein and Koszalka looked at trends from 1974–93, Klein and Ratzlaff (1989) examined changes in saltwater intrusion in the area of the Hialeah-Miami Springs well fields, Koszalka mapped the saltwater line in Broward County, and Fitzpatrick (1982 and 1986) looked at the problem in Cape Coral on the west coast.

Southeast Limestone Aquifer Systems Analysis, South Florida Subarea—Project Chief: Fred Meyer.

This project was one of five composing the Southeastern Limestone (Floridan) Aquifer Study whose overall objectives included (1) a complete description of the hydrogeologic framework and geochemistry of the system; (2) definition of the regional flow system, and; (3) assessment of the effects of large withdrawals of ground water and waste injection. This particular project was concerned with the Floridan aquifer system from Lake Okeechobee south in the region where the aquifer lies hundreds of feet below ground, and is too saline for most purposes.

In this area the aquifer is used for storage of liquid waste, as a source of brackish supply for desalination, and for the storage and later recovery of freshwater (ASR).

Mike Merritt examined the potential for the underground storage and recovery of freshwater in the Floridan by using numerical modeling techniques. His results were published in a Water-Supply Paper in 1985.

Other Saline Aquifer Studies—Because the shallow Biscayne aquifer was so highly productive, there had been little interest in the underlying brackish aquifers. However, as deep well injection of wastewater, ASR, and the possibility of using brackish water in RO facilities became technologically possible, the period covered saw a growing interest in the Floridan aquifer. The Southeast Limestone Aquifer Study looked at the Floridan regionally while other studies looked at it locally in regard to specific questions.

Dan Fitzpatrick identified and tested potential zones within the lower part of the Hawthorn Formation that could be used to store water from the Caloosahatchee for later recovery and use. His results were published in a 1985 report. Vicente Quiñones-Aponte did a similar study of an ASR well near Lake Okeechobee with Kevin Kotun and Joe Whitley and of an ASR well in Cape Coral with E.J. Wexler. Don McKenzie did a water quality study of recovered effluent from a Pompano Beach injection well.

Assessment of Canal Aquifer Interactions in the Surficial Aquifer System Using a Coupled Surface-Water and Ground-Water Flow Model, Broward County, Florida—Project Chiefs: E.J. Wexler and Eric Swain.

The objective of the study was to develop hybrid techniques for surface-water/ground-water flow modeling by modifying the USGS ground-water flow model (MODFLOW) to incorporate the flow routing techniques of the USGS surface-water flow model (BRANCH) to better simulate canal-aquifer interaction.

Ground-water and surface-water models were constructed and calibrated for south Broward County. The two models were interfaced and compared to a MODFLOW model to demonstrate that the linked model better simulated the ground-water/surface-water system. The hybrid model, called MODBRANCH, became a supported USGS model and was documented in a TWRI by Swain and Wexler, published in 1996.

The work done for this project led to a subsequent project in which MODBRANCH was modified to represent the canal-aquifer-wetland interactions widely found in the south Florida environment. This modification to MODBRANCH by Swain was published in 1993.

Water-Quality Studies

During the period covered, the Subdistrict was deeply involved in water-quality work. McKenzie and Waller looked at water quality in the canals in Boca Raton and Broward, respectively; the attenuation of stormwater runoff contaminants in Dade was studied by Waller, Klein, and Lefkoff and in Broward by Waller and Howie; McKenzie characterized the chemical characteristics of stormwater runoff from a highway bridge and examined stormwater management in Dade County; McKenzie also looked at water quality in the vicinity of the south Dade landfill and of recovered municipal effluent in Pompano Beach. The migration of septic tank effluent in Palm Beach County was studied by Wes Miller and in Broward County by Waller, Howie, and Causaras. Waller conducted numerous studies on the effects of agriculture on water quality and on water quality in and around Everglades National Park. Waller also looked at the extent of the plume of brackish water contaminating the Biscayne aquifer from a flowing artesian well at Chekika Hammock State Park. Howie examined the water-quality consequences of applying dried domestic sludge as a soil amendment in agricultural areas, and Hal Mattraw completed a study of water quality in trends in Conservation Area 3A.

GIS and Data Bases—As predicted by Aaron Higer, Geographic Information Systems (GIS) and spatial data bases became important tools in hydrologic investigations. Roy Sonenshein was a pioneer in developing GIS applications, and his publications established him as a national GIS expert.

Ft. Myers Field Office—The Ft. Myers office covered the area of Lee, Collier, and Hendry Counties in southwest Florida. Four to nine people were employed during the period of record, including both investigative and monitoring programs, although the monitoring program always predominated. Henry LaRose, who succeeded Frank Watkins as the hydrologist in charge of the Ft. Myers office in 1985,

completed reports with Ben McPherson on the Caloosahatchee River Basin in 1980, 1982, and 1983. LaRose also conducted a study on the plugging of old artesian wells, which because of degraded casings were contaminating potable aquifers. In 1981, Durward Boggess with Tom O'Donnell and former USGS hydrologist, Tom Missimer, published cross sections of Collier, Lee, and Hendry Counties. In 1986 Boggess and Frank Watkins produced a report on the surficial aquifer in Lee County.

Richard Krulikas freed some of his time from the Data Section to work with Jerry Giese on a study of recharge areas in Lee and Hendry Counties and to work with NRP researcher Jerry Brown on a study of the hydraulic effects of a series of sand channels in the water-bearing units of the intermediate aquifer system.

Stuart Field Office—The Jupiter Field Office became the Stuart Field Office in 1982. George Hill, the Office Chief, had transferred from California, but many of the long-time Stuart staff (Bill Scott, Gary Russell, Bill Long, Mike Dooley, and Wes Miller) transferred from the Subdistrict Office in Miami. The Stuart office covered Palm Beach, Martin, and St. Lucie Counties and had Data and Studies programs that were about equal. The office ranged in size from three to seven people.

From 1979 to 1983, the staff of the Stuart office worked with Ben McPherson (Miami) on an extensive study of the Loxahatchee River Basin and Estuary. In addition to defining the drainage basin characteristics, the study examined anthropologic changes in flow patterns, sediment transport, chemical characteristics, and floral and faunal communities. McPherson and Gary Russell authored a report on freshwater/saltwater distribution, and Russell and Carl Goodwin (Tampa) developed a circulation model of the estuary. Wayne Sonntag worked with McPherson on chemical and biological characteristics of the estuary and also looked at sediment loading to the estuary. MaryAnn Sabanskas and Bill Long assisted McPherson with the physical, hydrologic, and biological characteristics of the Loxahatchee basin and estuary.

Russell also worked with Richard Kane, who transferred from the Stuart Office to the Ft. Myers office, on a study of the effects of altered freshwater flows on circulation patterns within Matlacha Pass, which runs between Pine Island and the mainland.

Prior to 1989, most of the hydrogeologic investigations of the Palm Beach area were conducted out of the Miami office; Jack Fischer and Wes Miller both studied aspects of the surficial aquifer system in the Palm Beach area. Leo Swayze, also from Miami, and Miller studied a zone of secondary permeability in eastern Palm Beach County. In 1990, Miller became head of the Stuart Field Office and expanded the program to look at effects of urban and agricultural development on the surficial aquifer. Miller remained in charge of the Stuart Office until taking a disability retirement due to a head injury in 1991.

Hydrologic Monitoring

The period of record saw numerous changes in data monitoring as mechanical measuring devices were replaced by electronic and acoustic methods; remote transmission of data became a reality, sophisticated statistical techniques were used for data analysis, and geologists and engineers were employed to augment the work of hydrotechs.

John Warren and Jim Schneider were instrumental in the 1980 conversion of deflection vanes to electromagnetic flow meters, which signaled a major change from the past multidecade mechanical velocity indexing scheme to electronic (point velocity) indexing. Velocity indexing is one of the primary methods to monitor backwater conditions.

Aaron Higer and Ed Cordez experimented with remote data transmission technology from 1976 to 1981 and ended with mixed success based on the limitation of state-of-the-art Data Collection Platform (DCP) electronics of that period and the high incidence of lightning storms prevalent in South Florida. Finally in 1988 new technology DCP's began to be installed within the Miami Subdistrict and several significant cooperators began to rely on real-time telemetered data. Aaron Higer and Bill Haire were responsible for beginning the Subdistrict's conversion to DCP technology.

The Subdistrict was one of the few offices nationally in the forefront of AVM (Acoustic Velocity Meter) technology. In 1987 Russ Curtis and Mitch Murray worked with HIF to conduct tow tank and flood-plain verification tests to determine existing AVM precision and vendor capabilities. The results of these and other tests were documented in 1989 in WRIR 89–4090, which validated the AVM (line velocity) as a better velocity-indexing tool. In 1988–90 a portable, truck-mounted AVM was designed by an acoustic vendor to Miami specifications and used as a component of existing velocity indexing calibration.

These results were published in a WRIR, "Effects of Horizontal Velocity Variations in Open Channels," by Eric Swain.

Eduardo Patino took AVM technology a step further when he experimented with using the AVM acoustic gain signal to estimate sediment loads. He met with mixed success because of the limitations of the equipment of the day, but his work led to further studies on the St. Lucie Estuary that were more successful. The concept was still being tested and looked very promising at the end of the period of record.

Beginning in 1990–91 the Construction Unit, headed by Jack Overholser began to convert electromagnetic velocity indexing and some structure computation stations to AVM velocity indexing based on the result of the 1987–90 Miami AVM efforts.

In the early 1990's Russ Curtis procured the Subdistrict's first Acoustic Doppler Current Profiler (ADCP) and began testing the technology.

In August 1992 the Data Section faced its biggest challenge in the aftermath of Hurricane Andrew. In spite of the fact that most of the staff had been personally affected by the Hurricane, a large number of high-water measurements were made and all the stations that went down were quickly repaired or replaced. Mitch Murray produced an OFR compilation of inundation areas for South Florida. The study, requested by the Federal Emergency Management Agency, will be used to calibrate models of storm tides.

The Everglades Forever Act, passed by the Florida Legislature in 1993, delegated SFWMD as the major data-collection agency in South Florida. The role of the Data Section began to evolve to assist with the Water Management District with this responsibility.

Computer Section

At the beginning of the period of record, data processing was an auxiliary duty performed by Dave Maddy, a hydrologist, with two student assistants. In the early 1980's, Sharon Watkins came on duty as the Subdistrict's first full-time Computer Specialist.

ORLANDO SUBDISTRICT

By Joel Kimrey

The Orlando Subdistrict Office used two office name designations and two headquarters locations during the reporting period, 1979–94. The office began the period designated as the East Central Florida Subdistrict with headquarters in the Federal Building in downtown Orlando. The office designation was changed to Orlando Subdistrict in 1981, but headquarters remained in the Orlando Federal Building. A move to suburban Altamonte Springs was then effected in 1988, along with assumption of the present office designation. The move into leased space in Altamonte Springs offered several operational advantages, a major one being the opportunity to have office and adjacent warehouse space combined.

At the beginning of this period, the Orlando Subdistrict had a fully interdisciplinary WRD program that continued to grow in both size and technical sophistication throughout 1979–94. The Subdistrict staff grew from about 35 people in 1979 to about 55 people in 1994; and there was a commensurate increase in its operating budget from about $1.4 million to $3.9 million during the period.

The most significant hydrologic event of the 1979–94 period was likely the drought of 1981, which produced new record ground-water and surface-water lows in parts of the Subdistrict field area. The antecedent low rainfall resulted in cessation of flows in most of the upper basin of the Withlacoochee River in July 1981; potentiometric surface maps of the Upper Floridan aquifer indicated lower levels in many areas for September 1981 than for the preceding May—an also previously unprecedented observation. This drought was a contributing factor to the "Winter Park sinkhole," which achieved international notoriety because a number of expensive, imported automobiles were lost in the collapse in early May 1981.

Organization and Management

The Orlando Subdistrict was responsible for all WRD programs in the St. Johns River Water Management District (SJRWMD); the Withlacoochee and Green Swamp Basins of the Southwest Florida Water Management District (SWFWMD); and the Kissimmee Basin of South Florida Water Management District (SFWMD). This area, largest of the Florida

Subdistricts, includes all or parts of 21 counties in east-central and northeast Florida.

By 1994, the Subdistrict consisted of the headquarters office in Altamonte Springs and a field headquarters office in Jacksonville. The Ocala Field Headquarters was part of the Subdistrict from beginning of the period until it was phased out in 1980. Then, in 1983, the former Jacksonville Subdistrict merged with the Altamonte Springs Subdistrict as a Field Headquarters. Subdistrict activities were managed by the Subdistrict Chief and senior staff in Altamonte Springs and a Hydrologist-in-Charge, Jacksonville Field Headquarters. Program execution was shared by the Hydrologic Studies Section and the Hydrologic Records Section.

Personnel

Subdistrict Office Administration and Support—Joel Kimrey was the Subdistrict Chief from beginning of this period of WRD history to 1988, when he volunteered for a foreign assignment. He was succeeded by Wanda Meeks, from 1988 to 1991, who in turn was succeeded by Charles Tibbals, who served through remainder of the period.

Harry Rodis was the Assistant Subdistrict Chief from the beginning of the period until 1989. Internal reorganization following the retirement of Rodis resulted in the position not being filled again.

The position of Subdistrict Administrative Officer was held by Christine Hunter from its inception in 1982 until 1983. She retired and was succeeded by Carmine Scudero, who transferred from the West Virginia District to hold the position through remainder of the period. Carl Cash, Michael Holmes, and Roger Belles served successively as Subdistrict Computer Specialist.

Field Headquarters—Ocala: Richard E. Hedges was Hydrologist-in-Charge, Ocala Field Headquarters, from beginning of the period until his retirement in 1980. This office was then phased out by attrition and transfer of remaining personnel to other Florida WRD offices.

Jacksonville: In 1983, the former Jacksonville Subdistrict became a Field Headquarters of the Orlando Subdistrict, and Eugene Hayes served as Hydrologist-in-Charge from 1983 until his transfer in 1989. Subsequently, the direction of most investigative activities in Jacksonville, along with respective personnel, was phased into the Subdistrict headquarters office. Jacksonville then remained as a hydrologic data-collection and processing operation responsible for the northern part of SJRWMD. John Coffin acted as Hydrologist-in-Charge from 1989 to 1991 when James Sohm transferred in as Technician-in-Charge through the remainder of the period.

Hydrologic Studies—Robert A. Miller began the period of reporting as Chief, Hydrologic Studies Section; then continued as Chief, Surface Water and Water Quality Studies when the Section was split in 1990 until end of the period; he was also Subdistrict Surface Water Specialist during this period. The Orlando Subdistrict portion of the Statewide Florida Department of Transportation (FDOT) program grew significantly in size and sophistication under Miller's leadership.

Charles Tibbals served as Subdistrict Ground-Water Specialist from the beginning of the period until 1990 when the previous Hydrologic Studies Section was split, at which time he also assumed duties as Chief, Ground-Water Studies Section. Tibbals was appointed Subdistrict Chief in 1991. Early in the period he completed input to the Floridan aquifer Regional Aquifer-System Analysis (RASA) program with a regional digital computer model of ground-water flow in the Floridan aquifer system in east-central Florida and preparation of Professional Paper 1403–E. This led to a significant continuing aquifer modeling project in the Coop program in which Tibbals worked for several years to adapt RASA aquifer models to meet water-management needs.

Edward R. German combined the duties of Subdistrict Water-Quality Specialist and Project Chief responsibilities throughout the period of reporting. Earlier in the period he completed comprehensive interdisciplinary studies related to effects of urban development and waste movement and assimilation in wetlands related to construction and operation of Walt Disney World. He was then involved in a series of studies related to effects of land use and drainage wells on ground-water quality, methods for predicting wetland responses to hydrologic stresses, and geochemistry of lakes.

Louis Murray joined the Subdistrict staff in 1990 and assumed duties as Chief, Ground-Water Studies Section, in 1992. Murray, assisted by Keith Halford, developed and calibrated a more highly resolved digital computer model of the Floridan aquifer for the Orlando metropolitan area.

David Sumner entered on duty in 1991 and served as Subdistrict Ground-Water Specialist in 1993. He conducted studies related to unsaturated flow and transport under Rapid Infiltration Basins in western Orange County and evaluated various evapotranspiration (ET) models in a deforested part of the ridge area, central peninsular Florida.

A.T. Rutledge, on duty from the beginning of the period until his transfer in 1986, completed two key Volusia County ground-water studies: a county-wide reassessment of saltwater encroachment, and a quantitative evaluation of ground-water withdrawals for fernery irrigation in northwest Volusia. Rutledge also completed an areal evaluation of effects of land development on Floridan aquifer water quality in central Florida.

Trudy Phelps was responsible for a number of Subdistrict projects throughout this period. These included evaluation of ground-water potential, Geneva area, northeast Seminole County, and of the surficial aquifer system in Volusia County; delineation of recharge-discharge areas, SJRWMD; effects of wastewater disposal to the Upper Floridan Aquifer in the Gainesville and Ocala-Silver Springs areas; and (with Rick Spechler) saltwater encroachment in Jacksonville-Duval County.

Rick Spechler, also on duty throughout the period, conducted several projects related to mode of occurrence and quality of ground water in the Floridan Aquifer System in northeast Florida. These definitive studies have resulted in an improved understanding of processes and mechanisms of saltwater encroachment in northeast Florida.

George Schiner completed studies related to water-quality aspects of Floridan aquifer drainage wells and the water resources of Indian River and Osceola Counties prior to his retirement in 1990.

Donna Schiffer, on duty from initial hire in 1981 through end of the period, had responsibility for a number of projects related to occurrence and quality of surface water. Schiffer's studies of effects of highway runoff on surface-water and sediment quality were significant contributions to the FDOT program.

Warren Anderson completed documentation and reporting on 1981 drought conditions in east-central Florida prior to his retirement in 1985, after having served as the Subdistrict's preeminent surface-water hydrologist for many years.

The individual investigators cited above were assisted in field and office activities by an able group of Hydrologic Technicians. Principal technicians in support of interpretive studies during this reporting period were Charles Laughlin, Lewis Burgess, Edward Simonds, and W.M. (Max) Brogdon.

Hydrologic Records—Larry Fayard moved from the Louisiana District in late 1978 to assume duties as Chief, Hydrologic Records Section, and continued until his retirement in late 1992. Under Fayard's leadership the Records Section managed a number of investigative projects with large data elements in addition to the basic network activities. The Section achieved several firsts during this period, including the following:

- First office in Florida (and second or third in WRD) to process time-series data on a local computer, prior to the advent of WRD's minicomputers;
- First office in Florida (perhaps in WRD) to output data reports using personal computers; also among first to print reports on 8.5X11 paper instead of tabloid format.
- Among first offices in WRD to use electric data loggers (instead of strip chart or punch tape) in production mode, particularly for data collection/processing/interpretation in support of hydrologic investigations.
- Among first offices in WRD to incorporate Acoustic Velocity Meters (AVM's) as permanent installations to record continuous flow at tidal and other sites that had previously been all but ungageable.

Principal Hydrologic Technicians in support of hydrologic data activities during the period of reporting included Robert Bird, John Oberg, Howard George, Jim Sohm, Edward Simonds, and Richard Craig.

Scott Gain succeeded Fayard as Chief, Hydrologic Records Section, on Fayard's retirement in 1992. Gain also contributed to the FDOT investigative program.

Program Highlights

Cooperative Support—Throughout the period of reporting, major support for the hydrologic records program was from the three Florida Water Management Districts in which the Subdistrict field area lies. Funding for hydrologic records increased about 50

percent during the period and accounted for 55–60 percent of the total program funding by 1994.

Support for the investigative program changed significantly during the period, and there was an accompanying change in project emphasis. Early in the period, most cooperative support for investigations was from local governments including Alachua, Brevard, Duval, Flagler, Lake, Orange, Seminole, and Volusia Counties and the Reedy Creek Improvement District (RCID). Project emphasis tended to be problem oriented with scope somewhat limited to the cooperator's area of political jurisdiction. As the period progressed, the SJRWMD assumed a larger part of investigative funding and the nature of projects broadened in scope to include more areal and regional analyses, particularly by digital computer modeling, and process-oriented studies, such as evapotranspiration and fate of contaminants in ground water and surface water. These more sophisticated and complex projects commonly were supported by multiple cooperators.

Selected Programs—A number of major investigative programs were successfully undertaken during the period of reporting. Several, which are considered of special significance, are noted below.

Drainage Well Hydrology: Cooperative interest, particularly from Florida Department of Environmental Protection (FDEP), resulted in a series of investigations related to hydrogeologic aspects of gravity drainage wells particularly those that emplace surface water into the Floridan aquifer. Early in period of reporting, Kimrey and Fayard conducted a statewide inventory and analysis of the role of drainage wells throughout Florida. Specific aspects of the geochemical and hydraulic aspects of Floridan aquifer drainage wells in central Florida were later investigated by Ed German, George Schiner, Al Rutledge, Trudy Phelps, and Anne Bradner.

Volusia County: Essentially all recharge to the Upper Floridan aquifer in Volusia occurs within the county, and most discharge from this aquifer occurs at or near county boundaries. Over the years Volusia County has supported a long-term program of hydrogeologic investigations to provide an exceptional understanding of the system as background for its development and management. Studies during this period of reporting addressed such varied subjects as potential recharge, yield, and updated water quality of the Upper Floridan aquifer; potential of the surficial aquifers; and problems related to heavy withdrawals of ground water in relation to fernery irrigation. During this period Rutledge, Phelps, and Kimrey authored significant reports for the Volusia County program.

Reedy Creek Improvement District: The RCID, as the government-chartered agency that manages the land and natural resources of Walt Disney World (WDW), provided an excellent field laboratory for study of effects of urban development on water resources. During the period of reporting, there were opportunities for analysis of overall effects on water resources of WDW construction and operation as well as more specialized studies related to waste-assimilation capacity of wetlands and the hydrogeologic effects of rapid infiltration basins. German was the lead person for most RCID activities during most of the period, and David Sumner and Donna Schiffer took on increasing project responsibilities beginning in 1993.

Florida Department of Transportation: The Orlando Subdistrict Office (SDO) participation in the statewide Coop program with Florida Department of Transportation (FDOT) provided the opportunity for continuing evaluation of effects of highway construction and operation on water resources. These projects have included a long-term analysis of potential highway construction on lakes; effects of runoff management on water quality; and function of detention ponds in water quality improvement. SDO personnel who significantly contributed to these studies included Bob Miller, Edward H. Martin, Donna Schiffer, and Scott Gain.

Area and Regional Ground-Water Modeling: The SDO was heavily involved in ground-water modeling since digital computer models first became available to the WRD program. During period of reporting, Charles Tibbals completed the east-central Florida part of the Floridan aquifer RASA computer model and then worked several years with cooperative funding to refine and adapt the RASA models to meet Florida WMD management needs (the so-called "movable model"), which, in turn, has led to continuing programming of areal investigations making extensive use of digital models. Later in the period Lou Murray and Keith Halford developed and calibrated a more highly resolved model for the Orlando metropolitan area.

Ground-Water Occurrence and Quality, Jacksonville Area: The Jacksonville area (Duval County) has the largest concentration of population and water use in northeast Florida and is entirely dependent on

the Floridan aquifer for public water supplies. This has resulted in a continuing series of significant investigations related to use of the Floridan in northeast Florida. These investigations have included occurrence and significance of saline ground water; location, quality, and quantity of ground-water discharge to the upper St. Johns River; and improved definition of the various aquifer zones and their relation to distribution and control of ground-water quality. Rick Spechler led several of these projects; other SDO personnel who significantly contributed to this series of studies included David Brown and Trudy Phelps.

JACKSONVILLE FIELD HEADQUARTERS, 1979–94

By David Brown

The Jacksonville Field Headquarters had three office name designations during 1979–94. It began the period designated as the Northeast Florida Field Headquarters with headquarters in Jacksonville and with Warren Leve serving as Hydrologist-in-Charge. The office designation was changed to the Northeast Florida (Jacksonville) Subdistrict in 1982, and Leve was designated Subdistrict Chief. Upon Leve's retirement in 1983, the office was reestablished as the Jacksonville Field Headquarters under the direction of the Orlando Subdistrict Office, and Eugene Hayes served as Hydrologist-in-Charge.

The Jacksonville Field Headquarters had a fully interdisciplinary WRD program at beginning of the period. The staff remained relatively constant at about 12 people from 1979 to 1987; from 1988 to 1994, the staff gradually declined to about 8 people. During this period, several of the hydrologists were transferred to the Orlando Subdistrict where most of the investigations were headquartered. By 1990, the Field Headquarters staff was almost entirely involved in the collection of hydrologic data and was under the supervision of the Hydrologic Data Section, Orlando Subdistrict.

Administrative functions in Jacksonville were handled by Brenda Hanna (1979–80) and Jan (Douglas) Loggins (1981–94) with assistance from Pam Hatfield (1982) and Jackie Bickner (1983–85). Computer services and support were handled by Mike Holmes (1983–90, transferred to Tampa), Sandra Dickerson (1986–94, transferred to Orlando), and Patricia Bradt (1985–92).

Roy Stone served as Surface-Water Specialist and provided technical guidance to the Hydrologic Technicians until his transfer to Alabama in 1981. Al Summerlin served as Supervisory Hydrologic Technician until his retirement in 1985. The Hydrologic Technicians that served during all or part of the period include Neil Armingeon, Richard Broxton, Charles Crick, Richard Hayes, Clifford (Buddy) Phillips, Michael Reedy, and Marlon Savarino.

During this period, hydrologists headquartered in Jacksonville conducted numerous investigations. Some key personnel include Craig Bentley (1979, hydrogeology), David Brown (1979–86, hydrogeology), Bernard Franks (1979–80, hydrogeology), Paul Hampson (1981–88, chemistry), Trudy Phelps (1979, hydrogeology), Rick Spechler (1980–88, hydrogeology), and Thomas (Tommy) Thompson (1979–80, chemistry).

Program Highlights

Throughout 1979–94, major support for the hydrologic records and investigation programs was from the St. Johns River Water Management District, the City of Jacksonville/Duval County, St. Johns County, and the Ocean, Highway, and Port Authority of Nassau County.

St. Johns River Water Management District—The Jacksonville Field Headquarters has had a close relationship with the SJRWMD. This included continuous ground- and surface-water data-collection programs to determine the quality and quantity of water. One major program in cooperation with SJRWMD included a "Deep Aquifer" investigation to determine the depth and movement of saline water in the lower zones of the Floridan aquifer system in northeast Florida. Deep monitor wells, which were drilled to depths of over 2,000 feet, were installed in areas prone to saltwater intrusion. Hydrogeologic information was obtained during the construction of these wells to define the location, yield, and water quality of the various water-bearing zones in the aquifer.

City of Jacksonville/Duval County—The Jacksonville area (Duval County) has the largest concentration of population and water use in northeast Florida and is dependent on the Floridan aquifer. Various agencies within the City of Jacksonville have cooperated on a number of investigations of the quality and quantity of ground water in the Floridan aquifer.

Detailed subsurface investigations of the hydrogeology of the aquifer were done, including major water-quality and aquifer-testing programs and the development of ground-water flow models to identify areas within the county to develop future water supplies and to better manage the county's existing water supplies.

St. Johns County—Rapid development in St. Johns County required the county to locate and develop additional sources of water. As a result, the county cooperated on an investigation to determine the ground-water resources of St. Johns County. Based on results of the investigation, areas for development of a regional well field were identified, test wells installed, and detailed aquifer tests were conducted.

Ocean, Highway, and Port Authority—Saltwater intrusion was occurring in a number of deep industrial supply wells in Fernandina Beach, Nassau County. The Authority requested the Survey to investigate the occurrence of saltwater intrusion, determine the source(s), and recommend methods to prevent additional intrusion. A deep test well was installed in the area of known intrusion, and detailed hydrogeologic and geophysical information was obtained during and after completion of the test well. It was determined that the saltwater intrusion was caused by upward movement of saline water from zones in the aquifer that were penetrated by some of the deeper industrial supply wells. In order to prevent further saltwater intrusion, all of the deeper industrial supply wells were plugged back to seal off the deeper saline water-bearing zones.

TAMPA SUBDISTRICT

By Craig Hutchinson

In 1979, the Tampa Subdistrict Office management consisted of Robert L. Knutilla, Subdistrict Chief, and Joe Stewart, Assistant Subdistrict Chief. Although they were not formally recognized as Section Chiefs in the WRD Personnel Directory, supervisory hydrologists included Terry Thompson, Chief of Hydrogeologic Studies (ground water); David Brown, Chief of Reports; Jim Turner, Chief of Hydrologic Studies (surface water); Boyd Joyner, Chief of Environmental Studies (water quality); and Roman Mycyck, Chief of Hydrologic Records. Horace Sutcliffe was the Hydrologist-in-Charge of the Sarasota Field Office. Office personnel consisted of 56 people in Tampa and 3 people in Sarasota. In addition to the mentioned leaders, there were 18 hydrologists, 24 hydrologic technicians, and 9 administrative and other support personnel in the two offices.

Knutilla encouraged the transition from graphical ground-water level recorders to punch-tape data collection and initiated review of the surface- and ground-water data networks. He transferred to New Mexico in 1984, and Tom Yorke transferred from Pennsylvania to become Tampa's fourth Subdistrict Chief in 1984. He came to an office that was running smoothly and, through his charismatic personality, inspired continued production.

Yorke supported expansion of the Subdistrict involvement in water-quality studies in accordance with the national thrust. Under his leadership, the Coop program with the Southwest Florida Water Management District (SWFWMD) flourished. He transferred to Reston in 1989.

Walter Aucott transferred from Tallahassee to become Tampa's fifth Subdistrict Chief in 1990. Aucott was an excellent manager in that he delegated authority and introduced supervisors to new methods for tracking projects to their scheduled completion. He also demonstrated that the civil service system could actually be used to remove unproductive employees. Under Aucott's leadership, a Coop program began with the U.S. military to assess hazardous waste sites at MacDill Air Force Base. At its peak in 1993, this program accounted for about one-fourth the Subdistrict's annual budget.

Horace (Sut) Sutcliffe, Hydrologist, and Geronia (Moe) Bowman and Larry Windom, Hydrologic Technicians, provided the heart and soul of the Sarasota Field Office. Together they sold projects, operated a 29-station multicounty data network, and ensured 100-percent funding for the Subdistrict geophysical logger. Sutcliffe retired in 1983 and passed away a few short years afterward.

The saddest moment for Subdistrict personnel during the 1979–94 period occurred in March 1988. Engineer Steve Henderson suffered a heart attack while supervising the augering of shallow wells at a project site in eastern Hillsborough County. Colleagues Bob Wylie, Lew Burgess, and Lari Knochenmus made every effort to resuscitate Steve, but he succumbed at the site. Steve was survived by his wife Susan and 2-year-old daughter Molly. He was only 39 years old.

Personnel and Funding

The period between 1979 and 1994 was stable programwise for the Subdistrict. Although emphasis shifted to various national thrust programs, total personnel and funding were fairly level. In 1979 and 1994, Subdistrict personnel totaled 59 and 67, respectively. During this period, the SWFWMD remained the Survey's principal cooperator. However, SWFWMD increased its own capability for conducting projects, and hence, relied less on the USGS for technical expertise. The office budget reflects this in that in FY1979 the SWFWMD–USGS program totaled $1.7 million with $920,000 for projects and $778,000 for data collection. In FY1994, the program totaled $2.0 million with $742,000 for projects and $1.3 million for data collection and continuing data-related activities. Part of this shift in funding was due to the transfer of potentiometric-surface mapping from a project ($72,000 in 1979) to a data activity ($147,000 in 1994). However, the downsizing of the project work and rise in data collection indicates SWFWMD's commitment to its in-house projects and reliance on the USGS to collect data.

Cooperators and Principal Programs

In addition to the principal cooperator, the SWFWMD, local cooperators during the period included the cities of Bradenton, Clearwater, Pinellas Park, St. Petersburg, Sarasota, and Tampa and the counties of Hernando, Hillsborough, Manatee, Pasco, Pinellas, Polk, and Sarasota. Cooperating State agencies included the Englewood Water District, Florida Institute for Phosphate Research, Tampa Port Authority, West Coast Regional Water Supply Authority (later Tampa Bay Water), Florida Department of Environmental Regulation (later the Florida Department of Environmental Protection), and Tampa Bay Regional Planning Council. Federal cooperators included the National Estuary Program, MacDill Air Force Base, the U.S. Army Corps of Engineers, and the Department of Energy. The USGS wholly funded subsurface-waste storage, regional aquifer systems, and national water-quality assessment projects. With 23 cooperators to cultivate and 3 USGS programs to satisfy, the Subdistrict management team was very busy.

Hydrologic Data Collection

Roman Mycyck transferred from New York to the Southwest Florida Subdistrict in 1979 to head up the Hydrologic Records Section, which was formally named in 1981 and renamed the Hydrologic Data Section in 1988. Mycyck retired in 1990 and John Coffin transferred from Jacksonville as his replacement. Under their guidance, the SWFWMD's share of funding for the data program grew; however, data-collection sites reported in the palm tree books "Water Resources Activities in Florida" declined from more than 2,000 in 1979 to about 600 in 1994. While the total number of sites was being reduced, more sophisticated data-collection methods were being implemented at critical sites. Digital punch-tape recorders were replaced with electronic data-loggers recorders at all sites, and satellite telemetry was implemented at selected surface-water and ground-water sites to gain real-time data.

In 1981, the Hydrologic Records Section was split into north and south units headed by supervisory hydrologic technicians Lewis Fletcher and Junior Ogle, respectively. Ogle retired in 1987. Under reorganization, the Hydrologic Data Section included two supervisory hydrologic technicians: Lewis Fletcher, head of the Hydrologic Data Assessment and Publication Unit, which compiled records and the annual data report; and Roger White, who transferred to Tampa from the Louisiana District as head of the Field Coordination and Support Unit, which provided technical support for both hydrologic studies and operation of the data network. In 1991 the two Units were renamed the Data Publication and Special Projects Unit and the Network Surveillance Unit, respectively, and technical support was no longer provided routinely for hydrologic studies.

Another reorganization in 1992 under John Coffin eliminated subdivisions within the Hydrologic Data Section. The Section has the proud distinction for timely production of annual data reports, which list ground-water levels, lake stages, stream discharges, and chemical analyses for the data network.

Interpretive Studies

Terry Thompson, Chief of Hydrogeologic Studies (ground water); Boyd Joyner, Chief of Environmental Studies (water quality); and Jim Turner, Chief of Hydrologic Studies (surface water) supervised interpretive studies of the Southwest Florida

Subdistrict in 1979. Thompson transferred to Reston in 1989 and was replaced by Craig Hutchinson. Hutchinson transferred to the United Arab Emirates in 1993 and was replaced by Arturo Torrés from San Juan, Puerto Rico. Joyner retired in 1979, and his responsibilities were assumed by Turner. Turner transferred to Raleigh, N.C., in 1982 and was replaced by Briane Adams from Pueblo, Colo. Adams transferred to Atlanta in 1987 and was replaced by Carl Goodwin, who renamed the Section "Environmental Studies." Goodwin transferred to Tacoma, Wash., in 1990 and was replaced by Kathi Hammett.

Hydrogeologic Studies—Hydrogeologic studies pertain mainly to ground-water hydrology. During the 1979–94 historical period, emphasis was on refining the hydrogeologic framework, computer modeling of the aquifer systems, and chemistry of the ground water. Two important contributions to the understanding of the hydrogeology of west-central Florida included defining the intermediate aquifer system between the surficial and Floridan aquifer systems, and subdividing the Floridan aquifer system into "upper" and "lower" units. Ground-water models included areal models to evaluate effects of pumping at the Cypress Creek, Morris Bridge, and Cross Bar Ranch well fields; subregional models incorporating pumping from eight major well fields in an 875-square-mile area north of Tampa, projecting ground-water declines in a 3,500-square-mile-area encompassing the Highlands Ridge, and estimating hydrologic effects of the southward progression of citrus agriculture into De Soto and Hardee Counties; a large Regional Aquifer-System Analysis (RASA) model covering 10,000 square miles in west-central Florida; cross-sectional models perpendicular to the gulf coast to analyze saltwater intrusion; a model to estimate leakage between Tampa Bay and the Upper Floridan aquifer; an analytical model for determining areas of contribution to public-supply wells; and solute-transport models to simulate the effects of injecting millions of gallons of wastewater into the Lower Floridan aquifer between Pinellas and Sarasota Counties and to simulate withdrawing brackish water in Pinellas County for reverse-osmosis treatment. Paul Ryder, Jack Hickey, Dann Yobbi, Lari Knochenmus, Craig Hutchinson, Patty Metz, and Gary Mahon were the principal investigators on these modeling projects. A unique product of one modeling study was a 1993 video report that demonstrates animation of convection around a well that injects fresh wastewater into the saltwater-filled Lower Floridan aquifer.

Hydrogeologic reconnaissance studies were conducted on aquifer systems in the Sarasota–Port Charlotte area, coastal areas of Citrus and Hernando Counties, Hernando County, Pasco County, Hardee and De Soto Counties, Sarasota and Charlotte Counties, and the Sulphur Springs and Citrus Park 7.5-minute quadrangles. A reconnaissance also was made of the Venice clay in Sarasota County and of sinkhole distributions in the SWFWMD. Principal investigators on the reconnaissance studies were Richard Wolansky, Judy Fretwell, Dan Duerr, Craig Hutchinson, Joe Stewart, Miguel Corral, Lynn Barr, and Bill Sinclair.

Hydrogeologic studies emphasizing concern for ground-water quality included reconnaissance studies of the saltwater-freshwater interface in the northern half of the Subdistrict, effects of garbage dumps and wastewater holding ponds on ground water in Pinellas County, contamination through sinkholes in the SWFWMD, sources of anomalously high sulfate concentrations in the Upper Floridan aquifer, and potential for nonpoint contamination of the Upper Floridan aquifer in the SWFWMD. Principal investigators on these studies were Mario Fernandez, John Trommer, Laura Sacks, and Amy Swancar.

In 1991, the USGS began a study of nitrate contamination in the ground water around the golf courses at MacDill Air Force Base in south Tampa and by 1994 was deeply involved with nine contamination assessment projects at the base. A separate military studies team led by George Kish was dedicated to site-specific assessments of soil and ground-water contamination by lead, waste oils, fuels, solvents, pesticides, and PCB-filled capacitors. The increase in project work at MacDill coincided with the national thrust coordinated at USGS Headquarters through the Department of Defense Environmental Conservation Program.

Personnel from the Southwest Florida Subdistrict were involved in numerous other projects that do not fall within the categories described above. Among these were studies to delineate sinkhole-type areas, preparation of semiannual potentiometric-surface maps for dry- and wet-season conditions, compilation of aquifer tests, hydrogeologic mapping of aquifers and confining units, evaluation of environmental effects of phosphate mining and subsequent reclamation, and evaluation of limestone secondary porosity using borehole televiewer and geophysical logs. Inves-

tigators involved with these projects included Bill Sinclair, Richard Wolansky, Terry Thompson, Bill Lewelling, Dan Duerr, and others.

Hydrologic/Environmental Studies—Hydrologic/environmental studies pertain mainly to surface-water hydrology. During the 1979–94 historical period, the largest hydrologic/environmental studies of the Southwest Florida Subdistrict included the last 4 years of a 13-year research project at Tampa Bay led by Carl Goodwin and a 6-year research project at Charlotte Harbor led by Ben McPherson. Both projects produced circulation models for predicting rates of flushing by river inflow and for the movement of hypothetical contaminant spills. A related modeling project completed by Carl Goodwin in 1987 produced the Subdistrict's first eye-popping visual animation of the flushing action of hypothetical tidal gates at Cape Coral. Hydrodynamic models also were used by Kathi Hammett to study flushing characteristics of Kings Bay in Citrus County and Sarasota Bay. Marine research projects were conducted by Dave Schoellhamer on sediment resuspension by tidal currents, storms, and ship wakes in Tampa Bay and by Ben McPherson on light attenuation at benthic and shoreline seagrass environments in Tampa Bay and Charlotte Harbor. Other major hydrologic/environmental research projects of the Subdistrict used energy budget techniques to estimate evapotranspiration at four native vegetation areas in central Florida and to estimate evapotranspiration and water budgets at Lake Lucerne and Lake Barco. Principal investigators on these projects were Mike Lopez, Bill Bidlake, Briane Adams, and Terrie Lee.

During the 1979–94 historical period, reports generated from ongoing lake and estuarine studies were completed for stage-outflow relations of 89 lakes in the SWFWMD and hydrologic conditions for the Winter Haven chain-of-lakes and Lake Hancock in Polk County, Lakes Jackson and Placid in Highlands County, Lakes Padgett and Saxon in Pasco County, and Lake Carroll in Hillsborough County. Principal investigators on these studies were Kathi Hammett, Bill Sinclair, Steve Henderson, and Yvonne Stoker. Studies of estuarine hydrology, including relations of stream discharge and Gulf of Mexico tide to movement of the freshwater/saltwater interface, were conducted for the Alafia, Little Manatee, Weeki Wachee, Homosassa, Chassahowitzka, Crystal, Anclote, and Myakka Rivers. Principal investigators on these studies were Mario Fernandez, Dann Yobbi, and Kathi Hammett.

Support for Scientific Studies

The period 1979–94 was one of great technological change, and much behind-the-scenes effort was needed to support hydrologic data and scientific programs. In 1979, time-and-attendance cards were keypunched and transmitted from the Subdistrict's card reader to the Headquarters computer. In 1994, time-and-attendance data were transmitted by phone line from a workstation. In 1979, reports were processed by a clerk-typist from the author's handwritten original and illustrations were drafted with pen and ink. In 1994, word processors and graphics programs were used by several authors to prepare their own reports from first draft to approval. In 1979, the Subdistrict Office had a key-punch machine, card reader, and printer that were linked to a computer at USGS Headquarters. In 1994, nearly every desk had a workstation linked to a central computer in the office.

Administrative Services—In 1979, administrative services including training, billing, and budget preparation were the responsibility of Joe Stewart, the Assistant Subdistrict Chief. The Subdistrict's first Administrative Officer, Gail Nagle, was hired in 1980 to supervise the newly formed Administrative Services Section. She assumed many of Stewart's administrative duties and additional duties such as memorandum typing, telephone greeting, time-and-attendance, and travel authorizations. Many of these functions were streamlined under her supervision. Gail left in 1986 and was replaced by Sonny Wyant, who transferred to Tampa from Miami. Sonny and his crew of three kept the front office running smoothly for many years.

Reports Unit—In 1979, David Brown oversaw the production of all Subdistrict reports. He was assisted by Judith DeVarnne, Editorial Assistant, and Richard Clayton, Cartographic Technician. David transferred to Jacksonville in 1980. The Hydrologic Reports Section was formally named in 1981 and was headed by Kathi Hammett. After about a year, Hammett gave up this position to Dan Duerr, who served for 3 years, finally giving it up to DeVarnne, who had been reclassified as Writer-Editor. DeVarnne and Clayton were joined by Annette Seidenfeld and Evelyn Artis in 1984, and this team produced hundreds of high-quality reports for the Subdistrict. In

1994, Devarnne transferred to Sacramento and the position was occupied once again by Dan Duerr.

Computer Services—The period 1979–94 was the golden age of computerization and transition for the Subdistrict. A minicomputer was installed in 1982 and the old keypunch machines and card readers were mothballed. George Karavitis transferred to Tampa as head of the new Computer Services Section. Under his guidance and instruction, and with assistance from loyal computer operator Judy Scott, Subdistrict personnel soon became proficient with the various terminals used in the new system. George transferred to the Hydrologic Instrumentation Facility in Mississippi in 1985 and was replaced by Jay Kiesler, who transferred to Tampa from Kentucky. In 1988, the Computer Services Section was renamed the Information Management Section and was charged with producing some basic-data reports for cooperators and processing all data requests in addition to keeping the computer system up and running. At about this time, Larry Sanders was hired, and he was proficient on the new specialized workstation, which could be used to animate and visualize ground- and surface-water models—a stunning revelation compared to the old method of thumbing through reams of computer printouts. Kiesler transferred to Reston in 1990 and was replaced by Mike Holmes from Jacksonville. Under Holmes, the Section was renamed the Computer Support Unit, and individual terminals were replaced with workstations and personal computers.

GEORGIA

By Richard E. Krause, *including information provided by* Harold G. Golden, James B. (Jim) McConnell, David C. Prowell, Thomas R. (Bob) Dyar, Mark J. Sweny, Merritt E. Blalock, and Carolyn A. Casteel

INTRODUCTION

The Georgia District underwent extensive yet controlled growth during the period 1979–94. Funding, personnel, and program all increased substantially. New, innovative, and diverse programs were sought and developed, and the personnel needed to staff them were acquired. Management took risks in programming, staffing, and fiscal matters to build the program. Even with the risks taken and substantial growth, there were no significant fiscal or program setbacks. During the period, the program nearly tripled, and staff nearly doubled. Staff included world-renowned researchers, of which five were in the Research Grade Evaluation Program and advanced through the process successfully. The District also had four Merit Proposal winners. The District was liberal in training and symposium and conference participation because of management's philosophy and support. This was also made possible by having adequate funding, which resulted in a fiscally strong program. Diverse programs and studies were sought, which together with a well-funded program, attracted high-quality staff. This circular cause and effect produced a "critical mass" of a healthy, strong, robust, diverse program, staff, and budget enjoyed by the District. By the end of the period, the Georgia District bore little resemblance to the District that existed at the beginning of the period.

ORGANIZATION, MANAGEMENT, AND PERSONNEL

As the period began, the Georgia District consisted of a large Headquarters Office in Doraville, a suburb of Atlanta, and small Field Offices in Brunswick, Savannah, and Tifton. During the period, a Field Office was opened (Albany, in 1981) and another closed (Brunswick, in 1983) as emphasis in hydrology shifted from the coast to the agricultural region of the State in the early 1980's. Although the Southeastern Region office moved to the Richard B. Russell Federal Office Building in downtown Atlanta at the beginning of the period (1979), the District resisted pressure to collocate with them. District management argued the need to be out of the downtown area because of the field-oriented nature of its work. However, the District did share building space with one of WRD's two National Water Quality Laboratories, which also moved there in 1979. This collocation proved to be very beneficial to the District during the period.

District Headquarters, Atlanta

Office of the District Chief.—In 1979, the District Office was in its fifth year of a 5-year lease in office space in Doraville, a suburb northeast of Atlanta. In 1988, the District moved to new office space a few miles northeast of its Doraville location toward Norcross. The National Water Quality Laboratory, which was collocated with the District, closed in

1986, and the District included substantial laboratory space in its new facilities. While in Doraville, the District relied heavily on the National Water Quality Laboratory next door, not only for analytical services but also for stimulating collegial interaction and collaboration between Laboratory and District scientists. It was this interaction that led to the transfer of many laboratory employees to the District during and after the laboratory relocated to Arvada, Colo.

John George was the District Chief in 1979, having been in the position since 1968. In 1980, George transferred to the Southeastern Region office as Program Officer. After a short period of vacancy, Jeff Armbruster was selected and transferred from Maine to be the Georgia District's third District Chief. Armbruster was the District Chief until 1990, when he transferred to the Office of the Southeastern Regional Hydrologist as Southeastern Region Coordinator for the National Water-Quality Assessment (NAWQA) Program. Timothy Hale, who had been one of three Assistant District Chiefs under Armbruster, became Georgia's fourth District Chief and served in that position through the end of the period.

Assistant District Chiefs under John George were Harold Golden and Harlan Counts. Harold Golden continued in the role of Assistant District Chief under Jeff Armbruster until Golden's transfer to the Southeastern Region in 1988. Armbruster had three assistants during the remainder of his term: Timothy Hale, Chief, Hydrologic Analysis and Computer Applications Section; Richard (Rick) Krause, Chief, Hydrologic Studies Section; and William Stokes, Chief, Hydrologic Records Section, were assistants to Armbruster until his transfer in 1990. Krause and Stokes were assistants to Hale through the end of the period.

District secretarial duties in 1979 were handled by the Administrative Section; Cynthia Lott doubled as Chief, Administrative Services Section, and Secretary to the District Chief. Patricia Bentley became the District Chief's first Secretary in 1980 and served in that position until 1982, when Mary Ballew replaced her. Ballew was Secretary from 1982 to 1993; Rachael Reece was Secretary from 1993 through the end of the period.

Administrative services were handled by Cynthia Lott (1979), Jo Nell Stancil (1980) Carolyn Casteel (1981), Norbert Bengston (1982–84), Patricia Clark (1985–86), and Sylvia McClain (1987 through the end of the period). Administrative Services Section support staff fluctuated between three to five people during the period.

When the period began in 1979, there was no section devoted to reports preparation and publication. Instead, reports were developed out of the various sections—data reports from the Hydrologic Records Section (in a one-person unit called the "Data Processing and Report Unit") and interpretive reports generally from the Hydrologic Studies Section. A Reports Unit was created in 1980, and Charles Cressler, a Hydrologist/Geologist, served as Chief of the Unit until his retirement in 1988. The Unit had an Editorial Assistant who typed the reports and a Cartographic Technician who prepared illustrations and graphics and prepared the reports in camera-ready format. Reports Unit Chiefs following Cressler were Sandra Cooper (1988–89), Helen Peterson (1990–92), and Perry Olcott (1993 through the end of the period). By the end of the period, the Reports Unit had gone from typing and scribing and pen-and-ink cartography to text editing and computer-generated illustrations and graphics.

There was no computer services unit in 1979, but various computer-related activities were being conducted throughout the technical sections in the District, especially in the Hydrologic Studies Section and Technical Support Section. Computer applications were chiefly for data processing and manipulation and ground-water modeling and were project-specific. In 1979 and into the early 1980's, most computer jobs were run on a microcomputer using BASIC programming language. Ground-water modeling was done on a mainframe housed at the USGS Central Laboratory next door or were run as batch jobs and processed using a time-sharing method in which terminals dialed up to a computer at the Johns Hopkins University Applied Physics Lab for a fee. Other jobs were run using a mainframe in Reston, Va., by a dial-up using JCL (Job Control Language). Several types of computers were used to get the job done, but there was no overall District support for computer activities, especially for nontechnical uses. Seeing the need for District support of computer activities, Armbruster selected Merritt Blalock to oversee such activities. Blalock did so within the Office of the District Chief.

Around 1983, the USGS went to a more standardized computer environment with the implementation of minicomputers throughout the Survey. This computer technology was known as DIS1 (Distributed Information System 1). The first minicomputer at the

Georgia District Office had a 4-megabyte memory and three 630-megabyte hard drives. The cost was $246,000. The ADAPS program was written for the minicomputer and provided a general water data base that was standardized throughout the Survey for the first time. An administrative data base, AFIMS, was also implemented, which facilitated the processing of all payroll and budget information. Graphics packages such as DISSPLA and Surface3 enabled Georgia District scientists and engineers to create plots, charts, and maps for their reports.

In the late 1980's, the USGS introduced a new phase in computer implementation called DIS2. The goal was to migrate to a high-performance operating system for all applications, and a contract was procured for the hardware and software required. The Georgia District participated in this procurement and also helped conduct some testing.

In 1984, the District participated in development of the first prototype Interactive Controller Subsystem (ICS) of WRD's National Water Information System. The software development team, led by T.R. (Bob) Dyar, was responsible for ICS design specifications, program specifications, training and users guide, design review, systems testing, development, alpha testing, beta testing, and implementation of maintenance.

Merritt Blalock led the Computer Unit from 1982 to 1987, when he transferred to the Northeastern Region as Regional Computer Specialist. Mark Sweny transferred to the Unit from the Southeastern Region office in 1986 and took over the Unit when Blalock left. Sweny continued in the position until 1992, when a Computer Services Unit was created within the Office of the District Chief. Mark Sweny was selected as Chief and continued in the position through the end of the period.

Hydrologic Records Section.—The Hydrologic Records Section had two to three units under its purview and management at various times during the period: the Hydraulics Unit and the Hydrologic Data Unit for the entire period, the Data Processing and Reports Unit in 1979, and the Urban Hydrology Unit from 1992 through the end of the period. Field Headquarters in Doraville and Tifton also were under the management of the Hydrologic Records Section. Bill Stokes was Chief of the Hydrologic Records Section for the entire period.

The Hydraulics Unit, responsible for hydrologic investigations and research in flood studies and bridge-site studies, was headed by McGlone (Mac) Price from 1979 until his retirement in 1987. Timothy Stamey, who transferred from North Carolina, became Unit Chief in 1988, and remained through the end of the period. The Hydraulics Unit was small, staffed by only one or two for the entire period.

The Hydrologic Data Unit, responsible for surface-water and water-quality data collection, processing, and dissemination, had a vacancy for Unit Chief at the beginning of the period. Tim Hale, who had transferred to Kentucky several years before, transferred back to Georgia to take the position. Hale remained in the position until 1988. The position was vacant, being covered by Stokes, the Hydrologic Records Section Chief, until Roger McFarlane was selected to fill it in 1991.

The Data Processing and Reports Unit was operated as if it were the Hydrologic Records Unit and was staffed and headed by Fred Williams in 1979. Williams and the Data Processing and Reports Unit were incorporated into the Hydrologic Data Unit the following year.

The Urban Hydrology Unit was established as part of the Hydrologic Records Section in 1992. The Unit was responsible for all projects concerning urban hydrology (chiefly the surface-water discipline) in the District. Ernest (Joe) Inman was Unit Chief from its inception through the end of the period.

Hydrologic Studies Section.—The Hydrologic Studies Section was responsible for conducting and reporting mainly ground-water investigations and collecting, processing, and disseminating ground-water data. The Section also had, in 1979, what was to become the Reports Unit the following year. The Section had oversight of the Field Headquarters in Savannah (throughout the period), Brunswick (from 1979 until its closing in 1983), and Albany (from its opening in 1980 through the end of the period). Harold Gill was the Section Chief from the beginning of the period until his retirement in 1986. Rick Krause became Section Chief at that time and served in the position through the end of the period. The Section ranged in staff from about 20 in 1979 to nearly 40 by the end of the period.

Unlike most Districts, in which all basic ground-water data collection and dissemination are the purview and responsibility of the Hydrologic Records Section, in Georgia the Hydrologic Studies Section was responsible for this activity (during the periods 1979–81 and 1985–94). The Unit was assimilated

within the Hydrologic Studies Section from 1979 to 1981. Created as the Ground Water Information Unit and placed under the Hydrologic Analysis and Computer Applications Section (discussed later) from 1981 to 1985, the Unit moved back to the Hydrologic Studies Section in 1985 and remained there through the end of the period.

Technical Support and Hydrologic Analysis and Computer Applications Section.—At the beginning of the period in 1979, the Technical Support Section conducted miscellaneous water-quality, biologic, hydrologic, and ancillary investigations and provided some computer support to the District. Robert (Fred) Carter was the Section Chief. In 1981, the Section was renamed the Hydrologic Analysis and Computer Applications Section, and three Units were created within it—the Hydrologic Analysis, Ground Water Information, and Computer Applications Units. In 1984, the Ground Water Information Unit was moved out of the Section to the Hydrologic Studies Section. With the retirement of Fred Carter in 1988, Tim Hale became Section Chief, and in 1989, the Water-Use Program was included in the Section. The Section was dissolved in 1992; what had been the Hydrologic Analysis Unit became the newly created Urban Hydrology Unit, which was placed in the Hydrologic Records Section; the Computer Applications Unit became the Center for Spatial Analysis Technologies (discussed later); and the Water-Use Program was moved into the Hydrologic Studies Section. The Section ranged in staffing from about 10 in 1979, to as many as 17 toward the end of its existence in 1992.

Heads of the various Units in the Technical Support/Hydrologic Analysis and Computer Applications Section were as follows:

- Hydrologic Analysis Unit—Fred Carter from its inception in 1981 through his retirement in 1988; Bob Pierce, 1988; Joe Inman, 1989 through conversion of the Unit to the Urban Hydrology Unit in 1992.

- Ground Water Information Unit—Harold (Bud) Stiles, through the entire period while the Unit was in the Section, 1981–84.

- Computer Applications Unit, Bob Dyar, from its inception in 1981 through 1992, when the Unit was restructured and renamed the Center for Spatial Analysis Technologies.

Other Units in the Office of the District Chief.—Numerous units and projects under the Office of the District Chief were in existence at various times during the period. These units and their Chiefs were:

- Southeast Limestone Hydrology (Floridan aquifer system, Regional Aquifer-System Analysis [RASA]) project; Rick Krause through 1982, the end of the project;

- Cretaceous Tertiary Aquifer (RASA) project; Bob Faye, through 1985, the end of the project;

- Dryfall Deposition Research Project; Norman (Jake) Peters, from its inception in 1985 through the end of the period;

- Sediment Partitioning Research Project; Art Horowitz, from its inception in 1985 through the end of the period; and

- Apalachicola-Chattahoochee-Flint River Basin National Water-Quality Assessment project; Dave Wangsness, from its staffing in 1990 through the end of the period.

Field Offices

Throughout the period 1979–94, there were Field Offices in Savannah and Tifton. There was a Field Office in Brunswick until it was closed in 1983, in Doraville (in the District Office) until its abolishment in 1991, and in Albany from its opening in 1981 through the end of the period. The offices provided support to a mix of projects and basic-data collection, and were under either the Hydrologic Records Section or Hydrologic Studies Section.

Savannah Field Headquarters.—The Savannah Field Headquarters was located in the basement of the Federal Building and Courthouse in historic downtown Savannah during the entire period. (The office was first opened in the 1930's as a project office from which saltwater intrusion studies in the Savannah and Hilton Head Island, S.C., area were conducted.) Organizationally, the office was under the Hydrologic Records Section. O.B. Odom was the technician in charge (and the only staff member) from the beginning of the period until 1982, when the office expanded. In 1982, Welby Stayton transferred from Louisville, Kentucky, to fill the position of Lead Technician. Stayton continued in that position through the end of

the period. The Savannah Field Headquarters was responsible for a mix of ground water, water quality, and to a lesser extent, surface-water data collection and processing and support of ground-water investigations. The latter were mainly coastal ground-water evaluations and investigations, including saltwater-intrusion-related studies. The Savannah Field Headquarters also was responsible for the collection and processing of ground-water and water-quality data in the Lowcountry of South Carolina until 1984. Staff numbered from 1 to 3 during the period.

Tifton Field Headquarters.—The Tifton Field Headquarters was located in an old, refurbished high school on Tift Avenue near downtown Tifton, a small farming community in southern Georgia, during the entire period. The office was under the direction of the Hydrologic Records Section. Darrell Dorminey was the Lead Technician from the beginning of the period until his retirement in 1990. Ronald (Terry) Nichols, who had worked in the office since entering on duty, became Lead Technician in 1990 and continued through the end of the period. The Tifton Field Headquarters was responsible for a mix of surface water, water quality, and to a lesser extent, ground-water data collection and processing and support of ground-water studies, which were mainly county and multicounty ground-water evaluations. Staff numbered from 2 to 4 during the period.

Brunswick Field Headquarters.—The Brunswick Field Headquarters was located in the Federal Building in downtown Brunswick, a small city on the Georgia coast. At the beginning of the period, the office was under the direction of the Hydrologic Records Section. Later, it was reorganized to become part of the Hydrologic Studies Section. Charles Joiner was Lead Technician (and the only staff member) from the beginning of the period until it was closed in 1983. The office was responsible mainly for ground-water data collection and processing in support of the Brunswick/Glynn County and statewide ground-water network and coastal ground-water investigations, chiefly saltwater-intrusion studies in the Brunswick area.

Doraville Field Headquarters.—The Doraville Field Headquarters, located in the District Office in Doraville, was simply that part of the District's Hydrologic Records Section that was responsible for field collection and processing of basic hydrologic data (nearly exclusively surface-water data) in the northern part of the State. The Field Headquarters did not exist as a separate entity until 1979, before which staff and responsibility were in the Hydrologic Records Section. Toward the end of the period in 1991, the Field Headquarters was abolished and reincorporated into the Hydrologic Records Section. Audie Bradley was the first Lead Technician and led the Field Headquarters until his retirement in 1988. James Sohm transferred from the Jacksonville, Florida, office to become Chief of the Field Headquarters in 1988, remaining there until his retirement in 1991 and abolishment of the office. Staff numbered from four to five during the period when it functioned as a Field Office (1983–91). Staff numbered about 10 when it accounted for nearly the entire Hydrologic Records Section (1979–83).

Albany Field Headquarters.—The Albany Field Headquarters was established in 1980, in office space provide by the area's principal cooperator, the City of Albany, Water, Gas, and Light Commission. The office was located in downtown Albany, in the farming area of southwestern Georgia. The need for the office was a result of increased emphasis on ground-water resources, water quality, and related issues in this prime agricultural area, an area of increased ground-water use for irrigation and increasing application of agricultural chemicals. The office served as a project office from which several ground-water and water-quality investigations and research endeavors were conducted during the first 7 years. The office was under the direction of the Hydrologic Studies Section. David (Woody) Hicks, a Hydrologist, transferred from the District Office to Albany in 1980 to open the office as its first Chief. Hicks was in charge of the office until his transfer back to the District Office in 1986. Staff numbered four during that period (1980–86). After Hicks' departure, the office became more of a typical Field Office, having a Hydrologic Technician in charge and supporting a mix of hydrologic data collection and processing and support of ground-water and water-quality investigations. Mark Reynolds became the Lead Technician in 1986 and served in that position through the end of the period. Staff numbered two to three during this latter period.

Funding and Cooperation

Funding for the Georgia District increased nearly threefold during the period. Growth during the period was comparatively constant. A 2-year downturn, which began in 1989, interrupted that steady

Georgia District funds, fiscal years 1979–94

(Funds, in thousands of dollars; estimated for 1983)

Funding source	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	919	964	1,042	1,086	1,168	1,250	1,124	1,151	1,181	1,340	1,291	1,280	1,444	1,455	1,730	1,546
USGS	916	958	1,008	1,093	1,154	1,214	1,085	1,150	1,238	1,340	1,291	1,280	1,405	1,285	1,390	1,417
OFA	628	469	378	578	575	572	930	986	1,182	974	653	528	845	1,679	1,597	1,954
Federal	207	553	490	328	432	536	736	755	645	1,006	1,095	1,024	1,399	2,099	2,586	2,576
Total	**2,671**	**2,945**	**2,917**	**3,085**	**3,329**	**3,572**	**3,876**	**4,041**	**4,246**	**4,660**	**4,330**	**4,113**	**5,092**	**6,518**	**7,303**	**7,493**

growth but was corrected in 1991, when growth began to increase even more markedly.

The Federal-State Cooperative (Coop) program grew steadily but slowly during the period except for slight year-to-year decreases in funding in 4 of the 15 years. Total funding for the Coop program increased about 61 percent. Because Federal funding for the Coop program was restricted, it accounted for only about 55 percent of that increase while the State and other cooperators' contributions accounted for about 68 percent of the increase in the Coop program funding. At the beginning of the period, all but $3,000 of State and other cooperator contributions was matched; by 1994, about $130,000, or about 9 percent of Coop offering, went unmatched. The main cooperator, both in tenure and in funding amount, had been and continued to be the State of Georgia, Department of Natural Resources, Environmental Protection Division, Geologic Survey Branch. Other significant cooperators during the period were the State of Georgia Environmental Protection Division (various branches), Georgia Department of Transportation, Cities of Brunswick and Albany (Water, Gas, and Light Commission)—both agencies cooperating during the entire period—and the City of Valdosta. Other cooperators, some of whose funding was not matched, were DeKalb and Gwinnett Counties, Georgia State University, Georgia Forestry Commission, Georgia Regional Development and Planning Commissions, agencies in Alabama, California, and Florida, including three Water Management Districts, and other cities and counties in Georgia.

It was apparent that in order to grow the program in the State, the Georgia District would have to seek funding sources other than those related to the Coop Program. The other Federal agencies (OFA) category was such a source. The U.S. Army Corps of Engineers was a long-time cooperator and continued to be a funding source throughout the period. Other Federal agencies contributing to Georgia District funding during the period were the U.S. Environmental Protection Agency, mainly Region IV (but Region VIII and the Athens Research Laboratory as well); Department of Energy (DOE); Federal Emergency Management Agency; Centers for Disease Control and Prevention; U.S. Fish and Wildlife Service; U.S. Department of Agriculture, Agriculture Research Service; and the Department of Defense (DOD) Navy, Army, Air Force, and Office of Environmental Control. Funding in this category increased more than 210 percent owing to the development of many large programs, mainly with DOE and DOD. Most of the large growth in funding in the OFA program in the last 3–4 years of the period is attributed to these two Departments.

The remarkable growth in the Georgia District program was largely the result of a large increase in funding from the USGS—the Federal program. At the beginning of the period, the Federal program amounted to one Regional Aquifer-System Analysis project and a few small projects having little funding. A second RASA project began in 1981, and research projects in the Toxic Substances Hydrology Program and Methods Development in Inorganic Partitioning in Sediments in 1983 increased the Federal funding in the District. Large increases in funding also occurred in 1985 when a second Toxic Substances Hydrology research project was funded and a large research endeavor was started on acid deposition at the Panola Mountain Research Watershed as part of the USGS Global Climate Change Program. A third RASA project was funded in 1989, and in 1991 the District received funding for one of the original National Water-Quality Assessment Program studies, that for the Apalachicola-Chattahoochee-Flint River Basin. The latter accounted for large funding increases, not

only in 1991, but in the following years as well. Federal funding during the period increased about 1,145 percent. More than one-half of that growth took place in the period 1991–93.

Summary of Programs

The Georgia District program included a good balance of projects involving the collection and dissemination of basic hydrologic data and hydrologic investigations at the beginning of the period. With the large influx of studies involving research, and marked growth in hydrologic investigations, and only slight gains in the basic-data program, the Georgia District program became somewhat more weighted with projects involving investigations and research.

Hydrologic Data Collection

The Hydrologic Records Section was responsible for the collection, processing, and dissemination of basic data for nearly all surface-water sites, some water-quality sites, routine sediment sites, and for a small part of ground-water sites. These data were published annually in the District Water-Resources Data Report ("Water Resources Data, Georgia 19__"). Nearly all ground-water data were collected, processed, and disseminated by the Ground-Water Information Unit. Ground-water data were published annually by calendar year in the District Ground-Water Data Report ("Ground-Water Data for Georgia, 19__," later restructured and renamed "Ground-Water Conditions in Georgia, 19__").

During 1979–94, the number of continuous-record streamflow stations increased by about 20 percent, continuous ground-water observation wells increased slightly, and continuous-record water-quality stations fluctuated but were about the same at the beginning and end of the period.

Streamflow stations.—During 1979, the District operated 100 continuous-record stations, 10 stage only stations, 98 crest-stage gages, and 110 low-flow partial-record stations. The number of continuous-record stations gradually increased to 107 in 1986 and to 120 in 1994; the stage-only stations to 13 in 1986, and 26 in 1994; the crest-stage gages to 119 in 1986, and declined to 89 in 1994. Low-flow measurements were made at 236 and 149 sites during the droughts of 1986 and 1988, respectively, and none after that time.

By 1994 approximately one-half (54) of the active continuous-record stations had land-line telemetry. In the mid-1980's, data-collection platforms (DCPs) were installed at 16 rain gages and 6 stream-gaging stations in the Savannah River Basin in cooperation with the U.S. Army Corps of Engineers (Corps).

Ground-water stations.—Because Georgia has several physiographic settings and aquifer and aquifer systems, and a large land area, the network of ground-water stations necessary to monitor conditions has to be fairly extensive. In 1979, the statewide network, maintained in cooperation with the Georgia Environmental Protection Division, Geologic Survey Branch, included more than 2,000 wells, of which 150 were equipped with continuous recorders. The network increased gradually; by 1994, 156 wells were monitored continuously. The State also supported the District's ground-water site inventory (GWSI) data base. By the end of the period, the Georgia District had one of the best GWSI data bases in WRD.

Substantial water-supply and water-quality problems existed in the Brunswick–Glynn County area, where saltwater intrusion was occurring, and in the Albany area, where increased demands had begun to deplete aquifers used for water supply. Both Brunswick-Glynn County and Albany Water, Gas, and Light Commission had cooperative agreements with the Georgia District for investigative studies to address their respective problems. In addition, both programs had elements dedicated to the collection of basic ground-water-level and ground-water-quality data. The St. Johns River Water Management District in Florida, concerned over hydrogeologic conditions in northeastern Florida (their jurisdiction), contributed unmatched funds for the collection of ground-water-level and ground-water-quality data in adjacent southeastern Georgia.

Unlike most Districts, and unlike any other in the Southeastern Region, the Georgia District published ground-water data in open-file reports dedicated specifically to ground water. These reports presented the data in graphs and maps and were immensely popular to users.

Water-quality stations.—The surface-water network for monitoring stream-water quality consisted of 5 flow-through monitors and 151 periodic or continuing water-quality stations in 1979. During the period, five minimonitors were added to the continuous monitoring network, and by 1993, there were 133 stations where 1,286 water samples were collected.

Georgia EPD, which was the primary funding source for the work, provided laboratory services for the analyses of the water samples. Data were published in the annual Water-Resources Data Report.

Other data-collection activities included sampling of streams in the Chattahoochee River Basin, West Point Reservoir, and Lake Lanier for special studies. The reservoir studies were designed to determine the effect of upstream pollution on the quality of water in the impoundments.

Fluvial-sediment stations.—Periodic collections and analyses of sediment samples were obtained at eight streamflow-gaging stations at the end of the period. Stormwater sampling was done in the vicinity of major U.S. Army Corps of Engineers projects in cooperation with the Corps. Sediment samples were collected at other gaging stations during major floods, including the flood resulting from Tropical Storm Alberto. Sediment samples were obtained at selected NASQAN sites. Data were published in the annual Water-Resources Data Report.

Precipitation chemical quality station.—As part of a national study of the spatial and temporal variability of chemical quality of atmospheric deposition, a precipitation-sampling station was operated from 1981 to early 1994 at Tifton (Southeastern Watershed Experiment Station) as one of the National Trends Network Sites. The collector was moved in February 1994 to a nearby location near Chula. The rainfall chemical analyses were published in the annual Water-Resources Data Report.

Water-use data.—Water-use data were assembled statewide in cooperation with the Georgia Geologic Survey. Data were collected for various water users, by month since 1980, including industry, public supply, irrigation, domestic and commercial supply, and for thermoelectric and hydroelectric facilities. Selected data also were published in the annual Water-Resources Data Report and every 5 years since 1980 by the Georgia Geologic Survey.

Water-data dissemination.—The Georgia District, in cooperation with Georgia EPD, had a small program beginning before the period began and extending through 1981 that provided financial support for the District's "Water Resources Information System." The program provided special purpose water data and information and limited analyses to the public, water officials, and the like.

Interpretive Hydrologic Studies

Interpretive hydrologic studies conducted during the period represented a well-balanced mix of all hydrologic disciplines and multidiscipline studies. The era of the multicounty ground-water investigation was over. Replacing them were sophisticated investigations using state-of-the-science methodology tackling ever-increasing complex hydrologic problems. The extremely diverse hydrologic setting of the State also resulted in a wide range of hydrologic studies, from coal hydrology to seawater encroachment to effects of agriculture on water quality.

Cooperative hydrologic investigations.—The Federal-State Coop Program was strong throughout the entire period. Although the Federal side of the program funding became increasingly a lesser part of the total Coop funding, interest from the cooperators grew, and by the end of the period the number of cooperators had increased substantially.

State of Georgia, Geologic Survey Branch, Accelerated Ground Water Program.—The main State cooperator of the Georgia District was the Georgia Geologic Survey. As the period began, the Georgia Geologic Survey was beginning what they called the "Accelerated Ground Water Program." Emphasis was in ground-water occurrence, water-quality, availability, and development potential in the following areas:

Dougherty Plain physiographic district of Southwestern Georgia.—A large study was conducted to evaluate the Floridan aquifer system and estimate the aquifer's potential to sustain various rates of pumping for irrigation and other competing uses, and to investigate the effects of application of agriculture chemicals on the quality of both ground water and surface water. The investigation began in 1978 and ended in 1983; Larry Hayes was the project chief.

Cretaceous, lower Tertiary area of middle Georgia.—A study was conducted to better define the extent, hydrologic, and water-quality characteristics, water-use and water-level trends of the aquifer system. The study was conducted from 1978 through 1984. John Clarke was principal investigator on the study.

Coastal Georgia.—One of the largest cooperative studies undertaken by the Georgia District, this study spanned nearly the entire decade of the 1980's. Heavy ground-water pumpage, starting before the turn of the century chiefly in Georgia, and together with comparatively heavy pumpage in the Lowcountry of

South Carolina, decreased artesian pressure, resulting in seawater encroachment at the north end of Hilton Head Island. The State of South Carolina threatened to take legal action against the State of Georgia unless the situation was mitigated. The fresh ground-water flow system and the interface with saltwater were evaluated, and the effects of increased pumping on the system were estimated and predicted. Ground-water-flow models were developed and used to better understand the flow system. Principal investigators were Rick Krause and Bob Randolph.

Northern Georgia Piedmont.—The study resulted in development of techniques for selecting high-yield well sites in the complex Piedmont physiographic province and in an assessment of the quantity and quality of water available from the various rock types. The Georgia Geologic Survey and USGS funded the study, which was conducted by Charles Cressler and completed in 1982.

Later in the period, the Georgia Geologic Survey added to the Accelerated Ground Water Program, a study to address the ground-water hydrology of the Piedmont and Blue Ridge physiographic provinces of northern Georgia. In this area of crystalline rocks, ground water was underdeveloped, and its occurrence and potential for development poorly understood. However, surface-water supplies locally were being overused and became restricted, especially during times of drought. The study, directed by John Clarke, evaluated ground water as a supplemental source of water for the growing area, which included the Atlanta metropolitan area. Several small cooperative projects with municipalities resulted from the larger study: "Water-supply exploration" studies were conducted for the cities of Carnesville, by Clarke and Zebulon, by Melinda Chapman; a hydrogeologic evaluation of springs was made at Social Circle by Clarke.

City of Brunswick–Glynn County.—The longest running cooperative program not with the State has been with the City of Brunswick and Glynn County. The program started in July 1959 and has been active through the present period. The concern raised by the people of Brunswick and Glynn County was that their water supply, ground water from the Upper Floridan aquifer, was "salting up." The USGS was called in and the program began, with extensive data collection, interpretation, analysis, and reporting. Data collection included deep reflection seismology and other surface geophysical techniques; interceptor well testing, implementation, and monitoring; borehole packer and drill-stem testing; regional multiwell aquifer testing; and other state-of-the-science methods and techniques. Analysis and interpretation included ground-water flow and solute transport modeling and tensor analyses of multiwell aquifer testing. Principal investigators at various times during the period were Rick Krause, Harold Gill, Morris Maslia, and Reggina Garza.

In 1983, a proposal was developed and submitted for consideration in the Merit Proposal Process. The study was selected; it involved finite-element simulation of fluid flow in the limestone rock of the Floridan aquifer system in Brunswick, where saltwater intrusion was occurring. In 1987, a second proposal was developed and submitted in the Merit sweepstakes. It also was selected, and the project continued with an emphasis on solute-transport modeling. Although ground-water flow simulation succeeded in roughly simulating the ground-water flow system, the solute transport model was not adequate to replicate the system, and hence, could not be used for predictive purposes. Maslia conducted both projects.

Albany Water, Gas, and Light Commission.—Another long-standing cooperative program of the District has been with the Albany Water, Gas, and Light Commission. The program was prompted by the Commission's concern about the availability of sufficient water to supply the needs of Albany. The District conducted a sophisticated project to evaluate the existing water supply by investigating the hydrogeology and water quality of the aquifers used for water supply for the area. Woody Hicks led the program through the entire period.

Results of the District investigation by Hicks and Krause indicated that the multiaquifer water supply could not satisfy the growing needs of the city, so follow-on work was conducted to evaluate the potential of the Upper Floridan aquifer to supply water to Albany. Woody Hicks and Lynn Torak conducted the study, which ran from 1981 to 1986.

The finite-element, ground-water-flow model developed by Torak in the investigation identified stream-aquifer relations as being important; thus, another follow-on study was proposed and conducted to better define that relation. Results were reported by Torak in a Water-Supply Paper. The follow-on study used results from the initial model study to evaluate the effect of increased ground-water withdrawal on the

water quality of the Upper Floridan aquifer. The study began in 1987 and continued through the end of the period.

The Albany Water, Gas, and Light Commission entered into an agreement with the District to evaluate the migration and fate of contaminants associated with an abandoned manufactured gas plant. The study was initiated by Bruce Gallaher, and when he resigned, the project duties were assumed by Melinda Chapman, who finished the study. The work, begun in 1988, resulted in the characterization of the contaminants, evaluated the distribution and concentration of the identified contaminants, and identified potential ground-water flow pathways of contamination. The study was completed in 1992.

City of Valdosta.—Ground water in the Valdosta area is contaminated with surface water from the Withlacoochee River as it recharges the Upper Floridan aquifer and contributes water having high color and organic content, including bacteria and blue-green algae. The recharge also results in high concentrations of iron and hydrogen sulfide and other water-quality problems. In 1988, the City wanted previous work by the USGS updated. A delineation of areas of the aquifer where ample water of good quality could be provided was needed. The Georgia District conducted the investigation to better define the hydrogeologic framework, ground-water flow system, and flow paths to evaluate the effects of aquifer recharge from the River on the quality and quantity of ground water. Jim McConnell and C. Michael Hacke conducted the study.

District hydrologists, led by McConnell and National Research Program researchers Niel Plummer and Eurybiades Busenberg, proposed a study in which chlorofluorocarbons were used to trace direction of flow and area of contamination of river water in the aquifer in the Valdosta area. The proposal was submitted for Merit Study consideration and was selected. The work resulted in several publications and journal articles.

Statewide, State-cooperated, topical studies.—The State of Georgia understood and appreciated the importance of understanding the hydraulics and hydrology of streams and streamflow. During the period, the Georgia Environmental Protection Division cooperated with the Georgia District on several topical studies of streamflow. All work was done by the District.

Storage requirements for Georgia streams.—Streamflow data were analyzed to provide draft-storage curves that were used in planning and preliminary design of water-supply and waste-treatment facilities. Fred Carter conducted this work, which was completed in 1982.

Time-of-travel studies of Georgia streams.—Time-of-travel data were collected and analyzed to provide information on the rate of movement of leading edge and peak concentration and total time of passage of soluble, conservative materials. Results were used in stream models to provide for the economic design and operation of the water-treatment plant. James L. (Leroy) Pearman conducted the study from 1978 to 1981.

Low-flow characteristics of Georgia streams.—Computer programs were developed that provided seasonal streamflow statistics and graphic analyses of seasonal streamflow data. Fred Carter was the principal investigator. Bob Dyar also contributed substantially to the study, which was completed in 1982.

Low-flow profiles, which used the 7 Q 10 streamflow statistic, were developed for river basins above the Fall Line in Georgia and were published in several reports. Georgia EPD used the data for waste-allocation computations. Carter led these studies.

Flood and bridge-site studies.—Flood data were collected and analyzed and reports prepared that describe (1) the hydrologic and hydraulic characteristics of selected stream reaches, and (2) significant or unusual floods. Project chiefs were Mac Price until his retirement in 1987, and Tim Stamey for the remainder of the period.

The history of annual peaks and stages for gaging stations in Georgia through 1990 was documented by Glenn Hess and Stamey. Techniques for estimating the magnitude and frequency of floods in rural basins in Georgia were documented in a report by Stamey and Hess.

Simulation of flood hydrographs.—Techniques for estimating flood hydrographs to be expected from given flood peak-discharge information and other hydrologic and basin characteristics were defined by this study. Project chief for the study, which was conducted in 1984–85, was Joe Inman.

Ground-water-quality data inventory and network evaluation.—As part of compliance with provisions of the Safe Drinking Water Act, the Georgia EPD provided Coop funding to the District for inventorying ground-water-quality data in EPD

files and determining data usability, entering usable data into the USGS data base, and evaluating ground-water wells that are sampled periodically for inclusion in the ground-water-quality network. McConnell headed this effort, which was conducted in 1981.

Statewide, Federal, and other Federal agency-supported topical streamflow studies.—Several additional topical streamflow and related hydrologic studies were conducted by the District that were funded by the Federal program or through other Federal agencies during the period.

Flood investigations.—The Georgia District conducted evaluations to determine flood discharge and frequency relations and water-surface profiles and to map areas estimated to be inundated by the 100- and 500-year floods. Mac Price and others conducted the work, which was funded by the Federal Emergency Management Agency. The project was conducted from 1976 to 1979, was suspended then reactivated in 1984, and suspended again in 1987.

Computation of highly dynamic streamflow.—A method to compute instantaneous and daily mean discharge at stations having pronounced hysteresis loops under dynamic streamflow conditions was developed and successfully applied to an urban runoff station. The research was conducted during 1980–83 by Blalock and was funded by the USGS.

Urban Hydrology.—Urbanization certainly was an issue with which water-resource managers had to deal in Georgia, as rampant urban growth, especially in the Atlanta metropolitan area, but in other cities throughout the State, changed land use and produced vast changes in the hydrology of the area. The following District studies, led by Joe Inman, were conducted during the period: Flood Runoff Characteristics in the Atlanta Area, Flood Frequency Characteristics of Urban Streams, Effects of Flood Detention Reservoirs in Gwinnett County, and Quality of Stormwater Runoff in DeKalb County. Gwinnett and DeKalb Counties, Georgia Department of Transportation, and the U.S. Army Corps of Engineers provided funding for these studies. The Corps also funded a study of the effects of sewage effluent and stormwater runoff on the water quality of West Point Reservoir, an impoundment on the Chattahoochee River downstream from Atlanta. The study was led by Dean Radtke and was completed in 1983.

Studies to resolve multistate competing demands.—Although water supply was once considered abundant in the East, water demands began to outstrip supply in parts of Georgia and adjacent States. Competition for the water resulted as ground-water levels declined, streamflows were reduced, and salt-water intrusion limited development. Two such areas were in the Apalachicola-Chattahoochee-Flint River Basin in Georgia and adjacent parts of Alabama and Florida, and in the coastal area of Georgia and adjacent South Carolina.

Lower Apalachicola-Chattahoochee-Flint (ACF) River Basin stream/aquifer relations.—Ground-water pumping, chiefly for irrigation, was thought to reduce streamflow in the lower ACF River Basin in southwestern Georgia and adjacent parts of Alabama and Florida. A study, authorized under Section 308 of the Clean Water Act, was conducted to assess stream/aquifer relations by using computer modeling. The work was funded by the U.S. Army Corps of Engineers and States of Alabama (Department of Economic and Community Affairs), Florida (Department of Environmental Regulation), and Georgia (Department of Natural Resources), and the Federal program. Lynn Torak led this work.

Ground-water resources of the Apalachicola-Chattahoochee-Flint (ACF) River Basin.—Competing demands in the ACF River Basin had escalated to the level of the courts when the State of Alabama, which was later joined by the State of Florida, sued the U.S. Army Corps of Engineers to halt reallocation of storage in Lake Lanier, a Corps reservoir in Georgia near the headwaters of the Chattahoochee River. The States and the Corps agreed to conduct a "Comprehensive Study" of the ACF River Basin (and of the nearby Alabama-Coosa-Tallapoosa [ACT] River Basin). Ground water was one element of the $14 million study, and the USGS was selected by the Corps to do the ground-water element of the study. The Georgia District addressed the ACF River Basin study and the Alabama District, the ACT. Rick Krause directed the program. The ACF studies were conducted by Melinda Chapman, Greg Mayer, and Lynn Torak and evaluated qualitatively how changes in the surface- and ground-water levels affect surface- and ground-water availability in Alabama and Georgia; identified areas where ground-water resources are over- or underutilized; qualitatively and quantitatively determined how present and future ground-water withdrawal affected surface-water flow to the Apalachicola River and Bay; and developed water budgets that described the volume of water entering and exiting the area and(or) State.

Water-supply evaluation of the Savannah, Georgia–Hilton Head Island, South Carolina area.—A study supported by the Chatham County–Savannah Metropolitan Planning Commission addressed the interstate Savannah–Hilton Head water conflict. The study, conducted by Reggina Garza and Rick Krause, updated and refined the data from previous studies to develop a ground-water flow model that was used to assess the ground-water development potential of the Upper Floridan aquifer, including quantity and location of ground-water withdrawal that would not worsen the ongoing seawater encroachment at Hilton Head Island. The potential for additional seawater encroachment was estimated, and surface water was assessed as to its availability as a possible source of freshwater.

Assessment of streams as alternative water supply for coastal Georgia.—This study measured and estimated the inland travel of tide-driven saline water in the Altamaha, Satilla, and Saint Marys Rivers. The work was funded by the District and was led by Jim McConnell.

Department of Energy, Savannah River Site study.—In the late 1980's, the Department of Energy made plans to restart the K Reactor at their Savannah River Site, a plutonium development plant near Aiken, S.C., near the border with Georgia. Concerns over possible contamination of aquifers in Georgia by plant operations were expressed by Georgia Congressman Lindsay Thomas. The USGS was asked to evaluate and describe the conditions under which ground water at the Savannah River Site could migrate beneath the Savannah River to aquifers in Georgia. Extensive field work was conducted, analyses and interpretations made, and a detailed ground-water flow model developed and exercised. The South Carolina District, the Geologic Division, and Clemson University also participated in the study. Funding was provided by the Department of Energy and to a lesser extent, the State of Georgia, Geologic Survey. John Clarke conducted the study.

U.S. Army Corps of Engineers water-supply evaluations.—During the period, four studies were conducted as a result of the Corps' requirement for administering the Ground-Water Use Acts. Studies were conducted and results reported for the metropolitan areas of Brunswick, Savannah, Athens, and South Atlanta. The studies for the Brunswick and Savannah areas, by Bob Randolph and Rick Krause, resulted in development of ground-water models that were used for management purposes by the Corps and by State and local governments. The studies also were partly supported by the City of Brunswick and Chatham County, respectively. The studies for the Athens and South Atlanta areas were in the Piedmont physiographic province and focused on an evaluation of ground-water availability in the complex, fractured rock setting. Those studies were led by John Clarke.

Geographic information system (GIS) development.—A statewide GIS was developed to assist water managers and researchers, both State and local, in making environmental decisions, and to provide tools to determine hydrologic and water-quality trends, to site water-supply reservoirs, to locate sanitary landfills and hazardous-waste facilities, and to process permits for withdrawal and discharge. The program, led by Dyar and S. (Jack) Alhadeff, continued through the end of the period and led to the establishment of the Centers for Spatial Analysis Technologies at Georgia Institute of Technology.

Agriculture hydrology and water-quality studies.—Studies ranged from cooperative appraisals of the effects of agriculture on water quality to research with other Federal agencies on the fate and transport of agricultural chemicals in the subsurface. With the exception of a study in the Piedmont area of the State, all studies were done in the southwest part of the State, chiefly in the Dougherty Plain, an area of prime farmland.

Jim McConnell conducted a study of the effects of agricultural practices on stream quality. In cooperation with the State of Georgia, the study defined water-quality conditions of two typical streams in the heavily farmed area of southwest Georgia, established baseline stream quality for future comparisons, and assessed the magnitude and significance of stream pollution during periods of nonstorm and storm runoff conditions.

An investigation of ground water in Seminole County for the soil fumigant ethylene dibromide (EDB) was done in August 1983 by the USGS in cooperation with the Exposure Assessment Branch of the USEPA. The purpose of the investigation, led by Jim McConnell, was to determine whether EDB, which was previously detected in ground-water samples from four wells, was localized in the vicinity of the wells or was more widespread in the ground-water system. The study was a high-profile, high-pressure, short-timeframe effort. The USEPA participated in the field work and coauthored the report. The

compound EDB was detected in ground water in a 4-square-mile area.

Follow-on studies were conducted by McConnell in 1985 and 1987 to determine the transport and fate of the EDB plume. The studies were partly funded by the USEPA but were conducted by USGS. The studies indicated that the area of contamination was about the same (4 mi^2) but that concentrations decreased with time. However, the pesticide had moved downward from the surface soils through the residuum and into the Upper Floridan aquifer.

The USEPA Research Laboratory in Athens, Ga., was developing a model code to simulate the fate and transport of water and agriculture chemicals, mainly pesticides, in and through the crop root zone and needed a field site for calibration, testing, and verification of the model code (PRZM). The Georgia District instrumented a site in Lee County and collected the necessary physical, chemical, hydrologic, and climatologic data. Bromide was used as a conservative tracer, and aldicarb was the agriculture chemical subject to transformation (degradation). Most of the funding for the project was provided by the USEPA, Water Quality Administration, and a lesser amount by the USGS Toxic Substances Hydrology Program. Sandra Cooper led the study.

A similar study was done for the U.S. Department of Agriculture, Agriculture Research Service, Tifton, Ga. This study, done at a site in Plains, was designed to collect data needed for calibration, testing, and verification of the CREAMS and GLEAMS models. Bromide was the conservative tracer used in the study, and atrazine, alachlor, carbofuran, and nitrogen fertilizer were used to represent commonly applied agriculture chemicals. Most of the funding for the study was from the USGS Toxic Substances Hydrology Program; a lesser amount was from the USDA, Agriculture Research Service. Hicks and McConnell led the program.

An agriculture study outside the prime agricultural area of southwest Georgia was conducted in the early 1990's in the Piedmont physiographic province of northern Georgia. Agricultural practices in this area of the State were extensive livestock operations, including poultry and cattle. Water-quality concerns included high concentrations of suspended solids, nitrogen, phosphorus, fecal coliform, and high turbidity in watersheds and streams tributary to the Chattahoochee River, which flows into Lake Sidney Lanier, the main source of drinking water for about 60 percent of Georgia's population. The Georgia District, led by Mike Peck and Jerry Garrett, evaluated two small watersheds in White County. The work was done in cooperation with the Chestatee-Chattahoochee Resource Conservation and Development Council and findings were published in 1994.

Regional Aquifer-System Analyses.—Two Regional Aquifer-System Analysis (RASA) studies that covered aquifer systems in the State were completed during the period.

Floridan RASA: The Floridan aquifer system Regional Aquifer-System Analysis was one of the first RASA studies. Two Professional Papers, a Water-Supply Paper, and numerous other reports were generated from the two Georgia District projects that addressed the Floridan RASA. Several other Professional Papers, Water-Supply Papers, and other publications also were generated that covered the Floridan aquifer system in its entirety. The two Floridan RASA studies were led by Krause and Randolph for the area covering the eastern half of the Coastal Plain of Georgia and adjacent parts of northeast Florida and southern South Carolina, and by Hayes and Maslia for the area covering southwest Georgia and adjacent parts of southeast Alabama and the panhandle area of Florida.

Southeast Coastal Plain RASA: The second Regional Aquifer-System Analysis in Georgia was for the Southeast Coastal Plain (Lower Tertiary and Cretaceous) aquifers. The Georgia part of the study was conducted by Robert Faye, and the final report was published in 1998.

Coal Hydrology Program.—Coal measures of Pennsylvanian age lie in the Appalachian Plateau physiographic province of extreme northwest Georgia. The District received Federal funds from the USGS and Department of Energy and Coop funds from the Georgia Geologic Survey to acquire, interpret, and report water data and related information on the hydrology of the coal area. The study, which ended in 1979, addressed water quality in the region and was led by Jim McConnell. The study evaluating hydrologic monitoring was led by Tim Hale and ran from 1979 to 1981.

Military program and studies.—Military studies were not a large part of the District program during the period. An exception, however, was a large project with the Navy that addressed the hydrology, especially sediment sources and transport, in the Kings Bay area at the beginning of the period and programs

with Department of Defense Environmental Control (DODEC) and the U.S. Air Force, which began in the last couple of years of the period.

U.S. Navy Submarine Support Base, Kings Bay sediment studies.—The State of Georgia, through strong political influence of President Jimmy Carter and Senator Sam Nunn, landed one of the Nation's two docking and maintenance facilities for the U.S. Navy's Submarine Support Base at Kings Bay in the extreme southeast corner of the State. Kings Bay is an area of extremely high sedimentation rates and transport. Shoaling rates for specific reaches, identification of major sediment sources, and the rates and characteristics of sediment transport were needed by the Navy to effectively pursue, design, and evaluate alternative systems for the control of sediment. Jim McConnell developed the study design and led the initial study, which was conducted in November 1981, with the field work being done over a 13-hour tidal cycle. Jerry Glenn, an estuarine hydrologist from the National Research Program in Denver, provided technical assistance on the project. Dean Radtke of the Georgia District led a similar study in July 1982. The project objectives to provide basic hydrologic data that were relevant to the determination of the sources and transport characteristics of sediments in Kings Bay and vicinity were met with such completeness and success that not only were cooperator expectations met, but the study results have provided an excellent reference for future research projects.

Cumberland Island National Seashore hydrogeology.—Although not a military-supported project, the potential effects on ground water of dredging by the military in Kings Bay were addressed at nearby Cumberland Island National Seashore. The hydrogeology of the island was studied, and the freshwater/saltwater interface and areas of possible intrusion of saltwater as a result of dredging were defined. Work was led by Bob Randolph and was done in cooperation with Georgia State University and the National Park Service.

Other military programs.—The Georgia District developed a program with the Navy Southern Naval Facilities Engineering Command, as part of their Installation Restoration Program, to evaluate the hydrogeology of the Marine Corps Logistics Base, Albany, and a former Army facility at the Kings Bay Submarine Support Base. The efforts, begun in 1992, were led, respectively, by Woody Hicks and Harold H. Zehner. The District also assisted the Marine Corps in developing a Stormwater Pollution Prevention Plan at the Corps' Logistic Base. The effort was directed by Tim Stamey. Toward the end of the period, the District was requested by the Air Force Materiel Command to provide assistance and guidance regarding evaluation and remediation of contaminated ground water at Air Force Plant 6 near Marietta. Greg Mayer was the District liaison for the project.

National Water Quality Assessment Program: Apalachicola-Chattahoochee-Flint River Basin (ACF).—The District began a NAWQA study in 1991, which was well staffed, funded, and equipped. The basin covered the mountains of northern Georgia, the Atlanta metropolitan area, the Dougherty Plain agricultural area, and the Apalachicola River and Bay, a major commercial fishery at the mouth of the basin. The NAWQA study, led by David J. (Dave) Wangsness, was well on its way by the end of the period to accomplishing all its objectives, which were to: (1) describe present water-quality conditions; (2) define long-term trends in water quality; and (3) identify, describe, and explain factors that affect water-quality conditions and trends. In addition to base WRD funding, the ACF NAWQA study was eventually able to successfully obtain participation and funding from the Geologic Division of USGS, the National Park Service, USDA Forest Service, USEPA, Georgia Department of Agriculture, and Atlanta Regional Commission. By the end of the period, the ACF NAWQA had produced several reports.

Research Projects.—A consequence of the closing of the Water-Quality Laboratory in Doraville was the transfer to the District of principal researchers who were working on methods development for the determination of inorganic partitioning in sediment. This USGS program, which continued in the District under the direction of Arthur J. Horowitz, developed methods for total trace-metal analysis of sediments, a size separation technique that does not alter sediment chemistry, sampling techniques, and the separation of aqueous and solid phases of trace elements in surface water.

Several researchers who had conducted acid-rain studies in the Northeastern United States transferred to the Georgia District and continued studies at a field location just east of Atlanta, at Panola Mountain State Park. The objective of the program, led by Norman E. (Jake) Peters and funded largely by the USGS Acid Rain program, was to investigate terrestrial processes that control the production of acids in

the watershed and the neutralization of acidic atmospheric deposition by the watershed, and to evaluate and devise methods and instrumentation for measuring dry deposition. The study attracted WRD researchers from the National Research Program and the Geologic Division as well as faculty and graduate students from five local universities. Numerous publications, journal articles, abstracts, and proceedings resulted from the Panola Mountain studies. District scientists were able to apply the results of the research to other field situation; Richard P. Hooper modeled the hydrochemistry of Emerald Lake in California for the California Air Resources Board, and Thomas G. Huntington assessed air pollution loadings and resultant water-quality effects in Stewart County, Georgia.

The well-instrumented and studied Panola Mountain site was chosen as one of WRD's five Water, Energy, and Biogeochemical Budget (WEBB) sites in 1991. The Georgia WEBB study, led by Peters, focused on the hydrologic processes in a forested Piedmont watershed with emphasis on the movement and solute transport of water, and the sources of cations in stream water.

Extreme Hydrologic Events

Georgia experienced droughts and floods during the period. Droughts occurred frequently in the 1980's. Flooding occurred at the end of the period as a result of rainfall from a tropical depression.

Drought of 1980–81.—During 1980–81, a severe drought occurred in Georgia, chiefly in the southern part of the State. The normally rainy season during the winter and spring of 1980–81 failed to bring appreciable rainfall. Streamflows and ground-water levels continued their recession through this period and into the summer and fall when rainfall typically is low. The drought provided an opportunity to collect data under these conditions. The State requested the District to assist in collecting data more frequently on streamflow and ground-water levels.

Droughts of 1986 and 1988.—Severe droughts occurred statewide in 1986 and 1988 but affected the northern, Piedmont part of the State the most. Lower than normal rainfall reduced streamflows and lowered reservoirs upon which most of northern Georgia depended for water supply. Water restrictions were placed by Georgia EPD and local governments; some small municipalities had severe water shortages, and exploration for ground water as a supplemental or alternate source of water became widespread. The District was again busy filling information requests and augmenting its data-collection activities, including making base-flow measurements on selected streams. In late summer 1988, The Weather Channel asked the USGS to participate in a program on the topic. Rick Krause appeared on the Weather Channel's half-hour program, "Drought Watch," and discussed the ongoing drought, fielding questions from the program moderator and from viewers. The droughts hit the Atlanta area particularly hard and led to a keen awareness that the water supply was limited. The ensuing competing demands contributed to the "Water Wars" between Georgia, Alabama, and Florida described in the Apalachicola-Chattahoochee-Flint and Alabama-Coosa-Tallapoosa River Basins studies, among others.

Flooding from Tropical Storm Alberto.—During July 4–7, 1994, Tropical Storm Alberto brought record rainfall to southwest Georgia, as much as 28 inches in parts of the area. Floods in excess of 100-year and 500-year recurrence intervals resulted. Peak discharges were as much as 2.4 times greater than the 100-year recurrence-interval discharge. By the end of the month, there had been 31 flood-related deaths in Georgia. A state of emergency was declared in 55 counties and the President declared the counties Federal disaster areas. Damage was in the hundreds of millions of dollars.

The Georgia District made streamflow measurements where feasible during the period of peak flows. After floodwater subsided, data were collected indirectly from high-water marks and channel geometry, and as this reporting period ended, peak discharges were being computed. In addition, plans were being made to delineate flood extent and estimate recurrence intervals associated with the flooding, and to conduct other related spatial analyses. At the end of the period in late 1994, a study was approved and funded to do this work. Funding was provided by FEMA.

Special Activities

The Georgia District, because of its "critical mass," was also involved in several ancillary activities. These activities in turn, attracted even greater diversity, staff, and activities.

Collegial partnership with the Geologic Division.—Prior to 1980, the Georgia District office housed only WRD employees. In late 1980, David C. Prowell of the Branch of Eastern Regional Geology of

the Geologic Division was transferred to Atlanta to facilitate studies of seismic activity in the Southeast. John George, then District Chief, and Harold Gill, then Chief, Hydrologic Studies Section, saw the value of interdivisional research and offered office space in the District for Prowell and other Geologic Division personnel. Michael W. Higgins, also with the Geologic Division, had already spent several years in Georgia making geologic maps of the Piedmont and Blue Ridge. He was housed in downtown Atlanta with the Georgia Geologic Survey, which was undergoing organizational changes. To consolidate Geologic Division activities, Higgins relocated to the District Office shortly after the arrival of Prowell. A short time later, however, there were efforts made by the Geologic Division to relocate them back to Reston, but Jeff Armbruster, the new District Chief, also had seen the value in their being in the District and argued long and hard for their stay; Armbruster succeeded.

The two geologists contributed geologic expertise to ground-water studies across the State and into adjacent States. In particular, Prowell contributed to the Southeast Coastal Plain RASA study, the Greater Atlanta Region ground-water study, the acid rain studies at the Panola Mountain Research Watershed, and other RASA studies across the Southeast. Higgins contributed to WRD ground-water studies, chiefly those in the Piedmont.

In 1982, Helaine W. Markewich of the Geologic Division was transferred to Georgia. Markewich was an integral part of the USGS interaction with the Soil Conservation Service in the Southeast, so her relocation to the Georgia District office simply strengthened that alliance. In the 1990's, Markewich became a leader in the USGS Climate program, and her past association with WRD District scientists provided them with new research opportunities.

Participation in the 1984 New Orleans World's Fair.—The Chief Hydrologist decided that WRD should participate in the World's Fair and that we would demonstrate our new real-time, satellite data-collection capability. Merritt Blalock of the Georgia District was part of the team formed to program the collection and graphical display of hydrologic data from the one or more real-time gages in each State. The results of the team's efforts were very rewarding. During the World's Fair, attendees walked up to a screen, clicked on their State, and saw a graph of the recent streamflow at a gaging station in their State. The accomplishment was substantial, especially for 1984.

Development of the biennial Georgia Water Resources Conference.—The year before the period began, the Georgia District and the Georgia Department of Natural Resources sponsored the Georgia Water Resources Information Exchange, a 2-day conference held at Unicoi State Park in the Georgia mountains in April 1978. In September 1980, the second Georgia Water Resources Information Exchange was held in Atlanta. The two conferences each involved about 30 water-related agencies. Recommendations made at the conferences helped guide future water programs and identified needs for water information. The conferences also helped to set the stage for the immensely successful Georgia Water Resources Conference.

The Georgia Water Resources Conference, conceived by the Georgia District, USGS, and the University of Georgia, was begun in 1989 and has been Georgia's and the Southeast's premier water conference. Held every other year, the hugely successful conference provides a comprehensive forum for the presentation and discussion of current water research, water studies, and water management and law. The conference has been held at the University of Georgia–Athens (UGA) and has been sponsored by the Georgia District. Conference organizers each year have been hydrologists from UGA and the Georgia District.

Plan to incorporate Alabama District into Georgia District.—The Alabama District had program and financial difficulties in the mid-1980's. With the transfer of Briane Adams to the Southeastern Region Office, a dwindling program and staff in the Alabama District, and a strong, robust Georgia District, the Regional Hydrologist decided to place the Alabama District organizationally under the Georgia District and to make Jeff Armbruster the Chief of the combined District(s). Although this model was in place for several months and marked improvements in the Alabama District program resulted, it was never formally instituted.

Development of the Hydrogeology Program at Georgia State University.—In 1986, Dr. Vernon J. Henry, Chairman, and Dr. Ram Arora, Full Professor of the Geology Department of Georgia State University proposed to develop a hydrogeology program at Georgia State, the University System of Georgia's urban university in Atlanta. To this end, Drs. Henry

and Arora sought technical, advisory assistance and established an advisory committee. They asked the USGS Georgia District to participate, to which Jeff Armbruster agreed. Armbruster also sought assistance from Paul Hsieh, Menlo Park, and Allen Shapiro, NRP, Reston. In addition, he accompanied Dr. Arora to meet with Phil Cohen, Chief Hydrologist. Dr. Arora discussed his planned curriculum and received input from Cohen and others of his staff. Dr. Arora also requested of Cohen that USGS help the department by providing instructors to teach courses. Cohen and Armbruster agreed and loaned, at no cost to the University, two District hydrologists, Lynn Torak and Morris Maslia, both of whom taught courses on ground-water modeling. During 1989, Torak was located on-campus for 2 days a week, advising graduate students, developing course material, and strengthening the USGS–GSU academic relationship. The Center for Hydrogeology provided advanced education in the subject, leading to a Certificate of Hydrogeology for post- Bachelor of Science candidates. A further outgrowth of the USGS–GSU relationship was joint participation in the organizing of the International Conference on Fluid Flow in Fractured Rocks.

Participation in the Governor's Growth Strategies Commission.—The Governor's Growth Strategies Commission was created in the early 1980's, and the Georgia District was asked to participate. Rick Krause served as a member of the Natural Resources Task Force. The exercise was helpful to meet the intended goals set by the Governor, but more important to the District, it also gave insight into the direction the State planned to take regarding natural-resources issues in the foreseeable future.

Participation in Georgia Hazardous Waste Management Authority.—In the late 1980's, the State of Georgia made plans to site a hazardous waste facility, including incinerators, in Taylor County. Preliminary site assessments were underway and the State was poised to push the process through. However, resistance to the facility rose, and the State created the Georgia Hazardous Waste Management Authority to address the issue and to conduct a thorough evaluation of the potential effects of the facility in Taylor County. The Georgia District was asked to participate, and Rick Krause and Greg Mayer became members of the process dealing with natural resources. After deliberations, plans for the proposed facility were scrapped.

Establishment of the Centers for Spatial Analysis Technologies at Georgia Institute of Technology.—Georgia Institute of Technology (Georgia Tech) and the Georgia District combined efforts in 1991 to establish joint "Centers for Spatial Analysis Technologies." The Centers housed interdisciplinary teams working together in three aspects of spatial analysis technologies: education, service, and research. The Centers began with the establishment of a USGS Center for Spatial Analysis Technologies (CSAT), the Georgia Tech Center for Geographic Information Systems (GIS), and the Georgia GIS Clearinghouse, which are collocated on the Georgia Tech campus. Instrumental in establishing the Centers and the GIS program, in addition to Jeff Armbruster and Tim Hale, were Bob Dyar and Jack Alhadeff.

International Training.— The District at times was called upon by Headquarters Office of International Training to take trainees from participating countries for extended training and technology transfer. The District always accepted, and the students, from India, Pakistan, and other countries, came to the District for a mix of office and field training and on-the-job experience. It was the District's talented and diverse staff and the broad range of programs that allowed for this to take place. No matter what the training and technology transfer called for, the District most likely had the experience and skill and willingness to accomplish it.

Epilogue

The Georgia District epitomized all models for successful program development, scientific achievement, and response to clients and customers while attaining and utilizing a diverse and professional staff during the period. The District enjoyed substantial growth, while maintaining stability and as a result was held in high esteem, not only in the Southeastern Region, but throughout the Division as well. To paraphrase a popular song title, "It was a very good period."

LOUISIANA

By Darwin Knochenmus

INTRODUCTION

The USGS District Office in Louisiana began the new decade (1980's) with high morale and stable funding sources to continue its water-resources data-collection, investigative, and research activities. The District had 70 permanent employees. The organization consisted of a District Office in Baton Rouge, a Subdistrict Office in Alexandria, and two Field Offices in Lake Charles and Jonesboro. The District's mission and goals were accomplished through cooperative programs with local, State, and other Federal agencies.

The early 1980's brought change in leadership and additional investigative activities and technical personnel. The District's program included more investigative and research activities, which achieved the goal to move the District toward a more balanced program between hydrologic investigations and basic-data collection. The number of permanent employees grew to 96.

The Field Office in Jonesboro was moved to Ruston in 1983, and the Field Office in Lakes Charles was closed in 1985. Due to an unexpected and large reduction in cooperative funding in 1987, the District experienced major changes in programs and personnel from the middle 1980's to the early 1990's. Fourteen employees either transferred to another District, retired, or found other employment. The Subdistrict Office in Alexandria was closed in 1987. As a result of this consolidation, the Field Office in Ruston serviced the northern half of the State, and the new Field Office in Baton Rouge, which was established after the Lake Charles office was closed, serviced the southern half. The District Office was located in the Carrollton Building at 6554 Florida Boulevard in Baton Rouge for 27 years. In January 1993, the office was moved to an office complex located at 3535 South Sherwood Forest Boulevard.

In addition to internal District changes, a major flood occurred in southeastern Louisiana in 1983 when the Pearl River flooded and inundated Interstate Highway 10 for 5 days. This interstate is a major link between California and Florida, and closing it was a serious disruption of interstate commerce for the State and the region.

ORGANIZATION AND PERSONNEL

As an organizational unit under Region and Headquarters (in Reston, Va.) authority, the District was a part of two Regions during this period: the Central Region from 1979 to 1981 and the Southeastern Region from 1982 to 1994. In 1980, after a number of senior employees retired, the District was reorganized and consisted of the following sections: Office of District Chief, Administrative Section, Computer Operations and Data Management Section, Hydrologic Investigations Section, Hydrologic Surveillance Section, and Reports Section. The Hydrologic Surveillance Section included the Baton Rouge and Ruston Field Offices, Water Quality Services Unit, and Sediment Laboratory.

District Office, Baton Rouge

Office of the District Chief.—Three District Chiefs, Albert (Abie) N. Cameron, Darwin Knochenmus, and Edward H. Martin, guided the District during this period. A.N. Cameron (1971–81) transferred to Baton Rouge from Headquarters and served as District Chief from 1971 until his retirement in 1981. Darwin Knochenmus transferred to Baton Rouge from the Subdistrict Office in Laguna Niguel, Calif., and served as District Chief from August 1981 until his retirement in January 1993. Martin, who had been Chief of the Hydrologic Investigations Section for the District, became the next District Chief.

Other hydrologists in the Office of District Chief were John Musser, Associate District Chief (1971 to retirement in 1989); George Cardwell, Ground Water Specialist (1980 to retirement in 1985); Duane Everett, Quality of Water Specialist (1980 to retirement in 1987); Max J. Forbes, Surface Water Specialist (1983 to retirement in 1987); Angel Martin, Ground Water Specialist (1988 to 1991); and Charles Demas, Quality of Water Specialist (1988 to 1994).

District secretaries were Elizabeth Ellsworth (1983 to 1987) and Cheryl A. Johnson (1987 to 1993).

Administrative Section.—Ada Rich had the longest tenure as Administrative Officer (1971–79). She was followed by Lester Smith (1980–83), Elaine Gockel (1984–87), Linda Collier (1987–91), and Michael Kraemer (1991–95). During this challenging period of hiring freezes and financial shortages, the Administrative Section did a superb job in keeping morale high and tensions low.

Others who served in the Section were Kay Joachim, Jackie Colbert, Melissa Chavis, Lois Harlan, Marsha Holly, Genevieve Floyd, and Evon Williams.

Computer Services Section.—In the late 1970's and early 1980's, computers were coming into their own for data collection, storage, retrieval, and analysis. With the reorganization in 1980, a Computer Section was established with a site administrator. Max Forbes was the first Section Chief (1980–84) followed by Daniel Gockel (1984–87) and Scott Beddingfield (1987–94). (Dan and Elaine Gockel were the first husband and wife team in the Louisiana District. They transferred to Baton Rouge from the Iowa District in 1984.) Computer technology was changing rapidly and had become a viable tool in data analysis and interpretation. A mainframe computer located at Headquarters had been replaced by a minicomputer in the District. The next generation of computers was workstations with GIS, plotters, and color printers. By 1994 personal computers were used by most professionals and many technicians.

Others who served in the Section were Bobbie Mitchell, Linda Hollie, Gaynelle Gumpert, Robert L. Taylor, Tony Cangelosi, and Ron Riley.

Report Preparation Section.—Report preparation also evolved rapidly in the 1980's from first-generation word processing and manually prepared graphics with limited use of color to glossy paper and computer graphics with color. A big factor in upgrading the reports process was the introduction of computer word processing, which reduced the amount of time and effort in typing and formatting manuscripts. Under the reorganization of 1980, a Reports Section was established with George Cardwell as Reports Specialist (1980–85). After George's retirement, he was replaced by Geraldine Stallworth (1985–94) who supervised the processing of reports.

Others who served in the Section were William C. Martin, Wanza Clunan, Patricia A. Adams, Cheryl A. Johnson, June Brauner, Keith Myers, Darlene Smothers, Mary Phills, Mary Jordan, and Sebastion R. Brazelton.

Hydrologic Investigations Section.—In 1979, investigative projects were conducted by hydrologists and technicians in various Sections relative to the subject matter. There was an Appraisal Section, which conducted ground-water studies, a Data Studies Section concerned primarily with surface water, and a Special Studies Section, which focused on surface-water-quality studies. Under the reorganization of 1980, the three sections were integrated into a Hydrologic Investigations Section. The Hydrologic Investigations Section included approximately 20 employees, most of whom were hydrologists. During this transition period, most technicians were reassigned to data-collection units; when project leaders needed field assistants, technicians were assigned to the project on a temporary basis. Section Chiefs were George C. Cardwell (1979–80), Milton Cook (1979–80), Thomas Huntzinger (1981–85), John Harsh (1985–88), and Edward H. Martin (1989–93). Other personnel who served in the Investigations Section were Anthony Calandro, Anthony Duplechin, Duane Everett, DeWitt Pyburn, Frank Wells, Robert Hosman, Lynn Torak, William Walter, Harold Leone, Gregg Wiche, Stanley Skrobialowski, George Arcement, Alfred Lowe, Richard Herbert, Erik Schuck-Kolben, Eve Kuniansky, Donald Dial, Dale Nyman, Douglas Trudeau, Roger White, Nancy Baker, Dee Lurry, Philip Curwick, Harry McWreath, Kenneth Covay, Fred Lee, Charles Whiteman, Christie Stuart, Jeffrey Bonck, Charles Demas, Keith Halford, Bobby Nations, Dennis Demcheck, Josh Gilbert, Dan Tomaszewski, Gile Beye, Paul Ensminger, Robert Fendick, Mark Gremillion, Glenn Huff, John K. Lovelace, Benton D. McGee, Timothy Rapp, Otha Benton, Kurt Johnson, Larry Prakken, and Mary Anderson.

RASA Group.—Angel Martin transferred to the Louisiana District from Indiana in 1983 to head the Coastal Lowlands Aquifer System study as a part of a Regional Aquifer-System Analysis (RASA) of the west gulf coast. Other personnel in the group were Charles Whiteman, David Early, Miles Becnel, Ron Riley, and Duane Thigpen.

Hydrologic Surveillance Section.—The Data Collection Section was renamed the Hydrologic Surveillance Section. The Surveillance Section consisted of the Water Quality Services Unit, Sediment Laboratory, Baton Rouge Field Office, and Ruston Field Office. Section Chiefs during the period were Joe Holm, until he retired in 1980; Darrell Carlson, 1981 to 1988 when he transferred to the Southeastern Region Headquarters; and George Arcement from 1989 to 1994. Other employees in the Section were L.J. Dantin, Brian McCallum, Wendell Lovelace, Candiace Gordon, Charles Garrison, Pamela Montgomery, and Joseph Treadway.

At the beginning of the period, hydrologic data were collected by the Alexandria Subdistrict, Field Offices at Lake Charles and Jonesboro, and at the

District Office in Baton Rouge. By the end of the period, hydrologic data for the northern half of State were collected by the Ruston Field Office and for the southern half by the Baton Rouge Field Office.

Water Quality Services Unit.—With the establishment of National Laboratories and the abolishment of District laboratories, a Water Quality Services Unit was established to provide in-house services for routine analyses, consultation, and supplies for sample collection. The Unit also housed the District Sediment Laboratory, which analyzed samples for the District as well as a number of other States. The work in the laboratory was accomplished by employing students from Southern University and Louisiana State University. The Unit Chief was Alton Dupuy until he retired in 1992. Others in the Unit were Charles Garrison, Nolan Couvillion, Cheryl Joseph, Arthur Adams, Schyvanda Haslom, Scott Woodley, Pamela Montgomery, Lawrence Aucoin, and Catherine Demcheck. University students were Martin Harrison, Sharon Moy, Tamiko Thomas, Darrius Williams, Terry Keller, Angelicque Tucker, Lloyd Gauthier, Marlon Johnson, Nicole Johnson, and Albert Mitchell.

Jonesboro Field Office (1979–82).—Rufus Smith was Chief of the office until he retired in 1979. Smith was followed by Edward H. Martin (1981–82). Others assigned to the Field Office were James Elkins, Robert (Odis) Walsworth, Joseph Dark, Billie Greer, and David Abernathy.

Lake Charles Field Office (1979–85).—The Field Office was supervised by Anthony (Blackie) Devillier until it was closed in 1985. It was located in the Federal Building on Kirby Street. Others assisting with data collection and compilation were Edward Doran and Helen Harris.

Baton Rouge Field Office (1982–94).—Otha (Red) Benton (1982–85) was in charge of the Field Office from the time of its inception until the closing of the Lake Charles Field Office. When the Lake Charles Office closed, Devillier (1986–94) transferred to Baton Rouge and assumed supervision of the Baton Rouge Field Office. Others assisting in the collection and record compilation were Ronald Durr, Elton Goings, Marie Chaisson, Christine Resweber, Joseph Treadway, William Snee, Garron Ross, Paul Lawless, Anthony Thevenot, Michael Ross, David Walters, Daniel Stohman, Timothy Kolb, Charles Labbe, Errol Meche, Van Bergeron, Cindy Sibley, Calvin Jones, Glen Stevens, Gale Rabalais, and Ralph Walker.

Ruston Field Office (1983–94).—Odis Walsworth was the Office Chief from the time the office was moved from Jonesboro until his retirement in 1994. Others assisting with the data collection and record computation were David Bauer, Billie Greer, David Abernathy, Lane Austin, Lester Seal, Ronald Seanor, James Carter, Charles Smoot, David Sasser, Burl Goree, Sophia Nail, Ben McGee, Jeffrey Brantly, Troy Devillier, and Darrelyn Hutson.

Alexandria Subdistrict (1979–87).—James Rogers was Subdistrict Chief until he retired in 1984. The office was located in the U.S. Department of Agriculture complex on Government Street. Ground-water projects in northern and central Louisiana were conducted under Rogers' supervision. The office was responsible for data collection and compilation for central Louisiana. It was also the home of the District drill rig that serviced the entire State plus other Districts as requested. Others assigned to the Alexandria Subdistrict Office were John Snider, Gary Ryals, Ralph Lites, Coleman Leach, Charles Smoot, David Sasser, Lester Seal, Amy Fogleman, Joann Guillot, and Kenneth Covay.

Student Program (1988–94).—In 1988 a program to help minority students to stay in school and to provide them with work experience was established between Southern University at Baton Rouge and the Louisiana District. The program titled "Stay-in-School" was an official program from Headquarters and was very beneficial to both the students and to the District. At times there were as many as 17 students registered in the program. They were employed in various Sections such as Administration, Computer, Reports, and the Sediment Laboratory. After graduation, four of these students were hired as professionals and a fifth student was working full time while completing his studies. Geraldine Stallworth and the District Chief coordinated the program with the University, interviewed the students, and provided consultation.

FUNDING AND COOPERATION

In the early 1980's and previously, the Louisiana State budget was supported largely by oil and gas revenues. When the industry became depressed in the middle 1980's, funding for State agencies and, correspondingly, cooperative funds were reduced.

Funds for the District during the 1980's and early 1990's increased gradually from an annual

Louisiana District funds, fiscal years 1979–94

[Funds are in thousands of dollars; Coop, Cooperative program; OFA, other Federal agencies; Fed, Federal program]

Funding source	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	975	1,057	1,323	1,139	1,397	1,757	1,426	1,327	707	1,048	1,065	1,031	1,281	1,240	1,261	1,132
Matching	972	998	1,044	996	1,260	1,410	1,417	1,236	706	1,027	1,050	1,030	1,280	1,205	1,211	1,132
OFA	1,419	1, 346	1,163	1,110	996	928	826	1,142	1,228	1,082	1,291	1,661	1,423	2,068	2,283	2,820
Fed	192	246	186	492	299	317	593	626	909	575	408	303	319	168	410	145
Total	3,557	3,647	3,716	3,737	3,952	4,412	4,262	4,332	3,550	3,732	3,814	4,025	4,303	4,681	5,165	5,229

increase of $100,000 in 1980 to $300,000 in the early 1990's. However, due to the recession in the petroleum industry, cooperative contributions by the State began to be reduced; in 1987, funding was only one-half what it had been. Cooperative funding did not recover to previous levels until 1991.

The Louisiana Department of Transportation and Development (DOTD) through their Offices of Highways and Public Works had always been the largest cooperator in the Federal-State Cooperative Program. Most of the data collected and investigations conducted were funded by this cooperator. When the State of Louisiana faced budget difficulties in the middle 1980's, DOTD canceled their cooperative program in the 1986–87 State fiscal year. This caused havoc in the District Cooperative program. The Secretary of DOTD at that time did nothing to retain the program, and it was only through the efforts of a State Division Chief, a USGS employee's spouse, and the District Chief that the program was partly reestablished through discussions with a State Senator. Because of this funding loss, the program with the Office of Highways was not resumed, and as a result of the loss of this cooperator, peak-flow, flood-hydraulics, and partial-record station programs were adversely affected. In addition, all the water-quality monitoring stations in the program with the Office of Public Works were discontinued and have not been restored to date. The matching funds from DOTD did not again reach the level that they were prior to the crisis.

During the funding crisis with DOTD, other cooperators, old and new, helped support data programs. Such cooperators as Louisiana Department of Environmental Quality (DEQ) and Capital Area Ground Water Conservation Commission (CAGWCC) increased their contribution, and new cooperators such as Jefferson Parish started studies for evaluating new sources of drinking water and for developing systems for collecting and transmitting real-time data. Other studies were started with Louisiana Department of Wildlife and Fisheries and the Louisiana Department of Natural Resources to study coastal streams. The CAGWCC provided funding for modeling the aquifer system in five parishes in the Baton Rouge area, in addition to cooperative funding for ground-water networks.

The Federal Program (Fed) funding increased or decreased depending on the startup or end of special studies such as the Regional Aquifer-System Analysis (RASA). The Coastal Lowlands aquifer-system study, as a part of the West Gulf Coast RASA (1982–89), was conducted through the District Office during the middle 1980's. A water-quality program, the National Surface Water-Quality Accounting Network (NASQAN), was another major Fed program. Monthly samples were collected at 23 stations statewide. This program continued until 1987, was reduced to 19 stations with bimonthly sampling, and then further reduced to quarterly sampling by 1994. Constituents included major inorganic ions, trace metals, and sediment concentrations. Two of the stations were on the Lower Mississippi River.

Other Federal agency (OFA) programs also played a substantial part in the District program. The agency with the largest program was the New Orleans District of the U.S. Army Corps of Engineers. Much water-quality, flow, sediment, and salinity data were collected and analyzed by the USGS District laboratory for the New Orleans office of the Corps. The District assisted the Vicksburg District of the U.S. Army Corps of Engineers on a smaller scale. Another Federal agency in which assistance was given was the U.S. Army at Fort Polk. The studies at Fort Polk included evaluating sources of water supply and ground-water pollution assessment.

Summary of Programs

Hydrologic-Data Collection

The Field Offices collected, computed, and prepared for publication most of the hydrologic data produced in the District. In the 1970's, the Louisiana District was almost always first among all Districts to publish their Annual Report of Hydrologic Data. The publication included surface-water, ground-water, and water-quality records. During the 1980's and early 1990's L.J. Dantin reviewed the surface-water records; Charles Demas, Geraldine Stallworth, and Charles Garrison reviewed the water-quality records; and Susan Marshall and Christie Stuart reviewed the ground-water records.

Streamflow stations.— At the beginning of the 1980's, the District operated 290 stations. This included 78 continuous-record stations and 212 partial-record stations, including crest-gage and flood-profile sites. All of the continuous-flow stations were equipped with digital-tape recorders, and the records were computed by, and the data stored in, the computer. In 1988, there were a few real-time stations that were sending continuous data by satellite to the computer in the office. Throughout the period there was a gradual decline in the number of surface-water stations. By 1994, 64 continuous-record stations were operated, and about 50 percent were real-time stations equipped with data-collection platforms. Partial-record stations had decreased to 103 (26 were crest-gage stations). The greatest decrease occurred in 1987 when the Office of Highways program was discontinued. Some of the gages were continued under the Office of Public Works program.

Ground-water stations.—The District operated water-level networks throughout the State to monitor representative water-level changes in each of the major aquifers. Water levels were monitored continuously in 13 wells and measured periodically in approximately another 670 in 1981. Samples were collected in 112 wells for water-quality analyses. By 1994, the networks had been streamlined for producing the greatest information for the least cost. Nine recording and 200 periodic stations were operated for water levels in 13 aquifers for 8 networks. Chloride samples were collected in 46 wells for 3 networks. One of the networks was established in the middle 1980's for the purpose of mapping the location and monitoring the movement of the saltwater in the Chicot aquifer interface along the Gulf Coast. Special water-level networks were established in the intensely pumped area in and around Baton Rouge.

Water-quality stations.—At the beginning of the 1980's, surface-water-quality networks constituted a large program in the District. Most of the field work was conducted out of the Baton Rouge Office. In 1979, there were 23 stations in the NASQAN Program, a Federal program. The program at the beginning was designed for monthly sampling for major inorganic ions, trace metals, and instantaneous concentrations of sediments. Samples for determination of bacteria and biological oxygen demand (BOD) were collected at all of the stations. By the end of the 1980's, the program had been reduced to quarterly sampling at 19 stations. Two of the stations on the Mississippi River continue operation.

Another large surface-water-quality network was in the cooperative program with DOTD. This network included 47 stations: 5 in the southern part of the State which were operated with mini-monitors, 4 daily sites on the Mississippi River, 12 lakes, and 26 quarterly sites. Constituents included pesticides, nutrients, trace metals, bacteria, BOD, and bottom material for the analysis of nutrients, trace metals, and pesticides. This program came to an end with the funding crisis of 1987.

The U.S. Army Corps of Engineers (Corps) also provided funding for 5 sites on the Red River, 6 sites on the Mississippi River, and 43 coastal sites. The coastal sites were sampled for pesticides, bacteria, trace metals, nutrients, chlorophyll, BOD, and chemical oxygen demand.

Fluvial-sediment stations.— The District operated a large network of sediment stations under the Federal and OFA programs during the decade of the 1980's. Monthly samples were collected at 23 statewide NASQAN stations and at a Hydrologic Benchmark Network station. The samples were analyzed for sediment concentrations, sand-silt split, and instantaneous load. In addition, a daily station was operated at the Pearl River near Bogalusa.

A program funded by the New Orleans office of the Corps consisted of eight stations on the Mississippi and Atchafalaya Rivers, which were sampled four times each month. These samples were analyzed for sediment concentrations, and daily loads were computed.

The District sediment laboratory, in addition to analyzing the Louisiana samples, also analyzed all of

the Mississippi District samples and some for Arkansas, Texas, Georgia, Florida, and North Carolina. The District sediment laboratory was one of only three full-service laboratories in the Nation during this history period.

Water-use data.—The water-use program is driven by the need for data for national reports and the local management and jurisdiction of the resource. In areas such as the one managed by CAGWCC, monthly data are collected, recorded, and distributed periodically to the public. Other lines of communication have been developed with farm institutions and with various industries to record water-use data. This networking has provided a good set of water-use data. This cooperatively funded program is one of the largest in the country and continues to be one of the better funded programs throughout the Nation.

Interpretive Studies

Cooperative ground-water investigations.—The last areal study for the identification of ground-water resources of the State was completed at the beginning of this segment of the history ("Ground-Water Resources of the Rayville–Delhi Area, Northeastern Louisiana," by Kenneth Covay). Following the areal studies, the ground-water-resource investigations were focused more on current needs of the State.

Aquifer evaluations relative to water requirements for the growing of rice (Covay, Sturrock, and Sasser), for crawfish farming (Lovelace), and as an alternative source for municipal supply in Jefferson Parish (Rapp) were initiated. In rapidly growing areas in Livingston, St. Helena, Ascension, and Tangipahoa Parishes, ground-water hydrology studies were conducted (Tomaszewski).

As the knowledge of the State's aquifer systems grew and the methods for study became more advanced, digital modeling of aquifers became a common approach for evaluating concepts of ground-water flow and for the management of aquifers. Models for the simulation of the geohydrology and ground-water flow were developed for the 400- and 600-foot aquifers (Kuniansky), 1,200-foot aquifer (Halford), 1,500- and 1,700-foot aquifers (Huntzinger and others), and 2,000-foot aquifer (Torak), all of which are in the Baton Rouge area. Models were also developed for aquifers in the New Orleans area (Dial and Summer), Sparta aquifer (McWreath and others), and Chicot aquifer system (Nyman and others).

As part of the cooperative program with the State, a layman's report, "Guide to Louisiana's Ground Water" (Stuart and others) was published. Other ground-water studies focused on water quality: the statewide occurrence of minor elements (Dial and Huff) and the effects of pumping on salinity in the Sparta aquifer (Trudeau and Buono). An innovative approach was the study of the movement and fate of fecal-coliform bacteria in a shallow aquifer (Halford and others).

OFA ground-water investigations.—Fort Polk, a major military installation in Louisiana, supported many ground-water studies and data activities such as geohydrology and ground-water development (McWreath and Smoot) and ground-water quality data relating to the use of fuels and munitions on the military post (Fendick).

The study of the effects on ground water from the construction of the navigational project on the Red River by the Vicksburg office of the Corps of Engineers was another project that resulted in many reports and data compilations (Rogers and Smoot).

Federal ground-water investigations.—The Louisiana District was given the responsibility of conducting the Coastal Lowlands aquifer system part of the Gulf Coast Regional Aquifer-System Analysis (RASA) program. This Federal study of the major aquifer systems in the Nation contributed many reports and much understanding of the geohydrology and ground-water movement in major aquifer systems in Louisiana.

Cooperative surface-water investigations.—The emphasis in many surface-water projects during the 1980's was on computer simulations of flow in streams and bays along the Gulf Coast of Louisiana. Flow in the lower Calcasieu River (Arcement), flow and transport in the lower Mississippi River (Curwick), and the effects of U.S. Highway 90 on Pearl River floods (Gilbert and Froehlich) were all projects that used computer techniques for analysis.

Major flooding occurred during this period, and increased understanding and documentation of these events were recorded in floods of 1983 (Carlson) and in the analysis of backwater at the Interstate Highway 10 crossing of the Pearl River (Wiche and others). This was also the time when the crest-stage gage program (Herbert and others) was being evaluated on a national basis and resulted in a substantial reduction in the number of gages in Louisiana.

Other studies involved the development of hydrologic techniques, hydrologic processes, or basin analysis: dye-tracing techniques to determine mixing and circulation (Curwick), evaluation of techniques for measuring streamflow and for estimating flow characteristics in the Mississippi River Delta (Lee and White), hydrology of Fritchie Marsh (Kuniansky), and mean annual runoff in Louisiana (McWreath and Lowe).

OFA surface-water investigations.— The Federal Highway Administration funded research for determining Manning's roughness coefficients for natural channels and flood plains, especially those which were densely vegetated (Arcement and Schneider).

Cooperative water-quality investigations.— Water quality has always held a high level of interest in the State because the mouth of the Mississippi River, which drains a significant area of the Nation, is in Louisiana and many people near the coast use surface water as a source of municipal supply. In addition, Louisiana has a large seafood industry that is vulnerable to pollution. Studies that document the quality of water and further the understanding of transport processes are: hydrology, water quality, and biology of Baptiste Collette Bayou (Demas), limnology of Lake Bruin (Demas), suspended-sediment, bottom-material, and transport characteristics of the lower Mississippi River (Demas and Curwick), occurrence and fate of volatile organic compounds in the lower Calcasieu River (Demas and others), and water quality of upper Vermilion River (Demcheck and Leone). Most of the water-quality emphasis has been on surface-water quality, but ground water was not ignored. Tomaszewski developed an atlas map on the quality of freshwater aquifers.

Reference to all Louisiana District reports can be found in Water Resources Special Report no. 13 of the Louisiana Department of Transportation and Development.

Historical Hydrologic Events

Pearl River Flood of April 1983.—The flood of 1983 in the Pearl River Basin of southern Mississippi and southeastern Louisiana was a major flood having a recurrence interval greater than 200 years. The reason this event has such historical importance is that the floodwaters flowed over Interstate Highway 10 (I–10) east of New Orleans for 5 days. I–10 is a major transportation route between the East and West coasts. Having the highway closed for 5 days and only partly opened for 7 more days was a transportation crisis.

Catastrophic Draining of Lake Peigneur.—On November 20, 1980, an oil rig drilling in Lake Peigneur penetrated an underground salt mine. Diamond Crystal mine extended 1,000 feet below the lake's surface, and in less than an hour the lake was drained and a drill rig, 11 barges, and a tugboat were swallowed into the mine. Men in the mine scrambled to the surface and no one was killed. Draining of the lake caused much damage to structures and land surrounding the lake.

Sole-Source Aquifer designation.—In 1981, the U.S. Environmental Protection Agency (USEPA) requested ground-water information from the Survey on two aquifer systems. The District provided the USEPA District 6 in Dallas, Texas, hydrologic data on the Southern Hills aquifer system and the Chicot aquifer system. This information was used as supporting data for consideration of Sole-Source Aquifer designation. In 1988, the two aquifer systems were designated Sole-Source status. The designation protects these aquifer systems from the construction of any federally funded facility that would have the potential for contaminating the ground water.

MISSISSIPPI

By Larry J. Slack

ORGANIZATION AND PERSONNEL

Through most of the period, the Mississippi District consisted of a Headquarters Office in Jackson and a one-person Field Office in Tupelo. The number of employees during the period ranged from a minimum of 41 in 1982 to a maximum of 59 in 1986 (average 50). The largest growth year was from 1983 to 1984 when the number of employees increased from 44 to 50; the largest loss year was from 1981 to 1982 when the number of employees decreased from 47 to 41.

During the period, hydrologic technicians, hydrologists, and students made up the largest percentage of these totals. Hydrologic technicians made up 33 percent of the total on average, with a low of 24 percent in 1979 and a high of 39 percent in 1986. Hydrologists (a catchall category that, for Mississippi,

includes mostly engineers, geologists, and chemists) made up 32 percent of the total on average, with a low of 26 percent in 1991 and a high of 42 percent in 1979. Cooperative education students made up 11 percent of the total on average, with a low of 2 percent in 1982 and a high of 19 percent in 1986.

District Headquarters, Jackson

Office of the District Chief.—In 1979 the District Office moved from leased space at 430 Bounds Street in north Jackson to the new Dr. A.H. McCoy Federal Building at 100 West Capitol Street in downtown Jackson where it remained throughout this period.

Lamar E. Carroon served as District Chief until he retired in January 1980. Garald G. Parker, Jr., transferred from Oregon to become District Chief in July 1980. Parker transferred to Tacoma, Wash., in 1986 and Michael W. Gaydos became District Chief in January 1987. Gaydos moved on to become Assistant Regional Hydrologist for the Southeast Programs (Alabama, Georgia, and Tennessee) in 1990. Gerald L. Ryan was Acting District Chief until he was promoted to District Chief in October 1991; Ryan remained District Chief throughout the rest of this period.

The Section Chiefs served as Assistant District Chiefs during the period. These were Andrew G. Lamonds (1979–88), Ernest H. Boswell (1979–86), Gerald L. Ryan (1989–91), Charles H. Tate (1979–84), Ezra J. Tharpe (1984–90), and Michael L. Plunkett (1990–94).

Others who worked under the direct supervision of the District Chief during part of this period included the following: J. Kerry Arthur, Peggy S. Callahan, Terry E. Clark, Linda A. Lowery, Michael J. Mallory, Geraldine G. Montgomery, Bettie P. (Carol) Moss, Linda L. Parker, Charles Robertson, Larry J. Slack, Terry L. Sorey, Charles H. Tate, Richard E. Taylor, Melanie R. Thomas, Deborah M. Walker, and Kenneth V. Wilson, Sr. Arthur and Taylor served under the District Chief while studying the Mississippi Embayment aquifer system (as part of the Gulf Coast Regional Aquifer-System Analysis project) within the USGS Regional Aquifer-System Analysis (RASA) program. Kenneth V. Wilson, Sr., was the principal investigator in highway hydraulics and flood-data collection (until his death in 1982), assisted by James W. Hudson. Slack was District Reports Specialist and District Water-Quality Specialist from 1988 through the end of this period.

Administrative Services Section.—In 1979 the Administrative Services Section consisted of two people—Ruth D. Bourland, who was the chief Administrative Clerk, and Lewis E. Snyder. In 1980 Deloris F. Gale replaced Snyder. In 1981 the Section increased to four people, and Bourland became the District's first Administrative Officer, remaining until she retired in 1983. Gayl C. Brock informally led the Section until she was promoted to Administrative Officer in October 1985. The Section grew to six people in 1989 and generally remained at that strength (with Brock as Administrative Officer) throughout the rest of the period. Others who served in the Section during the 1979–94 period were Victoria D. Anderson, Irma J. Downing, Hilma D. Golden, Benita M. Grayson, Joycelyn Connor Humes, Mary S. Jones, Gail C. Keigley, Sharon London, Kimberly Moncure, Bettie P. (Carol) Moss, Martha B. Murphy, Cular B. Ransom, and Althelda R. Spiller.

Reports Preparation Unit.—A District Reports Preparation Unit was established in 1989 consisting of Carol Moss and Charles M. Hill. This Unit had previously existed as an unnamed unit within the Hydrologic Projects and Reports Section until that Section was renamed the Hydrologic Investigations Section in 1988. The Unit consisted of the same two individuals throughout the period.

Computer Applications Section.—As computers became more important to daily operations, a Computer Applications Section was established in 1984 with Terry E. Clark as head. The other employees in the Section at that time were Geraldine G. Montgomery, Computer Assistant, and Melanie R. Thomas, Hydrologic Aid. (Terry Clark's name was changed to Terry E. Gibbs in 1986.) In 1988 JoAnn R. Guillot, Computer Assistant, was added to the Section. Computer Applications was renamed a Unit from 1989 through 1993. In 1994, Computer Applications was renamed a Section. Gibbs remained in charge of the Section until her resignation in November 1989. In April 1990, William A. Winstead, Computer Programmer Analyst, transferred to Jackson and was put in charge of the Computer Applications Section. He remained in charge of Computer Applications throughout the period. Others who worked in the Computer Applications Section during the period were Tommy L. Chambers, Jack F. Green, and Willie J. Nathan.

The first computer resource in the District was a terminal that would read card decks and transmit their images to a host computer at Headquarters in Reston, Va. The host computer would do the computations requested by the submitter and transmit the results back to the terminal where the results would be printed. A major change came about in 1983 when a minicomputer replaced the terminal. This system provided a terminal connected to the minicomputer at most desks. Workstations arrived about 1991, but the minicomputer would remain in use for hydrologic records computation for several years because of a delay in program development for the workstations.

Hydrologic Data Section.—This Section was called the Hydrologic Records Section from 1974 through 1987, but its principal function remained the same, which was to oversee the basic-data collection and analysis, provide quality control and review, archive the data, and publish the Annual Data Report. In 1984 the Surface Water Records Unit was created within the Section. Section Chiefs during the period were Charles H. Tate, until he was reassigned to be under the District Chief in 1984; Ezra J. Tharpe, until he retired in 1990; and Michael L. Plunkett, from 1990 throughout the rest of this period. The Surface Water Records Unit was under the supervision of Tharpe, 1984–85; Plunkett, 1986–93 (during part of this time Plunkett served as Chief for both the Unit and the Section); and D. Phil Turnipseed, from 1993 throughout the rest of the period.

Others (including students, seasonal, and part-time employees) who served in the Hydrologic Data Section (some later served in other Sections) included the following: James H. Alvis, James A. Anderson, J. Kerry Arthur, Nancy L. Barber, Gene A. Bednar, Michael W. Bell, S. Harold Bishop, Janet R. Brown, Kenneth E. Burks, David E. Burt, James A. Callahan, James H. Carter, Linda R. Cassedy, Tommy L. Chambers, Theodore Chapman, Diana W. Cook, Miguel A. Corral, Joe P. Crout, Ronald P. Durr, Jo F. Everett, Gary D. Firda, Jeffrey Flowers, L. Joyce Gabourie, James D. Gayle, Frederick H. George, Douglas E. Gibbs, Paul E. Grantham, Todd Hammock, Jackson A. Herrington, A. Marie Hickman, Jane B. Hill, Kurt M. Hitke, Edward D. Holland, Gloria A. Johnson, Valerie M. Johnson, Regina D. Jordan, Stephen J. Kalkhoff, James F. Kelley, Coleman D. Leach, Charles H. Lee, Gloria J. Lucas, Michael A. Manning, Derek D. Matlock, Billy J. McCollum, Alvin R. McQuarters, Ethel R. Milton, Richard S. Moreland, Fred Morris III, Thomas V. Nevitt, William T. Oakley, Boyce C. Parker, George E. Peters, William D. Phillips, John E. Pinkard, James A. Powell, Terry M. Puckett, Bobby R. Richards, B. Allen Roberts, James D. Shell, Timothy Shumaker, Robert B. Simmons, Gala D. Smith, Robert B. Stephens, John B. Storm, Debra A. Thedford, Catherine A. Thompson, George L. Tillman, Dan J. Tomaszewski, Tommye L. Walker, Denver J. Washington, Edwin B. Wells, Todd C. Williams, Darrel T. Wilson, and K. Van Wilson, Jr. Bednar was District Water-Quality Specialist until he retired in 1988.

Hydrologic Projects and Reports Section and Hydrologic Investigations Section.—Ernest H. Boswell was Chief of the Hydrologic Projects and Reports Section until he retired in 1986. Andrew G. Lamonds was Chief during 1987–88. In 1988, the Section was renamed the Hydrologic Investigations Section. Gerald L. Ryan transferred to Jackson to become Section Chief in 1989. John F. Harsh transferred to Jackson to become Section Chief in 1992. Additional personnel serving in the Hydrologic Projects and Reports/Hydrologic Investigations Section included the following:

J. Kerry Arthur, Sarah H. Baker, W. Trent Baldwin, Nancy L. Barber, Martha V. Barker, Jason D. Beckler, Craig B. Bentley, Janet R. Brown, David E. Burt, Jr., Theodore L. Chapman, John A. Cheek, Billy E. Colson, Lance M. Cooper, Gerald J. Dalsin, Daphne Darden, Bennie E. Dawsey, Nancy A. Derryberry, Conrad T. Dobbs, Paul A. Dooley, Gary D. Firda, Paul C. Floyd, Deborah Franklin, Lynnette A. Gandl, Jennifer L. Gillian, Gala D. Goldsmith, Geraldine Goldsmith, Cassaundra Green, Patrick C. Harris, Charles M. Hill, Penny J. Hom (later Penny M. Johnson), James W. Hudson, Merle A. Hudson, Peter Hutchins, Paul Johnson, Sherry A. Johnson, Wendy M. Steffe, Stephen J. Kalkhoff, John M. Kernodle, Mark N. Landers, Linda A. Lowery, Paul M. Lucas, Michael J. Mallory, Michael Maraman, Mark S. McBride, Richard S. Moreland, James D. Morgan, Bettie P. (Carol) Moss, Charles G. O'Hara, Sean W. O'Neill, Charles O. Peel, Humphrey Planer, Michael L. Plunkett, John R. Ratliff, Richard A. Rebich, Michael S. Runner, Roger E. Schweitzer, James A. Smith, Rodney E. Southard, Charles A. Spiers, Nancy S. Stanford, John S. Story, Donald J. Strickland, Eric W. Strom, David M. Sumner, Richard E. Taylor, Pamela A. Telis, D. Phil Turnipseed, Russell C. Wallace, Billie E. Wasson, K. Van Wilson, Jr., Karl E. Winters, Donna D. Womack, and Charles D. Woods.

The Field Offices

The District maintained a one-person Field Office in New Albany until the end of 1982. When Billy J. McCollum, the Hydrologic Technician who operated out of that office, took a disability retirement, the office was relocated to Tupelo. The Tupelo Field Office was maintained as a one-person office until it closed in 1989, except for 1985 when it was maintained as a two-person office. Douglas E. Gibbs operated out of the Tupelo office during 1983–86; Todd W. Hammock, during 1985; and Jackson A. Herrington, during 1987–89.

FUNDING AND COOPERATION

Although not every year was marked by an increase in funding (indeed, some years were marked by decreases), Federal, OFA (other Federal agencies), State, Federal matching, and total funding increased during the period 1979–94 (table 1). Federal funding increased $205,100, or 150 percent from 1979 to 1994. OFA funding increased $783,980, or 143 percent. A large part the OFA funding for this period was for additional work being carried out for the U.S. Army Corps of Engineers (Corps). State funding increased $769,550, or 243 percent. Federal matching increased $517,000, or 137 percent. Total funding increased $2,215,630, or 154 percent. The only category to show a decrease for the period was "Other," which was eliminated in 1993 and remained zero in 1994.

SUMMARY OF PROGRAMS

The following is a listing of the principal projects being conducted by the USGS in Mississippi during 1979–94 and Project Chief and project period.

Salt Dome Hydrogeology in Mississippi

Project Chief: Craig B. Bentley (1977–85)

Tennessee-Tombigbee Divide Section Water-Quality Monitoring

Project Chief: Fred Morris III ((1978–87)

Potentiometric-Surface Mapping of Aquifers in Mississippi

Project Chief: Eric W. Strom (1978–94)

Table 1. Mississippi District funds, fiscal years 1979–94

[Source: Deloris F. Gale, Administrative Officer]

Fiscal year	Federal	OFA	State	Other	Federal matching	Total
1979	137,100	546,800	317,000	60,000	377,000	1,437,900
1980	137,100	805,350	328,600	78,000	406,600	1,755,650
1981	258,900	414,130	337,200	90,800	427,800	1,528,830
1982	294,200	703,200	629,300	83,000	649,000	2,358,700
1983	379,400	689,800	629,300	83,000	649,000	2,430,500
1984	423,950	787,910	599,130	64,000	613,800	2,488,790
1985	501,860	686,785	645,200	83,000	642,000	2,558,845
1986	366,000	1,183,860	577,000	90,000	620,000	2,836,860
1987	313,520	918,580	677,500	67,500	730,000	2,707,100
1988	293,700	1,040,980	650,900	137,800	788,700	2,912,080
1989	219,350	1,116,100	796,700	107,000	870,000	3,109,150
1990	149,200	1,292,850	975,700	16,000	840,000	3,273,750
1991	142,820	1,052,550	1,142,950	42,435	929,435	3,310,190
1992	139,665	1,251,729	1,274,700	34,000	875,000	3,575,094
1993	141,940	1,244,130	1,071,400	0	883,000	3,340,470
1994	342,200	1,330,780	1,086,550	0	894,000	3,653,530

Ground-Water Model – Simulations of the Effect of Proposed Navigation Control Alterations of the Yazoo River, Mississippi

Project Chief: John M. Kernodle (1978–83)

Hydrologic Impact of Deep Surface Mining for Lignite on an Alluvial Aquifer in Mississippi

Project Chief: Stephen J. Kalkhoff (1980–84)

Southeastern Coastal Plain Regional Aquifer System Analysis – Mississippi

Project Chief: Michael J. Mallory (1979–86)

Application of Digital Model to Ground-Water Supply Problems in the Tupelo Area, Mississippi

Project Chief: John M. Kernodle (1980–82)

Background Hydrologic Data in Potential Lignite Mining Areas in Mississippi

Project Chief: Stephen J. Kalkhoff (1980–86)

Digital Model of Eutaw-McShan Aquifer System in Mississippi

Project Chief: John M. Kernodle (1980–83)

Flow Characteristics of the Tombigbee River

Project Chief: Billy E. Colson (1980–85)

Brine Contamination of Shallow Aquifers and Streams in Mississippi

Project Chief: Stephen J. Kalkhoff (1981–86)

Synoptic Study of the Mississippi River Alluvial Aquifer in the Yazoo Basin

Project Chief: Billie E. Wasson (1981–85)

Ground-Water Resources in the Barnett Reservoir Area, Mississippi

Project Chief: William T. Oakley (1981–84)

West Gulf Coast—Southeastern Coastal Plain Regional Aquifer-System Analysis, Mississippi

Project Chief: J. Kerry Arthur (1981–90)

Water Resources of the Mississippi Gulf Coastal Region

Project Chief: David M. Sumner (1984–88)

Quality of Ground Water and Nature of Contaminants of Shallow Aquifers in the Gulf Coastal Plain of Louisiana and Mississippi

Project Chief: Gene A. Bednar (1984–86)

Jackson, Mississippi, Metropolitan Area Ground-Water Investigation and Digital Model

Project Chief: J. Kerry Arthur (1985–92)

Geohydrology and Simulated Effects of Ground-Water Withdrawals on the Miocene Aquifers in the Area of Jones County, Mississippi

Project Chief: Michael J. Mallory (1987–90)

Geohydrology and Simulated Effects of Ground-Water Withdrawals on the Miocene Aquifers in Selected Areas of Southern Mississippi

Project Chief: Eric W. Strom ((1989–94)

Bridge Scour Prediction Equations for Mississippi Streams

Project Chief: W. Trent Baldwin (1989–97)

Channel Meandering Estimation Using Remote Sensing and a Geographic Information System

Project Chief: D. Phil Turnipseed (1990–92)

Susceptibility of Major Aquifers to Surface and Shallow-Source Contamination

Project Chief: Richard S. Moreland (1990–96)

Determination of Methods for Characterization of Underground Injection Sites in Mississippi

Project Chief: Richard A. Rebich (1990–93)

Hydrogeologic Characteristics Affecting Vertical Recharge to the Mississippi River Alluvial Aquifer in Northwestern Mississippi

Project Chief: J. Kerry Arthur (1993–94)

Effects of Agricultural Best Management Practices on Concentrations of Nutrients, Pesticides, and Suspended Sediment in Surface and Subsurface Waters in the Mississippi River Alluvial Plain, Northwestern Mississippi

Project Chief: Richard A. Rebich (1993–2004)

Mississippi Embayment Study Unit of the National Water-Quality Assessment (NAWQA) Program

Project Chief: Michael J. Mallory (1994)

SUMMARY OF HYDROLOGIC-DATA COLLECTION SITES

The number and types of hydrologic-data collection sites operated in Mississippi during 1979–94 are summarized in table 2. These data were taken from the abstracts of the annual Water Resources Data for Mississippi series and include basic-data collection sites and some project data-collection sites. Other project sites were operated during the period but were not included in the abstracts (usually because of the short-term nature of the sites); hence, they are not included in table 2.

During this period, the number of hydrologic-data collection sites operated in the State ranged from 520 (in 1994) to 1,442 (in 1988) and averaged 874. The number of surface-water stations ranged from 158 (in 1982) to 678 (in 1988) and averaged 280. The number of ground-water stations ranged from 49 (in 1994) to 629 (in 1985) and averaged 360. The number of water-quality sites ranged from 44 (in 1986) to 551 (in 1992) and averaged 234.

SUMMARY OF REPORTS

The following is a brief description of report publication (excluding the annual Water Resources Data for Mississippi reports) by the USGS in Mississippi during 1979–94. To keep this discussion brief, the information applies only to the senior authors. Nonetheless, the USGS deeply appreciates the great contributions of the coauthors and others without whom many of these reports would not have been published.

During this period, USGS authors in Mississippi produced 220 publications. Of these, 93 (42 percent) were Water-Resources Investigations Reports; 74 (34 percent), Open-File Reports; 9 (4 percent), Water-Supply Papers; 6 (3 percent), Hydrologic Atlases; 2 (1 percent), Fact Sheets; and 2 (1 percent), Professional Papers. In addition, 34 (15 percent) were released as outside publications (for example, as journal articles or in a State series).

On average, about 14 reports were published per year during 1979–94. Ten or more reports were published every year except 1987 (7 reports, or 3 percent) and 1992 (9 reports, or 4 percent). More reports (20 reports, or 9 percent) were published during 1986 than during any of the other years.

Ten of the 51 senior authors produced almost one-half of the reports (109 reports, or 50 percent), and 20 of the authors produced over three-fourths of the reports (168 reports, or 76 percent). The following is a list of the most prolific authors and the number of reports they produced during the period: Daphne Darden, 16; Stephen J. Kalkhoff, 15; Billie E. Wasson, 13; Gene A. Bednar, 11; Larry J. Slack, 11; Billy E. Colson, 10; Fred Morris III, 9; Ernest H. Boswell, 8; William T. Oakley, 8; D. Phil Turnipseed, 8; K. Van Wilson, Jr., 8; J. Kerry Arthur, 7; James A. Callahan, 7; Gala D. Goldsmith, 6; David M. Sumner, 6; Andrew G. Lamonds, 5; Mark N. Landers, 5; Roger W. Lee, 5; Michael J. Mallory, 5; and Richard A. Rebich, 5.

Table 2. Number of data-collection sites by year and type, 1979–94

Water year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Surface-water stations																
Continuous streamflow	80	82	82	63	67	67	71	71	78	70	81	78	80	82	83	85
Continuous stage	3	4	4	5	5	5	5	5	5	6	6	6	6	6	6	6
Flood hydrograph	0	0	0	0	0	0	0	0	0	5	6	6	7	6	7	8
Low-flow partial record	0	0	0	0	0	0	0	0	0	158	20	0	0	0	0	0
Crest-stage partial record	94	94	91	90	89	89	58	56	56	55	55	55	55	55	55	54
Reservoir stage, contents	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Miscella-neous sites	0	0	0	0	0	0	106	162	263	301	143	103	113	91	107	97
Special study	0	0	0	0	0	0	0	0	0	83	62	42	51	30	46	35
Subtotal	181	184	181	158	161	161	240	294	402	678	373	290	312	270	304	285
Ground-water stations																
Observation wells (Subtotal)	360	360	324	317	346	315	629	609	498	505	504	244	241	235	231	49
Water-quality sites																
Streamflow gages	25	32	33	26	23	23	13	12	11	11	24	23	22	24	24	24
Ground-water wells	162	105	123	71	331	94	263	29	120	205	32	42	149	65	384	109
Partial-record, miscella-neous sites	0	19	18	85	63	66	0	0	0	12	9	9	8	8	6	4
Precipitation quality	0	0	0	0	2	2	0	0	3	3	3	3	5	4	3	0
Ungaged stream sites	0	0	0	0	0	0	8	3	2	2	2	2	2	2	2	1
Short-term study	0	0	0	0	0	0	0	0	0	26	43	96	59	448	21	48
Subtotal	187	156	174	182	419	185	284	44	136	259	113	175	245	551	440	186
Total	728	700	679	657	926	661	1,153	947	1,036	1,442	990	709	798	1,056	975	520

MISSOURI

By James H. Barks

INTRODUCTION

The 1979 to 1994 period was an exciting one in the history of the Missouri District. It was filled with change, growth, and special events. Early in the period, the National Energy Program and Regional Aquifer-System Analysis (RASA) Program provided unprecedented opportunities for major interpretive studies. New technical expertise recruited for these programs stayed in the District and became the core for building future interpretive programs. The most significant happening was the great flood of 1993, which not only taxed the resources of the District, but provided many opportunities for expanded data and interpretive work.

ORGANIZATION AND PERSONNEL

Throughout the period, the District continued to operate from offices in Rolla, St. Louis, and Independence.

Rolla

The District Office was collocated with the National Mapping Division's Mid-Continent Mapping Center (MCMC) and Mid-Continent Personnel Office at 1400 Independence Road. The Rolla Field Office was established in 1985 and because of a space shortage was located in a separate building at 1210 Homelife Plaza. Staff for the Ozark Plateaus National Water-Quality Assessment (NAWQA) project and the new District sediment laboratory were collocated with the Rolla Field Office in 1992.

Donald L. Coffin became Missouri's second District Chief when he transferred from Montana in 1977. Coffin was a colorful westerner who missed the wide open spaces and moved back to the West (Colorado) in 1982 to become the Central Region Program Officer. He was replaced by Daniel P. Bauer from the Colorado District. Bauer was at the helm until 1991 when he relocated to Wisconsin to become the Area Hydrologist for the Great Lakes Area. Marvin G. Sherrill came from Texas to be District Chief from 1992 to 1995.

Horace G. Jeffery was Assistant District Chief until his retirement in 1986. John Skelton was Assistant District Chief representing the Hydrologic Surveillance Program from 1986 until his retirement in 1993. Skelton was followed by Loyd A. Waite. James H. Barks, who had worked his way up through the ranks in the District since 1968, became the first Assistant District Chief to represent the Hydrologic Investigations Program in 1990. Barks went on to become the Associate District Chief in 1993 and would follow Sherrill as District Chief.

The District Secretary at the beginning of this period was Wanietia M. (Suzie) Kratzer. She also doubled as reports processor, literally retyping manuscripts several times before they were finally published. Kratzer became a member of the Reports Section when it was established in 1983, and Carole A. Coburn succeeded her as District Secretary. Coburn transferred to the Central Region Office in Denver in 1988. Carol L. Ellingson was District Secretary until she moved to the Computer Services Section in 1992. Rita J. Choate filled the position during the remainder of the period.

Pamela J. Keeney joined the Administrative Services Section in 1979. With the resignation of Bernice W. Bolding and transfer of Mary A. Dickey to the MCMC in 1980, Keeney was in a "sink or swim" situation. As it turned out she was a good swimmer. Barbara E. Wessner joined the staff in 1981, and these two formed a strong team that would endure. Leslie L. Burns-Rigsby became the third member of the Administrative Services team in 1991.

Rapidly emerging computer technology developed a need for computer support in the District. Steven J. Brady transferred from Kansas in 1983 to become the first Missouri District employee dedicated to this function. A Computer Services Section was officially established in 1985, with Brady in charge. Brady transferred back to Kansas in 1991, and Gabriel R. Newman became the District Systems Administrator in 1992. Other employees who worked in the Section were James E. Morris, Michael P. McNally, Carol L. Ellingson, and several students.

A rapidly growing interpretive program and stringent policies for published reports brought about the need for more report processing and publication support. In 1985, a Reports Section was officially established with John Skelton as its leader. Other members were Wanietia M. Kratzer and Katherine L. Jenkins. By the end of the period, Brenda J. Smith was the District Reports Specialist in charge of the Section, and it had expanded to include Rebecca S. Inman,

Felicia D. Headrick, L. Carlene Shoemate, and Charlotte A. Pepmiller. It had become one of the major publication units in the Nation and was responsible for District Outreach. However, it would later become significantly downsized because of a trend toward shorter reports, relaxed requirements, and advanced computer capabilities, enabling authors to do much more of their own processing.

Although the District previously had done sediment analyses, it began participating in the national quality-assurance program and was approved to do work for other Districts in 1992. Robert R. Holmes, Jr., provided oversight for a major laboratory upgrade, and Kathryn M. Love became the first certified Laboratory Chief. She was supported by short details of other permanent employees and by students.

Hydrologic Surveillance (Data) Section.—This Section was composed of the Field Offices in Rolla, St. Louis, and Independence. Section Chiefs were Horace G. Jeffery from 1979 until his retirement in 1986, John Skelton from 1986 until his retirement in 1993, and Loyd A. Waite.

Waite took over just in time to coordinate field work for the 1993 flood. Hubert L. Reed was the Lead Technician for surface-water activities and Pierce W. Cross was the Lead Technician for water-quality activities. The ground-water data program, traditionally operated by the State, was so small that it was handled entirely by Walter S. (Dutch) Oakes until his retirement in 1982. District ground-water data-collection activities primarily were in support of interpretive projects. Other personnel who served in the Hydrologic Surveillance Section in Rolla were Gary A. Alexander, Frankie B. Franco, Howard C. French, Lester L. Grayson, Henry S. Hauck, Samual C. Kimbrough, Larry J. Lumpkin, John W. Melton, Eric S. Southern, Sherry A. Ternes, Robert E. Whitaker, and many students.

Hydrologic Investigations (Studies) Section.—Most interpretive studies were done out of the Rolla office. James H. Barks was the Section Chief. A quarterly project review system was implemented in 1980, and Barks attended every project review. Fiscal responsibility for projects was shifted from District management to project leaders. Project leaders were encouraged to participate in program development, resulting in many more cooperator contacts, a larger cooperator base, and an overall growth in program. Other personnel in the Investigations Section in Rolla were Terry W. Alexander, Lawrence D. Becker, Wayne R. Berkas, Daniele T. Chafin, Pierce W. Cross, Jerri V. Davis, Leo F. Emmett, Suzanne R. Femmer, Howard C. French, Dennis C. Hall, Edward J. Harvey, Leland D. Hauth, Robert R. Holmes, Jr., Richard J. Huizinga, Jeffrey L. Imes, Robert B. Jacobson, Michael J. Kleeschulte, Gilbert B. Malone, Thomas O. Mesko, Douglas N. Mugel, Joseph M. Richards, John G. Schumacher, John Skelton, Brenda J. Smith, Marilyn A. Turner, Jerry E. Vaill, Jr., Loyd A. Waite, Robert E. Whitaker, Gary L. Wilson, Emitt C. Witt III, and many students.

St. Louis

The office in St. Louis was a Subdistrict Office until 1984, when the Engineer-in-Charge, Donald W. Spencer, retired. Interpretive project activities were moved to Rolla, and the St. Louis office was converted to a Field Office with Dale O. Hatten as the Technician-in-Charge. The remaining work was data collection, primarily stream gages along the eastern part of the State, including the Mississippi River. The office moved to 9351 Dielman Industrial Drive in Olivette in 1986. Hatten retired in 1991 and George W. Gray ran the office until his retirement in 1994. Gray was succeeded by Leonard G. Huber. Other personnel who worked in the St. Louis office were Willie E. Easterling, Suzanne R. Femmer, John H. Lambing, Roger N. Nygaard, and Spencer S. Waldron.

Independence

The Independence office was located in the Federal Building at 301 West Lexington in downtown Independence throughout the period. At the beginning of the period, Charles E. Watts and Michael C. Moody were the only two people in the office. They shared the responsibility for operating the stream-gaging network in the northwestern part of the State. In 1981, Dale W. Blevins transferred from Indiana to Independence to be in charge of the office and lead their first interpretive project. Under Blevins' leadership, the interpretive program quickly expanded and other hydrologists with various technical backgrounds were added to the staff. By 1993, the office had grown to 14 people, including students, and it was designated a Subdistrict Office. Terry J. Perkins transferred from New Mexico to Independence in 1984 and directed field activities until his retirement in 1994. Other employees in the Independence office were Thomas E. Harris, David C.

Heimann, Brian P. Kelly, Kevin D. Richards, Gregg K. Schalk, Donald A. Wilkison, Andrew C. Ziegler, and numerous students.

FUNDING AND COOPERATION

As shown in the table of funds, the District budget tripled during the period. The Federal- State Cooperative (Coop) program and other Federal agency (OFA) program grew steadily throughout the period. The Federal program was relatively constant until the Ozark Plateaus NAWQA project, the Management Systems Evaluation Area (MSEA) project, and some flood- related projects came along in the early 1990's.

There were some noteworthy changes that took place in the Coop program. From 1980 to 1983 there was a small amount of reverse funding to the Missouri Department of Natural Resources (MDNR) to support water-use activities, the only time this practice occurred. Direct credit to cooperators continued through the 1980's, was scaled back in the early 1990's, and was discontinued in 1993. By the end of the period, the demand for Coop dollars was rapidly outgrowing the availability, and the unmatched part grew significantly. Unmatched dollars averaged about $70,000 per year through 1992, then increased to $400,000 in 1993, and $686,000 in 1994. With a conscious effort on the part of District management, this trend would continue into the future.

The data program was larger than the interpretive program throughout the 1980's. However, while the data program was relatively stable in the early 1990's, the interpretive program grew rapidly, and by 1994 it was nearly twice as large as the data program.

The number of local and State cooperators expanded from 8 in 1980 to 13 in 1994. In 1980, the largest program by far was with the MDNR, Division of Geology and Land Survey (DGLS), but by 1994, budget cuts had nearly eliminated their part of the program. In the early 1990's, large programs had developed with the MDNR, Division of Environmental Quality (DEQ), Missouri Department of Conservation (MDC), and Missouri Department of Transportation (MoDOT).

The number of OFA customers increased from six in 1980 to eight in 1994. The largest by far was the U.S. Army Corps of Engineers (Corps), with five Districts supporting the stream-gaging program in Missouri.

SUMMARY OF PROGRAMS

Hydrologic-Data Collection

During the 1980's and the 1990's, when the number of stations increased and personnel decreased, the records were completed on time every year and the District met every Water Resources Division (WRD) target date for transmitting the camera-ready copy of the annual data report to the printer. The significant improvements in computer technology were the reason these dates were met, as several experienced personnel retired and were not replaced.

Streamflow stations.—In 1980, the Field Offices in Independence, Olivette, and Rolla were operating approximately 110 continuous-record gaging stations, 10 continuous stage-only stations, and no crest-stage gages, except those located at continuous-record gaging stations for peak verification. In 1994, the Field Offices operated 107 continuous-record gaging stations, and 30 continuous stage-only stations, with little change in the crest-stage gages.

The number of continuous-record gaging stations varied between 105 and 118 stations during the 1980's. In 1991 the MDNR withdrew all funding from the stream-gaging program, resulting in the discontinuance of 17 stations. The number of stations

Missouri District funds, fiscal years 1980–94

[Coop, Federal-State Cooperative program; OFA, other Federal agency program]

Fund source	Fiscal year (Funds, in thousands of dollars)														
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	684	822	743	666	914	962	998	1,144	1,400	1,294	1,314	1,380	1,598	1,878	2,190
OFA	758	729	748	932	1,018	1,091	951	982	1,184	1,184	1,293	1,244	1,606	1,768	2,120
Federal	385	453	446	541	468	446	506	303	241	490	331	542	660	1,441	1,296
Total	1,827	2,004	1,937	2,139	2,400	2,499	2,455	2,429	2,825	2,968	2,938	3,166	3,864	5,087	5,606

between 1992 and 1994 varied between 104 and 111. The District was without a crest-stage gage program from approximately 1984 until 1994, when four gages were added to the program beginning in water year 1995.

Data Collection Platforms (DCP's), used to transmit stage and other real-time data by satellite telemetry, were introduced into the District in 1982. By 1994, approximately 107 stations were equipped with DCP's, and most of these were operated in cooperation with the Corps. The DCP network was especially useful during the severe flooding of 1993 as real-time gage-height data were available to water managers and officials.

During the flood of 1993, the District purchased an Acoustic Doppler Current Profiler (ADCP) to measure discharge on large rivers. The ADCP enabled users to measure river discharge and survey current structure quickly and safely under a wide variety of river flow conditions.

Water-quality stations.—The ambient water-quality network included only surface water throughout the period. The network consisted of 41 stations in 1980, 14 of which were part of the National Stream Quality Accounting Network (NASQAN). The primary cooperating agencies for ambint water-quality data were the MDNR, DEQ (15 stations) and the National Park Service (NPS) (11 stations). Samples collected in cooperation with MDNR, DEQ were sent to their laboratory in Jefferson City, Mo., for analysis. The MDNR, DEQ was given direct-services credit each year for participation of the State laboratory in the District's water-quality program. Most samples collected at the 41 stations were analyzed for field parameters, indicator bacteria, nutrients, major ions, and trace elements; pesticides were included at some of the NASQAN stations.

The water-quality program continued at the same level until 1984 when MDNR, DEQ added an additional 18 stations to the network, and the use of the State laboratory for analysis of water samples collected in the Coop program ended. All samples collected during 1984 and beyond were sent to the USGS National Water Quality Laboratory (NWQL) for analysis. A Division review of the NASQAN program during 1986 resulted in the loss of five NASQAN stations in 1987, and State funding cuts resulted in the discontinuation of 15 MDNR, DEQ stations in 1988. State funding cuts persisted, and by 1992, only 7 MDNR, DEQ stations remained in the surface-water-quality network. The 11 NPS stations remained in the network.

The MDNR, DEQ Coop sampling program began rebuilding in 1993. By 1994, 30 stations were added to the surface-water-quality network. In addition to the constituents listed previously, most samples collected at the MDNR, DEQ stations also were analyzed for pesticides. The NASQAN program was reviewed again by the Division during the same time period, resulting in the loss of two more NASQAN stations. Starting in 1993, seven stations were sampled regularly by the District for the Ozark Plateaus NAWQA project. The surface-water-quality network consisted of 63 stations in 1994.

Fluvial-sediment stations.—One daily and 13 periodic sediment stations were in operation in 1980. In 1982, the program had increased to 12 daily and 9 periodic stations, primarily funded by St. Louis and Rock Island Districts of the Corps and the MDC. During 1986 to 1988, the program decreased to seven daily stations and one periodic station, as funding reductions caused stations to be discontinued. From 1982 to 1994, interest and available funds increased, and the program grew to 15 daily and 16 periodic stations in 1993. Long-term daily sediment data were collected for the Missouri and Mississippi Rivers.

Ground-water observation wells.—Statewide monitoring of ground-water levels continued to be done primarily by the MDNR, DGLS. Except for a short period, the District's involvement was limited to some miscellaneous sites and monitoring associated with interpretive projects. Continuous ground-water levels were monitored by the State since 1955, but they had limited capability to process the record. Berkas led an effort to process and clean up the historical record in the late 1980's, and the data for 1985 and 1986 were published in MDNR Water Resources Report No. 37. In 1988, the District upgraded and started to operate the State's network of 52 wells through the Coop program. The data were published in the annual data report. However, the State's funding for this effort ended in 1991 and the network reverted back to the State.

Water-use data.—The collection of water-use data in Missouri centered around the 5-year national compilations for the Estimated Use of Water in the United States (EUOWITUS) circulars. In 1983, the State of Missouri passed a law requiring "major" water users to report annual usage numbers to the State Water-Use program, and the first data began to be

collected in 1984. A major water user was defined as any entity capable of diverting 100,000 gallons per day or more. The 1985 EUOWITUS was the first use of the data collected by the State, and each 5-year compilation used the data provided by the State Water-Use program, along with data from other miscellaneous sources such as the State Public Drinking Water program, university agricultural extension offices, and individual large users.

In addition to the 5-year compilations, individual projects occasionally used water-use data to meet specific project goals, typically relying on data published annually by the State Public Drinking Water program and on information from individual users.

Interpretive Studies

Under the leadership of Barks, the interpretive program grew from $685,000 in 1980 to $3,638,000 in 1994. The U.S. Geological Survey (USGS) coal hydrology and Regional Aquifer-System Analysis (RASA) programs were dominant in the early to mid-1980's. Startup of the Ozark Plateaus NAWQA project and the MSEA project in 1991 and study opportunities resulting from the 1993 flood significantly increased the size of the interpretive program. The numbers of cooperators increased, resulting in more projects with an increasing proportion being funded with unmatched dollars. Several hydrologists were added to the District staff to work on the new projects.

Coal hydrology program.—The USGS coal hydrology program started in 1975 and continued until the mid-1980's. There were many abandoned and some active coal mines in north-central and western Missouri, so the District completed several projects under the USGS program. Early on, Vaill and Barks described the physical environment and hydrologic characteristics of coal-mining areas in Missouri (Water-Resources Investigations Report [WRIR] 80–67). This report also contained a history of coal-mining regulations and practices in the State. Water-quality data collected during this study were published in reports for coal areas 37 through 40. A study of the hydrogeochemical effects of strip mining coal in the Prairie Hill area lasted from 1980 to 1985. Barks started the project, and Hall took the project over after transferring to Missouri in 1981. The project produced a data report (Open-File Report [OFR] 87–119) and interpretive reports describing the hydrologic system and the effects of coal mining on water quality in the East Fork of the Little Chariton River and the alluvial aquifer between Macon and Huntsville (WRIR 86–4160) and ground-water movement and effects of coal strip mining on water quality of high-wall lakes and aquifers in the Macon–Huntsville area (WRIR 85–4102). This study contributed significantly to understanding geochemical processes affecting water quality where high-sulfur coals are mined in humid climates. Also, under the USGS coal hydrology program, standardized reports were produced from existing data for coal areas throughout the United States. Parts of four of these areas (37 through 40) were in Missouri. Skelton contributed to each of these reports. General hydrologic information was presented using a brief text with an accompanying map, chart, graph, or other illustration for each of a series of water-resources- related topics.

Regional aquifer studies.—The Missouri District participated in three USGS RASA studies—Northern Midwest (1978–84), Central Midwest (1980–88), and Western Gulf Coast (1982–89). Primary reports were Professional Papers (PP) prepared mainly by regional project staff. The District contributed hydrologic data and several secondary reports. Emmett and Imes worked on the Northern Midwest RASA; Imes modeled the ground-water flow system in northern Missouri (PP 1305). Imes had a major role in the Central Midwest RASA in that he led the Ozark Plateaus subregional part of the project. Imes prepared a hydrologic atlas series (HA–711, A–L) that describes the stratigraphy, geology, hydrology, and water quality of the primary geohydrologic units in and adjacent to the Ozark Plateaus. A noteworthy contribution was his development of a nomenclature for the aquifers and confining units that eliminated State-line differences and would become the standard for the Ozark Plateaus. Results of a hydrologic model of the Ozark Plateaus were published in PP 1414–D. Mesko was the Missouri participant on the Western Gulf Coast RASA. He described the subsurface geology of Paleozoic, Mesozoic, and Cenozoic units and studied the geohydrology and water quality of Cenozoic and Mesozoic units in southeastern Missouri (HA–719), and the discharge of ground water along the Ozark escarpment in southeastern Missouri and northeastern Arkansas (WRIR 95–4103) and contributed to other studies as a part of this RASA. One of the benefits of the RASA studies is that they provided opportunities to develop spin-off projects, especially with State cooperators.

Ozark Plateaus NAWQA.—The Ozark Plateaus NAWQA project was 1 of 20 study units started in 1991. It was about 40,000 square miles and included parts of northern Arkansas, southeastern Kansas, southern Missouri, and northeastern Oklahoma. Although the study was headquartered in Little Rock, Arkansas, the Missouri District contributed significantly to the project with Davis, Femmer, Malone, French, and Brady being assigned to it. Davis and Femmer led chemical and biological data-collection activities and contributed to several of the publications.

Missouri Management Systems Evaluation Area (MSEA).—The WRD Toxics Program funded a study of the movement of agricultural chemicals at a MSEA near Centralia. Blevins, Ziegler, Kelly, and Wilkison worked with National Research Program (NRP) researchers to develop and use new technology to investigate the movement of nitrate in claypan soils. This well-funded research would continue for 7 years and produce numerous technical publications.

Cooperative studies.—Toward the end of the USGS coal hydrology program, the District began cooperating with the MDNR, Mine Reclamation Program, in investigations of abandoned coal mines. Blevins studied the sources of coal-mine drainage and their effects on surface-water chemistry in the Claybank Creek Basin (Water-Supply Paper [WSP] 2305). He also studied the hydrology and water chemistry of an abandoned surface coal mine in southwestern Henry County (WRIR 90–4047). Blevins and Ziegler investigated the hydrogeology, water chemistry, and subsidence of underground coal mines at Huntsville (WRIR 92–4001) and the effects of reclamation on water quality and geochemical processes in lakes in an abandoned surface coal mine in Henry County (WRIR 92–4167). Mesko evaluated the geology, movement, and quality of surface and ground water in southwestern Bates County, focusing on acidic spring recharge from an abandoned coal mine (WRIR 87–4204). The two final projects in this program involved noncoal mining. Smith did an assessment of water quality in noncoal- mining areas of Missouri (WRIR 87–4286), and Smith and Schumacher evaluated the quality of surface water and sediment in the Old Lead Belt of southeastern Missouri (WRIR 93–4012).

Several studies were done in cooperation with the MoDOT. Becker developed techniques for estimating flood-peak discharges from urban basins (WRIR 86–4322) and for simulating flood hydrographs for small rural and urban basins (WRIR 90–4045). In 1988, he started a bridge scour project that would evolve into a series of projects that would last for many years and produce several reports. Huizinga took over the effort when Becker retired in 1994.

From 1986 to 1994, studies were made of the occurrence of pesticides and nitrate in shallow ground water in cooperation with the Missouri Department of Health. Mesko studied the southeast lowlands, Ziegler studied the Missouri River alluvium, Ziegler and Wilkison studied west- central Missouri, and Wilkison studied northwestern and northeastern Missouri. Together, these studies filled a large data void by providing pesticide and nitrate data for over 800 sites. The data and interpretive results were presented in several reports.

In 1989, Barks and Imes initiated an assessment of the potential environmental effects of lead mining in the Mark Twain National Forest, in cooperation with the MDC, U.S. Forest Service, and Bureau of Land Management. This project was destined to go through several phases over many years and become one of the largest projects in the District's history. Kleeschulte became the project leader and authored several reports.

Another major effort was Jacobson's investigation of the geomorphic changes and effects on aquatic resources of Ozark streams in cooperation with the MDC. The project started in 1988 and continued past 1994. This was the largest, most extensive study of the origin, transport, and fate of gravel in Ozark streams that had ever been done. Innovative research techniques resulted in significant findings that are included in many publications.

There were many other cooperative studies during the period. The MDNR, DGLS cooperated on investigations of water for irrigation in Audrain County (Emmett), water for energy development in northwestern Missouri (Skelton), specific capacity of wells tapping major aquifers in Missouri (Oakes), flow duration hydrographs for Missouri streams (Hauth), ground-water resources in Barton, Bates, and Vernon Counties (Kleeschulte), impacts of the December 1982 Missouri floods (Spencer), and water quality in the Missouri River alluvial aquifer near Kansas City and Independence (Imes). The MDNR, DEQ cooperated on studies of the sources and characteristics of sediment in the upper Salt River Basin (Berkas), characteristics of urban runoff in the Blue River Basin (Blevins), waste-load assimilative capacity for selected Missouri streams (Berkas), water-quality

characteristics of the Spring River Basin (Davis), effects of special-area land treatment on sediment and nutrient transport in the Higginsville Reservoir watershed (Blevins), ground-water leakage in the Ozark aquifer near Branson (Imes), potential contamination of downstream wells by agricultural chemicals during the 1993 flood (Heimann), and physical sedimentation and erosion processes associated with flood-plain inundation during the 1993 flood on the Missouri River (Holmes). The MDC cooperated on a study of the hydrologic and sediment characteristics of scour holes in the Missouri River flood plain after the 1993 flood (Heimann) and together with the City of Columbia cooperated on a hydrologic study of the Columbia/Eagle Bluffs wetland complex (Richards). There also were studies in cooperation with the cities of Springfield and Independence, Jackson County, St. Francois County, the Mid-America Regional Council, and the Watershed Committee of the Ozarks led by Skelton, Imes, Schalk, Kelly, Heimann, Schumacher, and Holmes.

Other Federal agency studies.—Several OFA studies were completed during the period. Barks and Berkas studied ground-water movement and water quality of the proposed Prosperity Reservoir near Joplin with the Corps, Tulsa District, funding. The U.S. Environmental Protection Agency (USEPA) funded a study of ground water in the Ozarks by Harvey and studies of dioxin sites in Missouri by Kleeschulte, Chafin, Mesko, and Barks. Berkas investigated the effects of land-improvement practices on the surface-water resources of the Little Black River Basin funded by the Soil Conservation Service. Kleeschulte and Emmett began studying ground-water movement and quality at Weldon Spring with funding from the WRD Low Level Radioactive Waste Program, and Kleeschulte continued it with funding from the Department of Energy (DOE). Schumacher did geochemical work at Weldon Spring with funding from the USACE, Kansas City District. The NPS funded Alexander's delineation of flood characteristics in the Ozark National Scenic Riverways. Sediment studies were done on the Mississippi River and its tributaries with funding from the Corps, St. Louis District. Imes started a geohydrologic and water-quality assessment of Fort Leonard Wood Military Reservation in 1994 that would evolve into several large studies. Results from all these studies are presented in technical reports.

NORTH CAROLINA

By J.F. Turner, Jr., Orville B. Lloyd, Jr., and M.D. Winner, Jr., *including* information and data provided by the North Carolina District, with District and colleague reviews by R. Gary Garrett, Raleigh, N.C., Thomas J. Zembrzuski, Reston, Va., and Charles C. Daniel III, Raleigh, N.C.

INTRODUCTION

The 1979–94 North Carolina District history focuses on organization, management, and personnel; cooperation and funding; operational and scientific programs; contributions to the State of North Carolina. In the late 1970's and early 1980's, the District program was small, consisting mostly of data-collection activities and a few interpretive projects. The Chief Hydrologist's favorite motto was "small is beautiful" in referring to Division programs. The number of cooperators and State cooperative funds were very limited; consequently, the District relied heavily on in-kind services to maintain the Cooperative (Coop) program. Efforts by various cooperators and State water organizations to increase State matching funds for the Coop program produced mixed results. However, as the Coop program began to relate more effectively to critical water problems and issues in the State, the District program began to grow, increasing from about $1.5 million in 1979 to nearly $9 million in 1994. Organizational and management structure also changed several times during this period to accommodate the growing complexities of the programs, and the staff grew during this period from fewer than 50 to more than 100 employees. New offices were established and existing ones were realigned to enhance overall field operations, thereby minimizing operational costs.

ORGANIZATION, MANAGEMENT, AND PERSONNEL

In 1979, the North Carolina District Office was in the Century Post Office Building on Fayetteville Street in downtown Raleigh, N.C. The Century Building was built shortly after the Civil War and is designated as a historical building. Subdistrict Offices were located in Asheville, Statesville, and Charlotte. The Subdistrict Offices in Asheville and Statesville were operated primarily as part of the statewide data program, and the office in Charlotte was a project

office that supported special projects for Mecklenburg County and the City of Charlotte. Later, field operations were organized under two Field Headquarters—one in Raleigh for the eastern part of the State and the other in Charlotte for the western part of the State. In 1986, the Statesville office was closed and operations were moved to Winston-Salem. A Field Office was established in Washington in 1990 to support the Albemarle-Pamlico Estuarine Study (APES) and, later, the statewide data program.

By the late 1980's, the District program had increased greatly. Minor reorganizations met growing program and staff needs. The District began discussions with North Carolina State University regarding cooperative research programs and possible relocation of the District Office to the new Centennial Campus that was under development. Relocation efforts ultimately were unsuccessful, however, because of high relocation and rental cost considerations. In October 1990, the District Office was moved to its present location on Sunset Ridge Road in west Raleigh, an urban area with ample office space, storage, and parking. The move had an immensely positive effect on overall District operations, especially field activities.

During most of the 1980's, Districts were under severely restricted manpower ceilings. Temporary, intermittent, and student appointments were about the only available options in filling many vacancies. In the summer of 1988, the Southeastern Region Office encouraged Districts to hire additional college students as a temporary measure to offset the anticipated effect of forthcoming manpower ceilings for the year. Unfortunately, 24 of the newly hired students were fired in December when the Water Resources Division mandated that newly established manpower ceilings be met. This had a devastating effect on morale and student programs and added to the District's ongoing challenge of attracting and maintaining high-quality technical staff. In 1991, the District sponsored a Districtwide retreat and began team-building sessions to deal with a variety of issues resulting from changes in supervisory and management staff, management's advocacy position on upward mobility for women, low morale following the student firings, a 7-year discrimination suit, and the accidental death of an employee while on duty. A Personnel Management Evaluation of the District and followup reviews indicated satisfactory resolution of most issues. In spite of these difficulties, the District had one of the most technically competent, dedicated, and hard-working staffs in the Division—a highly professional staff that almost always got the job done on time, every time.

In 1992, the District underwent a major reorganization as a result of additional program and staff growth. Major changes included the creation of the Associate District Chief position and the formation of several major sections, including the Management Operations, Lakes and Estuaries, Environmental Programs, Albemarle-Pamlico National Water-Quality Assessment study unit, Hydrological and Biological Research, and Hydrologic Information and Analysis Sections.

Office of the District Chief

The North Carolina District was under the leadership of Ralph C. Heath from 1979 through 1981. In 1982, James F. (Jim) Turner became the third District Chief. After Heath retired, he continued to work on special projects and activities for the Chief Hydrologist and Regional Hydrologist until 1985. Hugh B. Wilder, Assistant District Chief under Heath, retired in 1985. Clyde E. (Ed) Simmons and Wanda C. Meeks became Assistant District Chiefs for Records and Studies, respectively, in 1985. In 1989, Simmons retired and Meeks transferred to the Orlando, Fla., Subdistrict Office to be the new Subdistrict Chief. Orville B. (Bruce) Lloyd, Jr., was named Assistant District Chief in 1990 and became Associate District Chief in 1992. Also in 1992, Turner became chairman of the Southeastern Regional District Chief's Association and, in 1994, USGS State Representative. Cheryl D. Miles became Assistant District Chief for Management Operations in 1993. District secretaries were Mamie C. (Doris) Hodge (1979–88) and Karen J. Hughes (1990–92). The District secretarial position was merged into the Management Operations Section in 1993.

District Discipline Specialists

N. Macon Jackson, Jr., was the District's Surface-Water Specialist until he retired in 1987; his temporary replacement was Gerald L. (Jerry) Giese. In 1988, Thomas J. Zembrzuski transferred from the New York District to become the Surface-Water Specialist until his transfer to the Washington District in 1993. After Zembrzuski's transfer, Jeanne C. Robbins became the District's Surface-Water Specialist. W. Harold Eddins was named Flood Specialist in 1984.

Heath served as the District Ground-Water Specialist until he retired in 1981. Ronald W. Coble served as the Ground-Water Specialist from 1982 until he retired in 1994, at which time William L. Cunningham transferred from the Ohio District to replace Coble.

Wilder also served as the District Water-Quality Specialist until he retired in 1985. Simmons then served as Water-Quality Specialist from 1985 until he retired in 1989. Charles R. Barnes transferred from New York in 1986 and served as Water-Quality Specialist from 1989 until 1992 when he resigned. Carolyn J.O. (Callie) Childress transferred from the Ohio District in 1992 to take this position.

Management Operations Section

The Management Operations Section (MOS) was organized in 1992 under the supervision of Cheryl Miles, who transferred to the District from the Geologic Division in Reston, Va. This Section included the Administrative Services, Computer Services, and Publications Units. Prior to reorganization, some of these functions were performed by employees assigned to other units. This section greatly improved the coordination and efficiency of operations and support in the District.

Administrative Services Unit (ASU).—In the early 1980's, administrative functions were performed by Nannie A. (Nancy) Williams and Glenda F. McLeod. Jessica D. Barham and Catherine E. Harrington provided occasional support. In 1984, the Unit was officially organized and designated as ASU, and Williams became the Unit's supervisor. Several new employees were added later, including Rose P. Lyons, Mary C. Faulkner, Bobbie C. Corbett, Yvonne Ta, and Leigh A. Williams. Nancy Williams became the District Administrative Officer in 1987.

Computer Services Unit (CSU).—The Computer Services Unit was established in 1984. Joseph S. Riggsbee was the computer Site Manager for the minicomputer and supervisor of the Unit until he resigned in 1989. Riggsbee was assisted by Phyllis M. Joyner until her retirement in 1985, and then by Pamilee L. Breton and Thomas H. Frazier. Monique R. Head and Jerome A. Harrison, students, joined the staff in 1987. Donald R. Block replaced Riggsbee in 1990. Shortly thereafter, Block transferred to the South Carolina District. Mark Dillon was hired in 1990. The CSU staff provided training and assistance in the use of new hardware and software and streamlined the production of the annual data report by implementing procedures that allowed for the processing of data in the Field Offices. Riggsbee, Barham, and Frazier served on the Division's Administrative Financial Management System (AFiMS) Committee, along with Turner who was national chairman. The committee developed software that allowed Districts to directly input financial, program, and personnel management information prior to submission to the USGS Administrative Information System (AIS) in Reston, Va. In 1993, Nelson Williams transferred to Raleigh from Reston to become the District's first Computer Specialist.

Publications Unit.—In 1979, there was no formal Publications Unit, and Heath acted as the District Reports Specialist. John R. Teel prepared illustrations, and Catherine Harrington and Janet McBride typed manuscripts. After Heath retired, Coble became the Reports Specialist and served in this capacity until 1987.

In 1985, Rebecca J. Deckard, Writer-Editor, was hired, and the Publications Unit was formed in 1987. Maurice D. (Mike) Winner, Jr., Hydrologist, became the Reports Specialist and Unit Supervisor. Teel retired in 1989 and was replaced by Jeffrey L. Corbett. Deckard, assisted by Kay E. Hedrick, typed and processed manuscripts through review and approval, prepared reports for printing, and distributed published reports. Deckard was assigned as Unit Supervisor in 1992 when Winner became District and Regional Reports Specialist, and the Unit was incorporated into the Management Operations Section. Mary Kaeser, Writer-Editor, and Linda J. Wilkerson, Editorial Assistant, joined the Unit in 1991 and 1993, respectively. In 1979, the District published nine reports. In 1994, 45 reports were approved and 23 were published, reflecting the District's growth during this period.

Hydrologic Records Section

In 1979, Macon Jackson was Chief of the Hydrologic Records Section (HRS); Ed Simmons was his assistant. They supervised statewide data-collection operations in the Raleigh, Statesville, Charlotte, and Asheville offices. Howard E. Reeder provided technical support to the Section. H. Curtis Gunter supervised field operations for the eastern half of the State from the Raleigh office. Field operations for the western half of the State were conducted out of the

Statesville and Asheville offices, with some help from the Charlotte office. Hydrologic technicians in Raleigh were Joseph E. Shoffner, Sherman G. (Gorrell) Thompson, Ronald G. (Gary) Garrett, Edwin D. (Dale) George, Bobby C. Ragland, Rufus J. Allen, Russell G. (Gene) Barker, Lawrence T. Mann, Robert L. Meikle, Joe Riggsbee, James M. West, Stephen S. Howe, Lloyd A. Edwards, and Willie Blount. Riggsbee and Phyllis Joyner provided computer support for processing records. Peggy S. Oakley, Timothy Gill, Sharon A. Watkins, Pam Breton, Cheryl A. Fennell, and Kay Hedrick provided staff support to the section in processing and publishing the annual data report.

The District recognized senior technicians in 1979, but without formal designation. Thomas E. Dillard was the senior surface-water technician, and Gorrell Thompson specialized in constructing gaging stations for the District. Gary Garrett was the senior water-quality technician. After 1994, the Southeastern Regional Office supported the official title of Senior Technician, and Bobby Ragland, Steve Howe, and Gary Garrett officially became the Senior Surface-Water, Ground-Water, and Water-Quality Technicians, respectively, for the District.

In 1984, the Hydrologic Records Section was reorganized slightly, and the Raleigh Field Office was formed. Catherine L. Hill transferred from Statesville in 1984 to become head of the Raleigh Field Office. Other new employees included Robert R. Mason, Andrew J. Padyk, Sandra L. Van Meter, Deborah L. Gordon, and Tammy K. Manning. Timothy C. Stamey transferred from Asheville, and Curtis Gunter became the District Safety Officer. Jerry Giese and Robert Mason conducted interpretive projects directly related to the data-collection program. In 1986, Macon Jackson assumed full-time Surface-Water Specialist duties for the District, and Cathy Hill briefly served as the HRS Chief until she accepted a reassignment to the Director's Office in Washington, D.C.

In 1989, Tom Zembrzuski became Hydrologic Records Section Chief and retained Surface-Water Specialist duties. Several new employees were added to the Section, including hydrologists Marjorie S. Davenport and William S. (Scott) Caldwell; civil engineers John C. (Curtis) Weaver and Benjamin F. Pope; hydrologic technicians Terry L. Middleton, Bernice A. Allen, and Jonathan L. Chandler; and computer assistant Amy E. Fogleman, who transferred from the Louisiana District after their State cooperative program experienced a financial setback.

During 1992–93, the District underwent a major reorganization. The Hydrologic Records Section became the Hydrologic Information and Analysis Section (HIAS), with Eastern and Western Field Headquarters located in Raleigh and Charlotte, respectively. The new Section was responsible for both interpretive projects and for operation of the statewide data program. In 1993, Tom Zembrzuski transferred to the Washington District, and William J. Haire transferred from the Miami, Fla., Subdistrict to supervise HIAS. Several new units added to HIAS were Hydrologic Analysis, Water Use, and Geographic Information System. Sylvia A. Terziotti and Lloyd Edwards were assigned to the Water Use and Geographic Information Systems. Robert Mason supervised the new Hydrologic Information and Analysis Section, which included Scott Caldwell, Curtis Weaver, Bernice Allen, Ben Pope, Amy Fogleman, and two new employees, Bruce A. Billstein and Lori A. Keith.

The formation of the Hydrologic Information and Analysis Section, with Eastern and Western Field Headquarters, provided better statewide coordination of field activities and support for investigative studies and research. In addition, it enabled the Field Offices to work together better as a team in producing the annual data report, in carrying out field activities and operations under extreme conditions, and in helping the District fulfill its mission in general.

Asheville Subdistrict

In 1979, the Asheville Subdistrict Office was responsible for operation of the data network in the mountains of western North Carolina. Tom Dillard was in charge of the office, and other employees included Donald P. McGeary, Tim Stamey, and Ruth C. Linder. The Asheville office was converted to a Field Office in 1983, and Dale George transferred from Raleigh to Asheville in 1985. Gene Barker transferred from Raleigh to replace Tom Dillard when he retired in 1986, and Tim Stamey transferred to Raleigh. New employees in the Asheville Field Office included Charles D. (David) Fowler and Michael D. Penley.

Statesville Subdistrict

In 1979, the Statesville Subdistrict Office was responsible for data-collection network activities in

the Piedmont area of the State. Ernst G. Wollin was in charge of the office for many years. Employees included hydrologic technicians Isaac J. (Jewett) Forehand, Clarence M. Ray, Jerry F. Rinehardt, and Fern S. Wilcox. In 1982, Wollin retired and Cathy Hill took charge of the office, having transferred from the USGS Atlanta laboratory; Hill transferred to Raleigh in 1984.

Winston-Salem Field Office

The Statesville Subdistrict Office became a Field Office in 1985 and then closed in November 1986 and moved to Winston-Salem to become the new Winston-Salem Field Office. Jerry Rinehardt was in charge of this new Field Office. Other employees were Clarence Ray, Michael D. Cranford, Herbert O. Harris, Randall C. Palmer, and Donna G. Coates. The Winston-Salem Field Office was established to minimize travel associated with field work and to develop and support prospective new programs with the cities of Winston-Salem and Greensboro. Ray retired in 1990.

Charlotte Project Office

The Charlotte Project Office reported to the Hydrologic Records Section from 1979 to 1987, when it was reassigned to the Hydrologic Studies Section for a short time. The office was later reassigned to the Hydrologic Records Section and then to the Hydrologic Information and Analysis Section. Flood, urban, and landfill interpretive studies were conducted in this office; some field support was provided to the data program. The office became the Western North Carolina Field Headquarters in 1993 and was responsible for operating the statewide data-collection networks in the western half of the State, including the Asheville and Winston-Salem Field Offices. Harold Eddins was in charge of the Charlotte Office during the entire period.

Other employees were Douglas G. Smith, Bruce C. Steiner, William F. Hazell, and students Paul M. Brigham and Gordon J. Waite. Smith transferred to Raleigh in 1991, and Jerald B. (Boo) Robinson was hired from the North Carolina Department of Environment, Health, and Natural Resources.

Raleigh Field Office

In 1993 the Raleigh Field Office became responsible for the operation of all data-collection networks in the eastern half of North Carolina, including the Washington Field Office, and was formally designated as Field Headquarters for eastern North Carolina. Doug Smith supervised the Eastern Field Headquarters Office; other employees were Andy Padyk, Geoffrey D. Cartano, Bernice A. Allen, Moses Daniel, Marc L. Lineberger, and James R. Elkins.

Washington Field Office

The Washington Field Office was established in March 1989 to support regional data-collection activities for the newly implemented Albemarle-Pamlico Estuarine Study (APES). Dale George transferred from Asheville to become the office chief; Herbert Blue, Stanley C. Skrobialowski, Jack M. Tankard, and Stewart J. Johnson were assigned to the office. They operated marine-based monitoring networks and conducted water-quality surveys of the Albemarle and Pamlico Sounds. The office was reassigned 2 years later to the statewide data program when the APES data-collection activities were completed.

Hydrologic Studies Section

In 1979, Ron Coble was Chief of the Hydrologic Studies Section, which consisted of 10 employees. These included hydrologists Mike Winner, Charles Daniel, Jerry Giese, and Douglas A. Harned. Support staff included students Dan Meyer and Sharon A. Watkins, clerk-typist Karen A. Miles, illustrator John Teel, editorial assistant Janet McBride, and clerk-stenographer Catherine E. Harrington.

The Hydrologic Studies Section conducted interpretive studies and was responsible for the preparation and processing of reports. In 1981, hydrologist J. Kent Crawford and student Nancy Sharpless were added to the staff. In 1983–85, the Section staff grew to include Bruce Lloyd, Richard N. Benson, Robert A. Payne, geologist Marjorie S. Reid, Steve Howe, Carol H. Thomas, and students Robert M. Caple and Robert Hines.

In 1985, Wanda Meeks became Chief of the Hydrologic Studies Section. Additional new employees were Chuck Barnes, Alex P. Cardinell, Cathy Hill, Jerad D. Bales, Jo Leslie (Jody) Eimers, William L. Lyke, Marjorie S. Davenport, and Maurice W. (Rick) Treece, Lloyd Edwards, Alfred G. (Gerald) Strickland, Curtis Weaver, and Kathleen M. Keoughan. Meeks transferred in 1989, and Barnes

became temporary head of the Section. After Barnes resigned in 1992, John Powell transferred from the Richmond District Office and served as Section Chief until transferring to the Military Program in Reston, Va. In 1987–90, Martin E. (Marty) Gurtz, Louis C. (Chi) Murray, Steven A. Berg, Tony P. Schrader, Valerie McKoy, Abigail Odeneal, and Cynthia Woloszyn joined the staff. Davenport later transferred to the South Carolina District as Assistant District Chief. In 1992–93, the District underwent major reorganization, and the Hydrologic Studies Section was split into several sections to better accommodate the growing need for specialized interpretive studies. These sections are discussed below.

Lakes and Estuaries Section

The Lakes and Estuaries Section, under the supervision of Jerad D. Bales, was responsible for APES programs and similar studies of lakes and reservoirs in the western part of the State. Other employees included Jeanne Robbins, Mary L. Jaynes, Gloria M. Ferrell, Rick Treece, Gerald Strickland, Douglas Newcomb, Gary Garrett, Terry Middleton, John Taylor, Julie Peterson, Fritz Whitfield, and student Ranjit Mathur.

Environmental Programs Section

The Environmental Programs Section was responsible for conducting environmental programs with military installations, primarily Fort Bragg. Alex Cardinell supervised the Section. Other employees included Barbara Lisle, Steve Berg, and Stephen L. Harden, Steve Howe, Jamie Marlowe, Vickie Poole, Tony Schrader, Ray Strain, Kelly Blagg, Ronald Irvin, Joy Lukenbach, Philip Spivey, and Charles Wilkins.

Albemarle-Pamlico Study Unit

In 1992, the Albemarle-Pamlico (ALBE) Study Unit, one of the first 20 studies activated in the National Water-Quality Assessment (NAWQA) Program, was implemented in the District with Bruce Lloyd as Chief. Timothy B. Spruill transferred to Raleigh from Idaho in 1992 and replaced Lloyd in 1993. Jody Eimers, Chuck Barnes, and Michael D. Woodside (District office in Richmond) served as Ground-Water, Water-Quality, and Surface-Water Specialists, respectively, for the study. Carlton D. Wood and Benjamin R. Simerl, also in Richmond, assisted with surface-water work, and Jerry McMahon served as GIS and Data-Management Specialist. Barnes resigned in 1992 and was replaced by Doug Harned.

Peter M. Ruhl, a biologist, transferred to Raleigh from Illinois in 1992. Tammy K. Manning served as lead technician until she resigned in 1993 and was replaced by Stan Skrobialowski. The staff was assisted by Kelly E. Smith and part-time students Troy P. Bernier, Janie B. Williams, Kathleen A. Jelinek, and Kevin C. Lewis.

Hydrological and Biological Research

In 1979, District researchers (RGEG's) included Charles C. Daniel and Doug Harned. This group grew over the years and included Kent Crawford, Jerad Bales, Marty Gurtz, Thomas F. Cuffney, Michael R. Meador, Chi Murray, Bruce Lloyd, Jody Eimers, and Andrew Simon. District researchers were actively engaged in a number of research activities as part of ongoing District programs, and some took on work from outside the District. However, their research activities were part-time and they were, for the most part, unable to produce a large number of publications upon which promotion opportunities depended.

The North Carolina Ecology Group (NCEG) provided technical assistance to the NAWQA Program by developing protocols for ecological surveys. Marty Gurtz was head of NCEG, which included Tom Cuffney and Mike Meador. Their part of the program was fully underway during 1993–94.

COOPERATION AND FUNDING

The period 1979–94 covers four different Presidential and North Carolina gubernatorial administrations, all with contrasting philosophies, goals, and policies that affected District programs and operations. Because of prevailing economic conditions, State and Federal funding was very limited throughout most of the period. Some Districts benefited from some additional Federal matching funds when a cooperative program in another State either failed to get off the ground or was discontinued. During 1986–88, several proposed programs had difficulties late in the year, and the Southeastern Regional Office provided supplemental funds for the District to close out the fiscal year. In the early 1990's, general economic conditions began to show some overall signs of improvement. Consequently, some slight increase in funding levels

Table 1. Sources of North Carolina District funds, fiscal years 1979–94

FY[1]	Federal	OFA[2]	State	USGS[3] Coop	Total
1979	171,845	209,738	586,196	582,717	1,550,496
1980	239,487	184,249	609,411	610,923	1,644,070
1981	339,337	232,294	624,977	642,344	1,838,952
1982	338,164	336,718	682,160	677,668	2,034,710
1983*	428,400	280,700	755,500	755,500	2,220,100
1984*	385,500	337,500	942,900	942,900	2,608,800
1985*	493,800	422,300	1,102,700	1,102,700	3,121,500
1986	384,550	544,010	1,025,600	1,020,000	2,974,160
1987	287,300	639,635	1,295,600	1,390,000	3,612,535
1988	566,800	404,270	1,313,827	1,308,027	3,592,924
1989	698,210	731,185	1,380,692	1,374,892	4,184,979
1990	646,520	346,358	1,476,680	1,350,000	3,819,558
1991	1,029,240	1,119,740	1,680,425	1,500,000	5,329,405
1992	1,457,540	2,737,192	1,561,900	1,425,000	7,181,632
1993	1,885,900	2,462,269	1,627,620	1,475,000	7,450,789
1994	2,015,460	3,839,550	1,581,890	1,397,000	8,833,900

[1]Fiscal year is October through September and is identified by the year in which the 12-month period ends.

[2]Other Federal agencies.

[3]U.S. Geological Survey.

*District program documents for 1983–85; Administrative Information System records for all other years.

and relaxation of manpower ceilings began to slowly emerge. Because of the competition for Federal matching funds among Districts in the late 1980's, the Division implemented a competitive merit-proposal process whereby all new and reprogrammable Federal Coop funds were allocated on the basis of the good-science aspects of project proposals. Only the best science proposals were funded, and other programs had to live within the base funding levels allocated to each District. Because of this competitive process, the District was able to initiate research components of programs, such as APES and the Guilford County agricultural runoff study.

Major efforts also were made to improve the technical quality of publications and to complete all programs on time (otherwise funds to complete past-due reports had to come out of overhead accounts, a major source of concern to many of the State cooperators). District operations became more efficient as a result.

Major sources of District funding during the period included the Federal-State Coop program, Federal programs, and programs with other Federal agencies (OFA). More than 60 State, local and Federal agencies participated in District programs. District programs during the period amounted to nearly $62 million (table 1). In 1979, the proportion of funding for District programs was about 49 percent by USGS (Coop and Federal), 38 percent by various State and local agencies, and 13 percent by other Federal agencies. By 1994, these percentages had changed to 39, 18, and 43 percent, respectively (indicating a significant shift from State and local programs to OFA programs). Overall, the USGS (coop and Federal) contributed 46 percent of funding during the period, and State and local agencies and other Federal agencies contributed 54 percent.

In 1983, the District had 14 cooperators: 3 State, 4 OFA, and 7 local. In 1986, the number of cooperators had increased to 30. By 1990, the District had 39 cooperators: 10 OFA, 3 State, 3 regional, and 23 local agencies. Because of tight State and Federal budgets, direct-services credit was virtually nonexistent in the Federal-State Coop program by 1994. Some State cooperators provided more funds for cooperative agreements during a few years than did the District. In the 1990's, there were increasing numbers of cooperators requesting assistance from the District to begin new studies, some involving interstate ground-water problems and proposed interbasin trans-

fers. However, because Federal matching funds were inadequate, many proposed studies were never undertaken. Some cooperators also expressed concerns that District programs were focusing too much on service work for various military programs, leaving them (the cooperators) without adequate program support. Consequently, a few developed or expanded in-house staff expertise to sustain their programs.

Major State cooperators were the North Carolina Department of Natural Resources and Community Development (NRCD), later reorganized as Environment, Health, and Natural Resources (DEHNR), and currently the Department of Environment and Natural Resources (DENR), which included the Divisions of Water Resources, Water Quality, Environmental Health, and Environmental Management, and the Albemarle-Pamlico Estuarine Study (APES); the North Carolina Department of Transportation (DOT); North Carolina Department of Health (DHR); and the North Carolina State University Agricultural Extension Service.

Major OFA cooperators included the U.S. Marine Corps (Cherry Point Air Station and Camp Lejeune), U.S. Army Corps of Engineers, Federal Energy Regulatory Commission, Federal Highway Administration, Tennessee Valley Authority, U.S. Soil Conservation Service, U.S. Environmental Protection Agency, and the U.S. Army (Fort Bragg).

More than 45 towns and cities and several regional water agencies and commissions also cooperated with the District. In 1993, the military programs expanded considerably as the APES Program was winding down.

SUMMARY OF DATA PROGRAMS

In 1983, 67 percent of the District program consisted of data-collection activities. There were 155 active gaging stations, 53 observation wells, 8 daily and 40 periodic water-quality stations, and 1 daily sediment-sampling station. These programs were conducted by the Raleigh, Charlotte, Asheville, and Statesville offices in cooperation with the State Division of Water Resources (DWR), Departments of Health (DHR) and Transportation (DOT), and a number of local agencies. OFA cooperators included the Federal Energy Regulatory Commission (FERC), Tennessee Valley Authority (TVA), and U.S. Army Corps of Engineers (Corps). There were some changes in stations during the period; but largely, the networks remained about the same.

In addition to network operations, the Hydrologic Records and Hydrologic Information and Analysis Section conducted a number of projects and activities related directly to analyzing and interpreting much of the data that were collected, processed, and published. Primary among these were flow-regionalization studies involving low-flow and floodflow characteristics by Macon Jackson, Robert Mason, and Jerry Giese. Special field surveys also were made by the staff during the mid- and late 1980's to document severe drought and flooding conditions. Severe drought conditions (greater than 100 years) that prevailed for several years in areas of the Piedmont and Mountains Provinces and severe flooding (greater than 500 years) that occurred in the mountains were documented. Bob Meikle computed drainage areas and answered requests for low-flow information in a long-standing program of benefit to the State's Division of Water Quality. Gary Garrett studied the water quality of inflow and outflow from Falls and Jordan Lakes (1982–87) and published data reports. Harold Eddins conducted flood-insurance studies of unincorporated areas of Mecklenburg County and other areas (1989–94) and provided reports to cooperating agencies.

Tim Stamey studied the effects of channel restoration and bridge construction on floodflow characteristics of the Catawba River (1987–88) and prepared a report on his findings. Ed Simmons, Sharon Watkins, Robert Mason, and Tim Stamey studied the effects of channelization on the hydrology of selected streams in coastal areas (1976–87) and published several reports. Ben Pope and Tim Stamey studied the effects of stream restoration on small coastal watersheds and salt marshes (1982–91) and published their findings.

Scott Caldwell studied the physical, chemical, and biological characteristics of selected streams in forested areas (1986–89), and Robert Mason and others developed procedures for estimating peak discharges and flood hydrographs of urban streams (1988–94). Curtis Weaver studied reservoir sedimentation (1989–93). In 1993, Robert Mason documented a severe flooding event in the city of Fayetteville and initiated a bridge scour study at the H.C. Bonner Bridge over Oregon Inlet; Curtis Weaver led a mapping survey to define storm-surge flooding on Hatteras Island caused by Hurricane Emily.

Gaging-Station Network

In 1979, the gaging-station networks were operated routinely by employees in the Raleigh, Asheville, Statesville, and Charlotte offices. In 1983, there were 155 continuous-record gaging stations (fig. 1). Of these, 75 were supported by the DWR, 47 by the U.S. Army Corps of Engineers, 5 each by the TVA and DOT, 6 by the FERC, 13 by several cities, 4 by the USGS Federal program, and 5 by others. Nine gages were supported by contributions from private industry (through the DWR), and 13 were supported by public utilities. Four long-term sites were operated in support of special DWR and USGS projects. Time-of-sample discharges were provided to the DWR at 209 sites for compliance with the National Pollutant Discharge Elimination System (NPDES) permits. Numerous requests for data and information were received and processed.

In 1986, the network consisted of 154 stations and 103 monitoring sites, and 23 satellite and 14 landline telemetry stations were in operation. In 1987, the network consisted of 167 stations and 92 monitoring sites, and 23 satellite and 16 landline telemetry stations were in operation.

In October 1988, James West, hydrologic technician, drowned while making a flood measurement from a cable car at the Deep River near Moncure gaging station. Results of an investigation found that his sounding line became entangled in large floating debris, the cableway collapsed, and he was not able to free himself. The District made a priority of upgrading and improving safety of all cable car stations in operation. In 1990, District cableways were evaluated and most of them were discontinued; a plan of refurbishment was implemented for the remaining ones. Three of the four remaining cableways were rebuilt.

Ground-Water Network

During 1979–94, few changes were made in the ground-water network. In 1983, the network included 53 observation wells, including climatic, areal-effects, and local-effects wells. Climatic wells monitor effects of climate on ground-water storage and areal-effects wells monitor ground-water storage in major aquifers. Yield characteristics, recharge, and discharge characteristics of major aquifer systems undergoing development are monitored by local-effects wells. Cooperative funding for the network was provided primarily by the DWR.

In 1984, ground-water-level declines in the central Coastal Plain were of serious concern to the State. Review of the program indicated that observation-well data were not routinely being processed and entered into the USGS data base, and that there was need for a data-management group. In 1990, 49 recorders were operated on network observation wells, and the ground-water section of the annual data report was expanded. In addition, 2,000 well records were entered into the data base. In 1993, the State provided additional funds to make improvements in the network. Potentiometric surface maps were developed for one-third of the Coastal Plain. Jackson, Coble, and Strickland were primarily responsible for the program over the years.

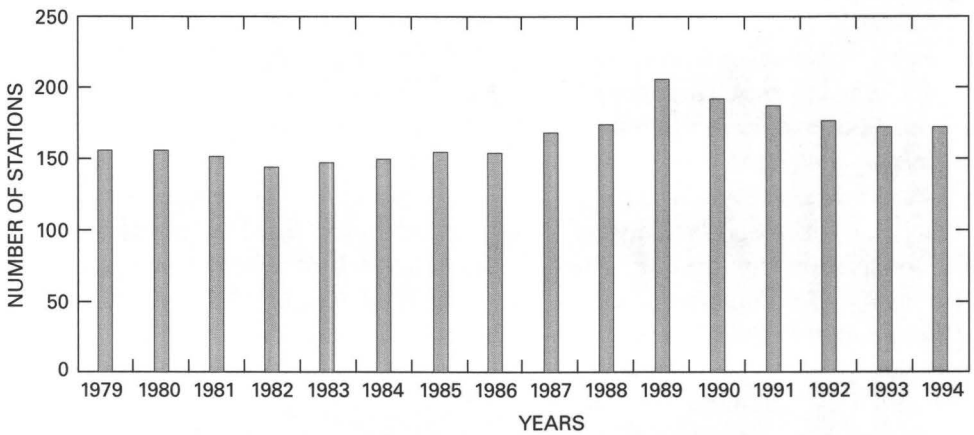


Figure 1. Number of gaging stations.

Water-Quality Network

In 1983, the water-quality network amounted to about 20 percent of the overall data-collection effort and included 18 daily sampling stations to characterize natural and developing conditions, 9 of which were supported by NRCD. Periodically, 40 sites were measured to determine characteristics of natural areas. In 1986, the network included 9 hydrologic stations and 46 trend stations, including 1 Federal Hydrologic Benchmark Network station and 8 National Stream-Quality Accounting Network (NASQAN) stations. In 1987, there were 10 hydrologic and 67 trend stations.

Ed Simmons, Doug Harned, and Gary Garrett conducted a research study funded by the Federal Highway Administration to characterize runoff effects from an interstate highway. When Simmons retired, Gary Garrett replaced him. In 1993, an employee resigned after falsified records for three network stations were detected during quality-assurance reviews. These and earlier identified problems were resolved, and appropriate corrections were made in each of the records.

Sediment Program

The District continued to operate one long-term sediment station on the Yadkin River at Yadkin College that had been monitored for decades. Gary Garrett was Project Chief during this period. The District sediment-analysis laboratory, which provided service work for other Districts, was closed in the early 1990's as part of the Division's goal of combining functions to reduce operational cost and improve overall quality assurance and consistency of field data. Ed Simmons conducted a statewide study to characterize sediment characteristics and published results in a formal report.

Water-Use Program

In 1983, Macon Jackson was the Project Chief of the Water-Use Program. Water use was a national program to provide input to other programs and projects in progress. In 1986, Rick Treece became the Project Chief. Program reviews indicated that efforts to collect, organize, and store water-use data were progressing well. Plans were made to expand the program to include ground-water-use data on agricultural irrigation and to develop a public-interest publication on water-use information.

The DWR requested assistance from the District to collect agricultural irrigation information in the State of Virginia in order to prepare an environmental impact assessment for the proposed Lake Gaston Pipeline Project. The project was very controversial because of proposed interstate and interbasin transfers of water by the City of Virginia Beach, Va. The USGS was not able to provide the information because of internal cooperator conflicts between the States of North Carolina and Virginia.

In 1987, DEHNR was given direct computer access to the USGS data base. And, in 1989, the District became a beta test site for the National Water-Use Data System. The staff conducted special training sessions for DEHNR personnel. A study in the southern Coastal Plain in cooperation with Pembroke State University was conducted, and special reports on public water supply were prepared by USGS staff.

In 1990, water-use data were expanded to support waste-load allocation programs, the central Coastal Plain ground-water study and model, requests for information, and a gaging station below Lake Wheeler. In 1993, a proposal for a regional agricultural irrigation study was prepared. In 1994, the report "Estimated Water Use, by County, in North Carolina, 1990" was completed. Central Coastal Plain water-use data were incorporated into the data base.

SUMMARY OF INTERPRETIVE PROGRAMS

In 1979, the District conducted 12 interpretive studies that were largely data intensive and accounted for about 43 percent of the overall program. Ron Coble and Mike Winner began the Regional Aquifer-System Analysis (RASA) study of the Coastal Plain in eastern North Carolina. In 1986, there were 20 ongoing investigations, which grew to 23 by 1987, including APES. In 1988, discussions began with Fort Bragg concerning ground-water-contamination problems on the base, and an urban hydrology study was begun with the City of Raleigh.

Ron Coble, Mike Winner, Jerry Giese, and Jody Eimers studied the multilayered Coastal Plain aquifer system in eastern North Carolina as part of the national RASA program (1979–88). They developed steady-state and transient ground-water-flow models using the hydrogeologic framework that had been constructed from regional data. The models were useful in evaluating ground-water-level fluctuations in

the Coastal Plain aquifer system. They published framework and ground-water-flow simulation reports.

Mike Winner, Bill Lyke, Allen Brockman (State employee), and Jody Eimers developed a hydrogeologic framework and digital simulation model for the central Coastal Plain area and published results in nearly a dozen reports and scientific papers (1983–90). This work was a spinoff from the RASA study of the entire Coastal Plain.

Doug Harned and Cathy Hill studied the effects of land-management practices on sediment and chemical transport of agricultural areas in Guilford County (1984–88). They published more than five papers and reports.

Bruce Lloyd studied the hydrogeology of the Cincinnati Arch region of Indiana, Ohio, and Kentucky and the Atlantic Coastal Plain from New York to North Carolina with regard to isolation of nuclear wastes and published results in scientific reports (1984–88).

Bruce Lloyd, Charles Daniel, Chi Murray, Jody Eimers, and Kathy Keoughan evaluated the potential for contamination of ground-water supplies at Cherry Point Marine Corps Air Station. They published four reports and papers (1986–92). Alex Cardinell, Bruce Lloyd, Rick Treece, Doug Harned, and Steve Berg assessed ground-water resources at Camp Lejeune Marine Corps Base, and Jody Eimers, Ron Coble, and Charles Daniel developed a digital model for Cherry Point Marine Corps Air Station. The models were for evaluating alternative water-use and management practices; several reports were published (1986–92). David Breedon began a model of a jet-fuel spill site on Fort Bragg, but the work was terminated before completion.

Charles Daniel studied the geologic framework of fractured rock areas and developed models describing areal flow systems. The results of his work were highly useful in siting and managing municipal wells in the Piedmont. Also, records for more than 6,200 wells from the Piedmont and Blue Ridge Provinces were entered into the Ground-Water Site Inventory (GWSI) data base.

Marge Davenport conducted a reconnaissance evaluation of surface-water, drinking-water, and wastewater quality in Greensboro. The results were published in two reports (1986–87).

Bruce Lloyd studied ground-water conditions in Illinois, Indiana, Ohio, Kentucky, and Tennessee as part of the National Ground-Water Atlas Program; he authored an extensive report. Marge Davenport, Harold Eddins, Kent Crawford, Alex Cardinell, Chuck Barnes, and Ron Coble studied characteristics of leachate discharge from solid-waste disposal sites in Mecklenburg County (1989–94) and results were published in several reports. Chuck Barnes conducted a surface-water-quality assessment for the North Carolina Triangle J Council of Governments (Chatham, Durham, Johnston, Lee, Orange, and Wake Counties) in 1989–92. Followup studies were expanded and conducted by Callie Childress and Gary Garrett who authored several reports.

Ron Coble studied ground-water-contamination potential of the Sand Hills aquifer of the Aberdeen area (1990–91) and prepared a special assessment report for the USEPA. The report included a digital ground-water flow model.

In 1988–94, the APES and ALBE NAWQA studies were implemented in the District. The ecological protocol work as part of the NAWQA Program also began at this time.

Albemarle-Pamlico Estuarine Study

The Albemarle-Pamlico Estuarine Study (APES) was an $11-million cooperative effort sponsored by the North Carolina DEHNR, the USEPA, and numerous other agencies. Four committees consisting of almost 100 persons guided the work of this study. This was the first major good-science program initiated in the District during the 1980's as part of the Federal-State Coop program.

The goal of APES was to identify problems in the estuarine system, generate research where information gaps existed, increase public awareness of issues, and find solutions to the issues. The Comprehensive Conservation Management Plan (CCMP) was the culmination of the 6-year study and was implemented in 2000. The District played a major role in the APES Program. During the height of this program in the early 1990's, annual funding for APES-related projects was about $2 million, and more than 20 publications were produced during the program. Jim Turner was a member of the Technical Committee, which provided overall guidance to the study, and chaired the subcommittee that reviewed and recommended proposals. Jerad Bales was the program manager for the District and principal researcher for a number of the special studies.

A two-dimensional, spatially detailed, unsteady-flow model was developed for both the Pamlico and Neuse River estuaries. An extensive data-collection network of tide gages, wind anemometers, and continuous salinity recorders provided data to construct and test the models. The District opened a field office in Washington under Dale George's supervision to operate the large data-collection network.

As part of the Pamlico and Neuse River model-development project, temporally and spatially detailed velocity data were collected throughout each estuary. Because of the remoteness of the Pamlico estuary, more than 30 District employees camped for 3–4 days on the shore of the estuary near Aurora in 1990 as part of an intense velocity data-collection effort. Harold Eddins, Chief of the Charlotte Field Office, mobilized camping and cooking gear from the National Guard for the exercise. Staff worked in around-the-clock shifts for about 2 days collecting velocity data.

Other APES studies conducted by the USGS included an investigation of the effects of tidegates on nutrient delivery to the sounds (Rick Treece), a retrospective analysis of water-quality data in the sounds (Doug Harned and Marge Davenport), and the system-wide continuous monitoring program (Gary Garrett). Stan Skrobialowski and Mary Jaynes also made significant contributions to the study. Jeanne Robbins participated in the development of the Pamlico and Neuse flow models and later became Chief of HIAS.

In large part, because of the success of the APES Program, the quality of the science produced, and the visibility given to the region, the Albemarle-Pamlico drainage basin was selected to be one of the first 20 study units to begin intensive data collection as part of the NAWQA Program in 1994.

North Carolina Ecology Group

In 1989, the District began a NAWQA Ecological Survey Protocol study. Marty Gurtz, who was participating in a review of the National Hydrologic Benchmark Network, was named Chief of the group. Shortly thereafter, Tom Cuffney and Mike Meador were hired to help Gurtz with the protocol work. In 1989–90, the North Carolina Ecology Group (NCEG) was formed and participated in a reconnaissance of the Yakima River in Washington and the upper Illinois River Basin for fish, invertebrates, algae, habitat, and water and sediment chemistry. During 1990–91, activities included protocol development for NAWQA ecological surveys, including testing of hypotheses about variability of aquifer ecological systems and establishing a framework for site-specific research studies. In 1993, a draft national protocol report was completed, and by 1994 five national protocol reports were published.

Albemarle-Pamlico NAWQA Study Unit

In 1991, the 27,500-square-mile Albemarle-Pamlico drainage was among the first 20 areas selected for full-scale implementation in the NAWQA Program. The Neuse, Tar, Roanoke, and Chowan River Basins compose the study area, about one-third of which is in Virginia. Surface-water and ground-water quality were characterized in time and space, and pertinent information was made available to the public through liaison meetings and published reports.

Bruce Lloyd began study development plans, including staffing, prototype, and pesticide sampling and procedures. In 1992, the project was partly staffed, and some data collection began. In 1993, Tim Spruill assumed leadership of the program and began some intensive field activities with the establishment of sampling stations and monitoring wells and initiation of retrospective and environmental setting investigations. Field activities and report preparation continued in 1994.

Environmental Programs

The District conducted hydrologic work for the U.S. Marine Corps at Camp Lejeune and at Cherry Point Air Station for many years. This work consisted of mapping the aquifers and confining units beneath the bases, reporting on the quantity and quality of water supplies, and investigating the potential for contamination from wastes dumped or spilled at land surface, and from salt or brackish water in adjacent rivers and sounds and in deep aquifers lying beneath the bases. The resulting reports in the late 1980's and early 1990's were used in support of the Department of Defense Installation Restoration Program (IRP) to locate, prioritize, and clean up hazardous-waste sites at all U.S. military bases. The IRP was replaced by the USEPA Resource Conservation and Recovery Act (RCRA), and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) programs.

As a result of the work at Camp Lejeune and Cherry Point, Fort Bragg asked the District to do similar work at their on-base RCRA sites. However, the District was unable to expand the Fort Bragg program because most of the additional work would have involved intensive, routine field activities that were of marginal scientific interest to the USGS and because required manpower for any additional work far exceeded District resources. Alex Cardinell, Barbara Lisle, Steve Harden, and Steve Berg, with the support of staff technicians, conducted a few good-science studies, such as determination of natural biodegradation rates of various petroleum compounds in the unsaturated and saturated zones; evaluation of surface-geophysical methods, including ground-penetrating radar and seismic-reflection techniques to characterize the nature and extent of contaminants in shallow subsurface areas; and surface-geophysical methods development and biodegradation studies to assist in locating artifacts at the Monroe Crossing Civil War Battlefield site.

Intensive field activities at Fort Bragg included RCRA Field Investigations (RFI). Surface and borehole geophysical surveys were conducted, and soil-gas and related water data were collected at numerous sites. Seismic-reflection surveys also were conducted at the Cherry Point Marine Corps Air Station to delineate buried river channels.

OTHER ACTIVITIES

In 1983, Jim Turner began efforts to form a local section of the American Water Resources Association (AWRA) in the Raleigh area. In 1984, the North Carolina Section of the AWRA was officially formed, with a student section at Duke University. Kent Crawford and Doug Harned worked with students at local universities and others in getting student sections started.

In 1989, the District held its third annual District conference in Raleigh, "The New Decade: Changes, Challenges, and Opportunities in the 1990's." All District employees participated, along with representatives from local cooperating agencies, universities, and USGS representatives from Atlanta, Ga., Denver, Colo., Rolla, Mo., Reston, Va., Bay St. Louis, Miss., Miami, Fla., and Albany, N.Y.

In 1989, Charles Daniel, Richard K. White (Clemson University), and Peter A. Stone (South Carolina Department of Health and Environmental Control) organized a national conference on Ground Water in the Piedmont of the Eastern United States. The conference was held in Charlotte, North Carolina, in October 1989. Numerous scientists from USGS and other water organizations attended the conference.

In 1990–91, the District recruited heavily at Historically Black Colleges and Universities, including Elizabeth City State, Winston-Salem State, and Fayetteville State, resulting in several student enrollments in the USGS Minority Participation for Earth Sciences program. A number of cooperative students and interns from North Carolina State University and the University of North Carolina at Chapel Hill also became part of the District staff.

In 1992, Bill Lyke was general chairman of the American Water Resources Association International Symposium held in Wilmington, and Jim Turner was appointed by Governor Hunt to the North Carolina Information and Coordinating Council. Tim Spruill and Doug Harned made outreach presentations at a Greensboro Elementary School.

In 1992–93, the District underwent a general classification review as followup to the reorganization, and the North and South Carolina Districts attempted inter-District projects. Efforts in this regard were not successful, however, because of lack of cooperator support and competition among a few staff members in both Districts.

In 1994, the State of Georgia experienced record floods in late summer. Doug Smith, Rodney Thompson, David Fowler, Mike Cranford, Jerry Rinehardt, Gene Barker, and Harold Eddins assisted the Georgia District in collecting flood data for the purpose of making indirect flood-discharge measurements. The record flooding was due to Tropical Storm Alberto.

PROGRAM AND SCIENTIFIC CONTRIBUTIONS

Major program contributions to the District program during the period include extensive and detailed, statewide, computer-accessible data bases for surface water, ground water, and water quality necessary for State water agencies to manage, plan, and protect the State's water resources. Near real-time data were made available at numerous key monitoring stations. More than 20,000 (noncomputer accessed) requests for water information and data by consultants, State, Federal, local water agencies, and others were answered. In addition, technical assistance and expertise were provided on numerous occasions to various State agencies and others.

The size and scope of the program near the end of the period allowed the District to attract quality scientists. This allowed the District to shape its programs more closely to fit the critical needs of the State. Data and technical and scientific information were published and made available to the public. These reports provide the mainstay to many operational, planning, and regulatory functions provided in the State. The District took heretofore unusual steps toward informing the public of its programs, activities, and products, such as establishing an Internet Web site. This computer link allowed for direct-data access from the statewide data-collection networks and listings of available publications and brochures about District programs and activities.

The major scientific contributions made during the period include the results of interpretive studies conducted during the period and reported in numerous official publications of the agency. These include 37 data publications from the statewide data networks and 250 official publications of the USGS, journal articles, and abstracts (fig. 2). Additional products include flood maps, unpublished special hydrologic evaluations and assessments provided to other Federal agencies, and physical, chemical, and biological analyses of various studies reported in other publications and media.

The principal ground-water contribution during the period was the development of the hydrogeologic framework and flow model for the Coastal Plain aquifer as part of the national RASA program. Other major ground-water contributions include the hydrogeologic framework and flow model of the central Coastal Plain aquifer, flow models of fractured rock areas, and seismic-reflection profiling of estuarine areas of Camp Lejeune.

Major surface-water contributions include documentation of statewide floods and droughts, the APES streamflow studies and two-dimensional flow and circulation models of the Neuse and Pamlico estuaries, the low-flow studies of major State streams, statistical methods for estimating flood-frequency information at ungaged streams, drainage areas for sites on streams across the State, and an unsteady flow model of the Roanoke River. Water-use data, in which surface water was a major component, for various uses and types of land use and development across the State also was an important contribution.

Major water-quality contributions include scientific data and technical information for various land uses and stream systems and landfill studies in Mecklenburg County. Statewide sediment characteristics of streams were defined. Numerous flow, chemical, and biological computer-simulation models for evaluating the effects of development on water resources were major contributions. Also, regional water-quality monitoring data for the Albemarle-Pamlico estuary greatly contributed to the success of the APES and NAWQA studies.

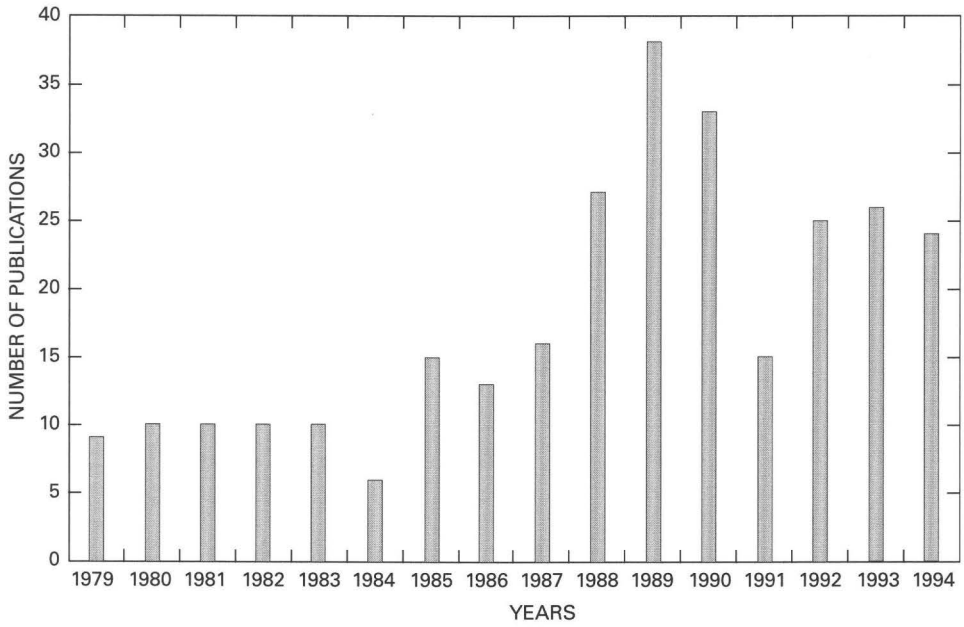


Figure 2. Number of scientific, technical, and data publications for North Carolina, 1979–94.

SOUTH CAROLINA

By Rodney N. Cherry

ORGANIZATION AND PERSONNEL

In 1978, the South Carolina District consisted of the District Office in Columbia and a Field Office in Conway. These combined offices were staffed by 7approximately 20 permanent full-time and 9 part-time employees. In 1985, Field Offices were opened in Aiken and Beaufort. The District's program consisted primarily of statewide gaging-station operation and a ground-water program in Myrtle Beach. By 1991, the combined offices were staffed by approximately 60 employees, 57 of which were permanent full-time employees.

In general, the 1980's were characterized as a time of growth and change in District program, with emphasis shifting from data collection to data-collection and interpretation activities. Major changes in the District programs included an increased emphasis on interpretation of basic hydrologic data, increased hydrologic modeling of streams and aquifers, improved delineation of aquifer systems, introduction of "real-time data acquisition," and initiation of a microbial research section. The early to mid-1990's were characterized by expansion of initiatives such as streambed scouring at and near bridges, cleanup of contaminated sites, and commencement of new initiatives such as the Regional Aquifer-System Analysis (RASA) and the National Water-Quality Assessment (NAWQA) projects.

Office of the District Chief, Columbia

In 1979, the District Office was located at 2001 Assembly Street, then moved to the Strom Thurmond Federal Building at 1835 Assembly Street and later to 720 Gracern Road in the Stephenson Center where it is located today. Rodney N. Cherry transferred from Atlanta, Ga., in November 1979 and retired in November 1991 as the fourth South Carolina District Chief. Cherry was replaced by Glenn G. Patterson.

Assistant District Chiefs for Hydrologic Surveillance were Arthur L. Putnam (1976–83), who later transferred to Office of Surface Water in Reston, Va., and C. Scott Bennett III (1983–94). Assistant District Chiefs for Hydrologic Investigations were William J. Carswell (1983–86), until he transferred to the Nevada District, and Glenn G. Patterson, who transferred from the Oregon District in 1980 and became Assistant District Chief after Carswell's departure. Marge Davenport joined the District Staff in 1992 as Water-Quality Specialist and later became Assistant District Chief for Hydrologic Investigations in 1993.

Administrative Services Section.—District Administrative Officers were Frances J. Whetstone, who served in this capacity from 1954 until her retirement in 1988, and E. Ann Cates, who served as Administrative Officer from 1988 until her retirement in 1997. Others who served in the Administrative Services Section were Barbara C. Hill, Dianne E. McNelley, Shirley I. Milton, H. Theresa Rose, T. Keith Durham, Francis L. Eargle, Marsha K. Alverson, Violet W. Fetner, Vonzorra C. Hairston, Vonette C. Boylston, Kim S. Crutchfield, Pat Deeds, Carolyn E. Reno, and N. Jo Ernst.

Computer Services Section.—The Computer Services Section was initially staffed by Shirley J. Gaines and David A. Shaw, and later by Janet C. Ciegler and Margni Shealy. The 1980's and early 1990's saw the emergence and integration of computer technologies into routine District operations. Perhaps most significant was the introduction of electronic instrumentation and satellite telemetry into the data-collection and analysis process. The South Carolina District was a pioneer in use of electronic instrumentation for collection and transmission of hydrologic data in near real-time to the District Office for checking and analysis by hydrologic technicians. The Computer Services Section also received data transmitted by all Districts in the Southeast and Puerto Rico and redistributed the data by way of the computer network to the originating District. Most of the surface-water data-collection stations in South Carolina were equipped with data transmitters, and data included water stage, pH, dissolved oxygen, specific conductance, and water temperature. Most ground-water recording stations were equipped to transmit water levels and specific conductance in coastal wells.

Computer Services Section employees played a critical role in this evolution of modern computer technology usage. The initial central computer equipment was a minicomputer that was later replaced by workstations. These more powerful workstations enabled the District to handle large-scale models.

Publications Services Section.—The Publication Services Section was initially managed by William F. Lichtler and later by Glenn G. Patterson and Susan S. Lambert. Others who served in the Publi-

cation Services Section were Kathy D. Dubose, Violet W. Fetner, Mark A. Lowery, Cindy R. Myer, J. Ray Douglas, and W. Boyce Blanks.

Surface-Water, Ground-Water, Water-Quality, and Reports Specialists.—Surface-Water Specialists during this period were C. Scott Bennett and C. Lamar Sanders. Ground-Water Specialists were William F. Lichtler, Donald A. Vroblesky, and Bruce Campbell. Water-Quality Specialists were Ronald A. Burt, Peter B. McMahon, and Woodrow Wang. The Reports Specialists during this period were Glenn G. Patterson and Woodrow Wang.

Research Section.—The Research Section was initiated by Francis H. Chapelle, accompanied by Peter B. McMahon and later by Donald A. Vroblesky, Marjorie C. Aelion, Paul M. Bradley, and James Landmeyer. Research activities included understanding relations between microbial activity and geochemical interactions, and microbial processes in petroleum-contaminated ground water. The research on microbial activity in water by Chapelle, Vroblesky, Bradley, and Landmeyer is considered cutting-edge science. Collectively, they determined that microbial activity occurs even at depths greater than 1,000 feet under land surface and provided a basis for an understanding that some of the chemical changes that occur in water are not just a product of solution activity but are a result of microbial activity. Too, this newly found technology enabled the District to address problems such as ground-water contamination and possible remedial actions to clean the water. Francis Chapelle completed a textbook on microbial activity in water and is an international authority on the subject.

Hydrologic Surveillance and Analysis Section.—This Section was under the direction of C. Scott Bennett. Surface-water activities were primarily directed to gaging-station operation, real-time data collection and operation, publication of the annual water-data report, and analysis of surface- and ground-water data. In 1988, the Hydraulic Data Management and Analysis Unit was formed specifically to maintain the gaging-station network that was managed from the District Office. Personnel in the Hydrologic Surveillance and Analysis Section and Hydraulic Data Management and Analysis Unit were John W. Gissendanner, Jr., Henry Herlong, Gregory L. Murray, William L. Morris, Jr., Donald P. Scott, Arthur J. Gerswold, J. Michael Hall, Zachary J. Corontzes, Charles R. Meetze, Theodore W. Cooney, Richard Lofton, Richard D. Hayes, Donald E. Leary, Ronald E. McGonigle, James D. Scerra, Kathy H. Jones, Frank Melendez, Jr., Henry L. Hite, Jane E. Larson, James M. Rhett, Jr., Shirley J. Gaines, William M. Bloxham, Jeffrey A. Gordon, Francis A. Johnson, Donald I. Cahal, Donna L. Belval, Michael R. Eckenwiler, Ivan S. Roberts, Benjamin H. Whetstone, Dale M. Johnson, Wladmir B. Guimaraes, John M. Barton, Jeffrey D. Christman, Bill W. Church, Carroll A. Barker, David E. Bower, John M. Smith, John A. Breyfogle, Frank H. Dew, Donald R. Block, Whitney J. Stringfield, James T. Spell, Jan B. Carrino Booth, Sarah W. Logan Ellisor, Brady Long, Robert A. Thorn, Troy Dover, Doug D. Nagle, Brian F. Wahl, Connie J. Eckenwiler, Albert A. Jackson, Brian Daniels, and Natalie S. Rice.

Field Offices

The Aiken Field Office was established in 1985 in nearby New Ellenton, S.C., on South Main Street and was staffed by Lawrence C. Morey, Jr., Frank Melendez, Dan L. Graves, Randy M. Pochel, and Dennis Y. Scott throughout this period. In 1992, the official designation of this office was changed to the New Ellenton Field Office. The Field Office in Conway was moved from Conway to Myrtle Beach in 1981, and was staffed by Allen L. Zack, Frank M. Beckham and later John M. Miller, Sharon W. Coble, Dale M. Johnson, Harold Cox, Ivan S. Roberts, Matthew E. McBeath, Alan C. Brown, John W. Erbland, Paul A. Drewes, and Larry G. Harrelson. The Beaufort Field Office was established in 1985 and was staffed by Donna Belval. The Field Office was closed in 1989.

Hydrologic Investigations Section.—The Hydrologic Investigations Section was established in 1981 and was managed by Phillip W. Johnson, followed by William J. Carswell, Jr., in 1983, Glenn G. Patterson in 1987, and Marjorie Davenport in 1993. Individuals who served in this Section were Allen L. Zack, Donald I. Cahal, James M. Cahill, Francis A. Johnson, Benjamin H. Whetstone, Walter R. Aucott, William M. Bloxham, Gary K. Speiran, Bill W. Church, Ronald E. McGonigle, Kathy H. Baker, Shirley J. Gaines, Donald A. Johnson, Bryan B. McDonald, Donald P. Scott, William E. Hardwick, Elizabeth R. Kennedy, Jeffrey D. Christman, William F. Lichtler, Larry R. Bohman, Donna L. Belval, Marvin E. Davis, Richard M. Harvey, C. Lamar Sanders, Kevin F. Dennehy, Robin S. Meadows, R. Erik Schuck-Kolben, Ronald A. Burt, Michael R. Eckenwiler, Peter B. McMahon, Noel M. Hurley, Sarah Logan Ellisor, Craig T. Reeves, James T. Spell,

Carol Lowery, Donna E. Harper, Paul A. Drewes, Barry S. Smith, Bruce G. Campbell, J. Fred Robertson, Doug D. Nagle, W. Fred Falls, Marijke VanHeeswijk, Paul M. Bradley, Dean F. Salisbury, Whitney J. Stringfield, James T. Morris, James E. Landmeyer, Howard W. Reeves, Francis H. Chapelle, Marjorie C. Aelion, Ted R. Campbell, Liesl C. Rhodes, and Donald A. Vroblesky.

In the 1970's and early 1980's, ground-water investigations consisted mostly of county studies. Principal investigators were Philip A. Johnson, Allen Zack, William F. Lichtler, and James M. Cahill. Johnson was the lead geologist during much of the ground-water work completed in the 1970's. Allen Zack was a major contributor to understanding the geochemistry of water in the Myrtle Beach area and concluded that fluoride in the ground water was released from sharks' teeth within the sands and clays of the geologic formations in the area. Cahill headed the investigation of storage of low-level radioactive material in the ground near Barnwell. Lichtler served as the principal coordinator of projects with the Department of Energy, Savannah River Site, and reviewed of all ground-water activities.

Hydraulics Section.—In 1979, Benjamin Whetstone managed the Section until it was combined with the Hydrologic Data Section in 1981. The Hydraulics Section was recreated in 1988 and managed by C. Lamar Sanders, followed by Larry R. Bohman. Others who served in the Section were Paul A. Drewes, R. Erik Schuck-Kolben, Noel M. Hurley, Wladmir B. Guimaraes, David E. Bower, Dale M. Johnson, Paul A. Conrads, Brad Jennings, Michael G. Zalants, Stephen T. Benedict, Larry G. Harrelson, Timothy H. Lanier, Toby Feaster, Andral W. Caldwell, and J. Mike Sullivan. The Section was reorganized and renamed the Hydrologic System Analysis Section and headed by Noel Hurley, Jr. in 1992.

FUNDING AND COOPERATION

The South Carolina District program more than quadrupled during the 1980's and early 1990's, led largely by a steady increase in the Cooperative (Coop) program and a tenfold growth in programs with other Federal agencies. The Federal program grew modestly, reflecting funding levels for RASA projects and studies related to ground-water contamination.

Principal cooperators were the South Carolina Water Resources Commission (later to become a part of the South Carolina Department of Natural Resources), South Carolina Public Service Authority, South Carolina Department of Health and Environmental Control, Spartanburg Water System, South Carolina Department of Highways and Public

South Carolina District funding, fiscal years 1979 –94

Fiscal year	Federal	Other Federal agencies	Cooperator match	Federal match	Total
1979	$228,000	$273,900	$420,450	$420,450	$1,342,800
1980	$288,500	$329,300	$483,700	$483,700	$1,585,200
1981	$498,300	$495,000	$474,650	$474,650	$1,942,600
1982	$438,800	$632,200	$562,400	$562,400	$2,195,800
1983	$401,000	$745,500	$601,750	$601,750	$2,350,000
1984	$555,700	$1,056,600	$755,650	$755,650	$3,123,600
1985	$530,300	$1,100,400	$750,000	$750,000	$3,130,700
1986	$456,300	$1,161,600	$803,150	$803,150	$3,224,200
1987	$387,700	$ 977,500	$1,026,000	$1,026,000	$3,417,200
1988	$405,700	$1,131,100	$1,180,000	$1,180,000	$3,896,800
1989	$259,200	$1,108,700	$1,272,600	$1,272,600	$3,913,000
1990	$417,500	$1,468,600	$1,240,000	$1,240,000	$4,366,100
1991	$307,000	$1,663,600	$1,455,500	$1,455,500	$4,881,600
1992	$343,900	$2,359,100	$1,377,000	$1,377,000	$5,457,000
1993	$270,000	$2,592,445	$1,495,529	$1,414,100	$5,772,074
1994	$457,000	$2,773,231	$1,613,989	$1,448,000	$6,292,920

Transportation, City of Myrtle Beach, City of Charleston Public Works, Cooper River Water Users Association, Waccamaw Regional Council of Governments, South Carolina Sea Grant Consortium, Spartanburg Sanitary Sewer District, Grand Strand Water and Sewer Authority, Beaufort/Jasper Water and Sewer Authority, Oconee County Sewer Commission, York County, Georgetown County Water and Sewer Authority, Newberry County, City of Florence, Marion County, Darlington County, Richland County, Lexington County, Lake City, Dillon County, City of Irmo, and the South Carolina Department of Wildlife and Fisheries. The District received funding from these Federal agencies: the Federal Energy Regulatory Commission, U.S. Navy, U.S. Army Corps of Engineers—Savannah and Charleston Districts, U.S. Department of Energy—Savannah River Site, Federal Emergency Management Agency, the National Park Service, and the U.S. Environmental Protection Agency.

The principal growth in the Federal-State Coop program was related to the real-time data system and modeling efforts. Major programs were developed with the South Carolina Water Resources Commission the South Carolina Department of Highways and Public Transportation, Grand Strand Water and Sewer Authority, and the Cities of Myrtle Beach, Charleston, and Florence.

The cooperative program with the South Carolina Department of Natural Resources (SCDNR) included installation of a network of gages on small streams (including real-time data acquisition), ground-water-level and salinity monitoring networks, and a study of velocities required during certain seasons for fish egg transport. The SCDNR, in cooperation with the City of Hilton Head, contributed to a study of ground-water flow and saltwater encroachment in the Floridan Aquifer System in Beaufort and Jasper Counties (WRIR 87–4285). Hilton Head Island was faced with saltwater intrusion as a result of ground-water withdrawals in South Carolina and Georgia. The modeling effort was led by Barry Smith. The SCDNR also cooperated in studies to determine the potentiometric surface of the Tertiary limestone aquifer system in the Southeastern United States (OFR 81–486), the distribution of dilute seawater in the aquifer system in Horry and Georgetown Counties (WRIR 84–4076), the hydrology and geology of wells in Marion County, the documentation of a major flooding event in Newberry County (WRIR 88–4148), and aquifer tests in the Coastal Plain (WRIR 86–4159).

Cooperative programs with the South Carolina Department of Highways and Public Transportation included a finite element modeling study of the impact of the proposed Interstate 326 crossing on flood stages of the Congaree River (WRIR 81–1194, WRIR 84–4280), estimating peak discharges for small streams in the State (OFR 82–337), estimating the magnitude and frequency of floods in the State (WRIR 91–4157), flow characteristics of Filbin Creek at the proposed Interstate 526 crossing near Charleston (WRIR 87–4157), base-flow measurements at partial record sites (OFR 86–143), and low-flow frequency and flow duration of selected streams (WRIR 91–4170). Other work included support for a crest-stage gaging program, study of bridge scour, and a statewide flood study and development of dimensionless hydrographs for rural and urban areas of the State (WRIR 89–4087). The bridge-scour program was substantially expanded in 1993. The counties of Richland and Lexington and the City of Irmo cooperated in a study of flooding in urban areas (WRIR 89–4077), also of great interest to this State agency.

Cooperative efforts with the City of Myrtle Beach, Waccamaw Regional Council of Governments, Georgetown County, and Grand Strand Water and Sewer Authority led to the development of hydrologic models to determine the potential of the Atlantic Intracoastal Waterway to supply water to the area (OFR 88–4066), monitoring of saltwater (OFR 89–409) and effects of high concentrations of sodium ions and dissolution and ion-exchange reactions (WRIR 84–4076) in the Intracoastal Waterway, and the hydrology of the Sampit River (OFR 82–243).

Modeling of the Atlantic Intracoastal Waterway provided the technical basis for locating the water supply for the City of Myrtle Beach. The city had relied on poor-quality ground water prior to locating freshwater intakes on the waterway. The water source is a pocket of freshwater formed at the confluence of the Pee Dee and Waccamaw Rivers near Myrtle Beach. To the south of this confluence is Winyah Bay and to the north is the Little River Inlet, both of which contain seawater. The potential of this pocket as a major water-supply source was pointed out in the late 1970's by Francis Johnson. The acquisition of data, including measurement of flow over several tidal cycles, and the modeling effort followed.

The cooperative program with the South Carolina Public Service Authority included operation of streamflow-gaging stations and a major study of the storage of toxic materials adjacent to Lake Marion (WRIR 91–4056 and WRIR 93–4183). Other studies included the bathymetry (WRIR 88–4062) and rate of movement of water in Lake Marion and sediment inflow and deposition in Lake Marion (WRIR 88–4160), the ability of microbial communities to degrade xenobiotic compounds (OFR 89–409), and benthic invertebrates in Lake Marion and its tributaries (WRIR 91–4140).

Programs with the South Carolina Department of Health and Environmental Control included studies of the fluoride concentrations of Coastal Plain ground water (WSP 2067, OFR 81–140), low-level radioactive solid-waste disposal near Barnwell (OFR's 82–863, 84–806, 85–476, and WSP 2345) and quality of water from bedrock aquifers in the Piedmont (WRIR 84–4028).

Investigations funded by other Federal agencies were varied and diverse. Studies with the Department of Energy included a large-scale water-monitoring system of streamflow and systematic measurements of stream-water temperatures, investigation of glassifying nuclear waste (WRIR 88–4221), and initiation of a ground-water monitoring system in the vicinity of the Savannah River Site. A study of potential contamination moving through the aquifer system to Georgia was commenced in 1993. Studies with the National Park Service included documentation of metal concentrations in streams (OFR 90–370) and the hydrology and its effects on vegetation in the Congaree National Monument (WRIR 85–4256). Studies with the U.S. Army Corps of Engineers included documenting the effects of the Cooper River Rediversion on sedimentation in Charleston Harbor (WRIR 83–4198), flood frequency of the Savannah River at Augusta, Ga. (WRIR 90–4024), unsteady flow modeling of the Savannah River between Augusta and Clyo, Ga. (WRIR 84–4158), and a major streamflow-monitoring network. Cooperation with the Federal Emergency Management Agency included documentation of the extent of flooding as a result of the tidal surge from Hurricane Hugo in September 1989.

Large-scale modeling efforts included the RASA program, a federally funded national initiative. RASA was the first study in South Carolina to delineate, characterize, and model the aquifers of the Coastal Plain of the State. This study, led by Walter Aucott and Gary K. Speiran, served as the basis for much of the ground-water modeling efforts that have followed. The study pointed out the need for additional data. As a result of this need, a network of monitoring wells was installed and a major coring effort to obtain the needed data was begun. Cores were collected and monitoring wells were installed in the newly identified aquifers. The District contributed to the construction of the Geologic Sample Repository, which is maintained by the South Carolina Geological Survey. The cores collected as a part of the project are stored in the repository. Principal cooperators were the U.S. Geological Survey (Geologic Division), U.S. Department of Energy, South Carolina Department of Natural Resources, Cities of Charleston, Myrtle Beach, Lake City, and Hilton Head, and Florence, Darlington, Dillon, and Marlboro Counties.

The Microbial Studies Unit, the successor to the Research Section, began major studies of site contamination for the Southern Division of the U.S. Navy in 1993. Personnel of the Unit did studies throughout the Nation and provided expertise to other Districts conducting similar studies.

The NAWQA Program in South Carolina, a water-quality assessment of the Santee River and coastal drainage basins, began staffing in 1994. This major study was headed up by W. Brian Hughes. Other NAWQA Program personnel included Terry Sicherman Maluk, Thomas Abrahamsen, Eric J. Reuber, Whitney J. Stringfield, W. Boyce Blanks, Lance Wilhelm, Robert Thorn, and Donald Leary.

TENNESSEE

By Charles R. Gamble and *reviewed* by Michael W. Bradley, Assistant District Chief, Tennessee District

ORGANIZATION AND PERSONNEL

Through most of the period, the Tennessee District consisted of a fairly large Headquarters Office in Nashville and medium-size Subdistrict Offices in Knoxville, Nashville, and Memphis. The average number of employees during the period was 70.5 and ranged from a minimum of 61 in 1981 to a maximum of 84 in 1993 and 1994. The largest single growth year was from 1987 to 1988 when the number of employees increased from 67 to 77 employees.

During the period, cooperative (coop) education students and Hydrologic Technicians have made up a significant part of these totals. Coop students made up

about 8 percent of the total on average, with a low of 2 percent in 1982 and a high of 17 percent in 1979. Hydrologic Technicians made up 27 percent of the total on average, with a low of 19 percent in 1985 and a high of 30 percent in 1987. Part-time or seasonal employees in 1984 made up 24 percent of the total. These employees were a means of "beating the system" as during these years part-time and seasonal employees, and perhaps Coop students, were not counted in the personnel ceilings.

Office of the District Chief, Nashville

In 1979 the District Office was located on the fourth floor of the U.S. Courthouse Annex at Eighth and Broadway in downtown Nashville where it remained until 1990. At that time the office moved across Broadway into a part of the building once occupied by the Nashville Branch of the University of Tennessee. The address was 810 Broadway, Suite 500.

Stanley P. Sauer served as District Chief until 1980 when he became Surface-Water Branch Chief. Arthur L. Putnam transferred from South Carolina to become District Chief in 1980 or 1981. Putnam transferred to Reston, Va., in 1984 and Larry R. Hayes became District Chief. Hayes moved on to become Chief of the Yucca Mountain Project in 1987 and was replaced by Ferdinand Quiñones-Marquez, who remained as District Chief until the end of January 1993 when he was reassigned. Charles R. Gamble served as Acting District Chief until July 2, 1993, when he retired and Harold C. Mattraw, Jr., became District Chief.

Assistant District Chiefs during the period were Donald R. Rima (1979–81; retired), Michael W. Gaydos (1983–86; became District Chief in Mississippi), V. Jeff May (Hydrologic Data, 1987–89; retired), Michael C. Yurewicz (Hydrologic Investigations, 1988–90; became Massachusetts District Chief), Charles R. Gamble (Hydrologic Data, 1989–93; retired), Michael W. Bradley (Hydrologic Investigations 1992–94), and Jess D. Weaver (Hydrologic Data, 1993–94).

Thomas J. Quarles, longtime District Administrative Officer, retired in 1979 and was succeeded in 1980 by Virginia Ann Cantrell, who was succeeded by Diane McNelly in 1982. Nancy C. Tedder was Administrative Officer from 1985 to 1993 when she transferred to another agency. Tedder was succeeded by Elizabeth C. Pinitsch. Personnel who have served in the Administrative Services Section during the period are Thelma H. Jackson, Kathleen F. Champion, Diane M. Brown, Eva G. Baker, Mary A. Kopta, Robert J. Beckley, Janet K. Dillon, Bridgett C. Frame, Teresa D. Holt, Vicky M. Brantley, Nicole D. Glafka, Debby P. Tully, Patricia L. Sorey, Katrina L. Hoadley, and Loretta J. King.

Reports Unit.—The District Reports Unit, established in 1982, consisted of Lewis G. Conn as Chief, Barbara H. Balthrop, and Eva G. Baker. Bobbie F. Quinn was added in 1985. Conn was reassigned in 1986 and the Unit was changed to the Publications Section with Barbara H. Balthrop as Chief. James E. Banton and Vickie H. Walters were added at this time. Joel C. Smith and P. Lynn Pruett came into the Section in 1987. Wayne T. Ashmore, and Lisa L. DeWilde came in 1988. Robin F. Blackman was added in 1989. David A. Webster moved from the Hydrologic Investigations Section to the Publications Section in 1991. Barbara B. Oldson came in 1993. The Section also had several Student Trainees (Coop students) or part-time employees over the period, including Renda C. Massingill, Henry C. Moore III, Cindy M. Gates, Carrie M. Wright, and A. LaShawn Patterson.

During the late1980's and early 1990's, the Publications Section evolved into a Regional Publications Center and provided cartographic, editing, and desktop publishing services to other Districts in the Southeastern Region and sometimes to Districts outside the Region. The Headquarters Office also became a client at times. The Center developed training programs and conducted training in cartographic, editing, and desktop publication techniques throughout the country. During this period the number of persons assigned to the Section did not quite keep pace with the amount of work available. Consequently, the publication of some reports was delayed beyond the approval dates.

Computer Unit.—As computers became more important in the daily operations, a Computer Unit was established in 1985 with William R. (Bill) Barron, Jr., as head. The other employees at that time were Robert D. Hutchinson, programmer, and Georgia Lynn McCauley, computer operator. Hutchinson left the following year and Michael R. Williams was added. The name was changed to Computer Section in 1986. Kenneth R. Mullins was added in 1988. Joseph F. Connell, Tom T. Thornburgh, and Letitia A. Ables came in 1989. Connell became the District expert on Geographic Information Systems and developed

several projects that used this technology. Nancy M. Flexner was added in 1991 and Lori R. Mercer and Paul M. Baggett in 1993. Bill Barron transferred to the U.S. Army Corps Of Engineers in 1992 and Lori R. Mercer became head of the Computer Section. Several Coop students also served the Computer Section: Robert M. Anderson III, Pamela G. Norris, David C. Greene, Tracy L. Ewing, Mark W. Davis, Eric S. Alsup, Cheryl M. Bledsoe, and Reavis L. Mitchell.

The first computer resource in the District was a terminal that read card decks and transmitted their images to a host computer at Headquarters. The host computer did the computations requested by the submitter and transmitted the results back to the terminal, where the results would be printed out. This system was large in terms of floor space required and was somewhat unreliable, especially when reading large card decks. A major change came in about 1983 or 1984 when a minicomputer replaced the terminal. This system provided a terminal connected to the minicomputer at most desks. Workstations arrived about 1991, but the minicomputer remained in use for hydrologic records computation for several years because of a delay in program development for the workstation.

Hydrologic Data Section.—This Section has been called the Data Management Section at times, but its principal function remained the same: to oversee the basic-data collection and analysis, provide quality control and review, archive the data, and publish the Annual Data Report. The Chief of this Section acted as supervisor over the Subdistrict Chiefs. Section Chiefs during the period were V. Jeff May until 1988, Roy H. Bingham, Charles R. Gamble, and Jess D. Weaver. Others assigned to this Section in Nashville were Mary D. Perkins, E. James Crompton, Georgia M. Jones, Ronald Casler, Michael W. Gaydos, Joseph B. Largen, Jerry F. Lowery, William R. Barron, Dyanne M. Brown, Clarence H. Robbins, Mark Smith, Arthur D. Bradfield, Gregg E. Hileman, Anne B. Hoos, George S. Outlaw, Randy Thomas, Donnis D. Cathey, John T. Pankey, Lori R. Mercer, and Donna F. Flohr. In addition, the following Coop students served in the Section: Stephen P. Hart, John D. Hendrix, Jill J. Jonas, Mark A. Hunter, Jimmy L. Elder, Joel P. Logan, W. Byron Hinchey, Kenneth S. Nave, Rodney L. Wilson, Michael D. Woodside, Carrie G. Chatham, Joseph F. Gonzales, Phillip W. Walker, James R. Barham, G. Scott Adams, and Anant R. Patel.

Subdistrict Offices

As the period began, responsibility for collection of basic hydrologic data was distributed among three Subdistrict Offices, each responsible for roughly one-third of the State. These were located in Knoxville, Nashville, and Memphis. In addition, a Field Headquarters was established in 1981 in Oneida to service a project in that area requiring frequent visits to keep data-collection instrumentation running properly and to collect sediment samples frequently. This Field Headquarters operated until 1986. It was administratively attached to the Knoxville Subdistrict Office. Frederick H. George established the office and worked there all during its brief operation (1981–86). Others who served there were Peter M. Shell, Lela M. Newport, and Bradley A. Bryan.

Knoxville Subdistrict.—As the period began, Bernard J. Frederick was the Subdistrict Chief, but he retired in 1980. He was replaced by Robert D. Livesay who served as Chief until 1989. Jess D. Weaver was Chief from 1989 to 1993 when he transferred to Nashville. Bradley A. Bryan transferred back to Knoxville to become Subdistrict Chief in 1993.

Others who served in Knoxville during the period were David A. Webster, Joe Connell, Patrick H. Counts, Clarence H. Robbins, Gordon B. Smith, Donald M. Dewey, Betty B. Hill (Keener after her marriage), Patrick M. Benjamin, James G. Lewis, Mary W. Dossett, Steven S. Lyng, Ronald D. Evaldi, Martha G. Hill, Jo Ann Macy, Cynthia L. Hundley, Harold H. Zehner, Terry D. Phillips, John C. Barnett, George S. Outlaw, Andrew C. Hickey, Gregory C. Johnson, Patricia Powers, Terry D. Turner, James K. Carpenter, and Charles W. Comstock. In addition, the following Coop students or short-term employees served in Knoxville: Jeffrey S. Beatty, William S. Tranum, Michael R. Williams, Charles F. Glassard, W. David Canaan, Richard J. Conner, Jr., Melissa L. Roberts, Lawrence M. Brede, Jimmy L. Elder, Jr., and Bruce McMaster.

Nashville Subdistrict.—At the beginning of the period, Charles R. Burchett was Subdistrict Chief and remained so until 1982 when transferred to Texas. Delmer J. O'Connell transferred from Wyoming to replace Burchett and remained until 1989 when he transferred to Iowa. Jerry F. Lowery served as Subdistrict Chief the remainder of the period.

Others serving in the Nashville Subdistrict during the period were F. Derward Edwards (acting

chief during the transition between Burchett and O'Connell), Gerald M. Christiansen, Jesse T. Hamilton, John F. Kerestes, Jerry W. Anderson, Joseph B. Largen, Arthur D. Bradfield, Shannon L. Chapman, Gwendolyn L. Jones, Jayne E. May, Andrew Simon, Dianne M. Brown, Gilbert J. Engelmeier, Arthur K. Brachman, Michael R. Williams, Beri N. Fraley, W. David Canaan, Donna F. Flohr, Ron L. Kemp, David E. Butner, Michael W. Bennett, Patricia L. Sorey, Donald E. League, and John M. Shelton. In addition, the following Coop students were assigned to the Nashville Subdistrict Office: Gary E. Pickens, Crystal D. Batts, Mark A. Hunter, David W. Thompson, Richard E. Harkins, Therese L. Flat, Jimmy L. Elder, Michael E. Lewis, Robert C. Vear, Gregory L. Burton, Robert R. Perry, Mark A. Smith, Benny S. Junkins, Aaron T. Oaks, Donald V. Shoemaker III, Rodney R. Knight, Wilma R. Johnson, Diane Johnson, and Harold G. Cox.

Memphis Subdistrict.—The Memphis Subdistrict had two Chiefs during the period. They were Braxtel L. Neely until 1984 and W. Harry Doyle, Jr., for the remainder of the period.

Others who served in Memphis were William S. Parks, Howard L. Edmiston, David D. Graham, Jerry F. Lowery, Ruby S. Ingram, Susan S. Hutson, George J. Wenger, Charles S. Palmer, Jerry W. Garrett, Doyle Avant, Jr., John K. Carmichael, Katherine S. McCain, David L. Perry, David E. Bazemore, Larry B. Thomas, Michael E. Lewis, W. Kevin Kelly, Randy Thomas, Robert W. Stogner, Carolyn F. Glover, June E. Mirecki (an intermittent employee and professor at University of Memphis), James A. Kingsbury, Richard A. Orr, Amy J. Fielder, and John T. Pankey. In addition, the following Coop students served in Memphis: Forrest C. Ward, Mark E. Ballard, Joan H. Moller, Bruce W. McMaster, and Salane L. King.

Hydrologic Studies Section.—This Section was headed by William J. Randolph until his retirement in 1981. At this time the Section merged with the Areal Studies Section and was renamed Hydrologic Investigations Section (see below). Personnel in the Hydrologic Studies Section during the period 1979–81 were Lewis G. Conn, Fred N. Lee, William P. Carey, Edward B. Boyd, Charles R. Gamble, Frederick H. George, Lloyd E. Peterson, James G. Lewis, and Clarence H. Robbins. Coop students who served this Section were James D. Odum, Dana Y. Petway, Mark E. Settle, Larry T. Stone, David W. Thompson, and Jack W. Frazier.

Areal Studies Section and Hydrologic Investigations Section.—This Section was headed by Donald R. Rima until his retirement in 1981. At that time the Section was renamed Hydrologic Investigations Section and absorbed most of the personnel in the Hydrologic Studies Section upon the retirement of William J. Randolph. Michael W. Gaydos became Chief of the Hydrologic Investigations Section in 1981 and remained in that capacity until he became Mississippi District Chief in 1986. Este F. Hollyday acted as Chief for a short period until replaced by Michael Yurewicz. Michael W. Bradley replaced Yurewicz as Section Chief.

Personnel serving in the Areal Studies Section were Este F. Hollyday, John Van Brahana, Steven C. McCutcheon, Patricia Ann Zurawski, Patricia L. Goddard, Terry W. Evans, Ann K. Sparkes, Michael W. Bradley, Barbara Balthrop, Kathleen N. Simmons, and Jo Ann Macy. The following Coop students were also assigned to the Section: James D. Lewis, Dale A. Less, David R. Bauer, and Dolores M. Mulderink.

Personnel making up the Hydrologic Investigations Section in 1982, in addition to the Chief, were Roy H. Bingham, John Van Brahana, Este F. Hollyday, William P. Carey, Clarence H. Robbins, Edward B. Boyd, Charles R. Gamble, Michael W. Bradley, and Dolores M. Mulderink. Those added after 1982 were Arthur D. Bradfield, Andrew Simon, Stanley Trimble (WAE), Zelda C. Bailey, Patrick Tucci, Bradley A. Bryan, Pamela J. Pulliam, Dolores M. Mulderink, Joseph F. Connell, Vickie H. Walters, John K. Carmichael, Robert E. Broshears, Anne B. Hoos, Cliff R. Hupp, Roger W. Lee, Dorothea B. Withington (Hanchar after her marriage), Gregg E. Hileman, David E. Bazemore, Carolyn N. Short, David A. Webster, Connor J. Haugh, Dianne J. Pavlicek, Michael W. Bennett, Elizabeth N. Mahoney, Mark A. Smith, Angel J. Román-Más, Stephenie E. Johnson, Robert A. Aycock, Kristie G. Hamilton, Thomas D. Byl, Thomas M. Smith, and David E. Ladd. Coop students that served in the Section were David Thompson, Rodney L. Wilson, Frederick D. Siewers, Rachel C. Merwin, Jason P. Anderson, Malcolm A. Dugliss, Romona L. Hunt, Jason E. Duke, John A. Robinson, Patrick A. Harrell, Paul A. Pearson, Jason P. Weeks, Cynthia D. Willis, Brett A. Weaver, and Joshua B. Broadwater.

Ecological Investigations Section.—This Section was established in 1989; the following year the name was changed to Geomorphologic/Ecological

Investigations Section to better describe its work. During the reporting period some of the subjects dealt with by this Section were sediment-transport problems, fluvial morphology at bridge crossings, channel-evolution studies, impact of strip mining on channel geometry and sediment transport, sediment yields, geomorphic changes in response to channel dredging, sediment deposition and vegetation response near bridges, evaluation of critical scour at bridge sites, hydrologic regime of wetlands, and debris accumulation at bridges.

Andrew Simon was Section Chief until 1990. Bradley A. Bryan was Chief from 1991 to 1993. In 1993 Bryan transferred back to Knoxville as Subdistrict Chief, and the Section was absorbed by the Hydrologic Studies Section.

Other personnel serving in the Section during this reporting period were Cliff Hupp, George S. Outlaw, David E. Bazemore, Steven A. Kautz, Timothy N. Diehl, William J. Wolfe, and Donald E. League. Coop students assigned to the Section were Rachel C. Merwin, Kristie G. Hamilton, Shanna N. Curley, Melissa P. Walker, G. Scott Adams, Jeffrey D. Stevens, and Jason A. Weeks.

FUNDING AND COOPERATION

The funding table shows the Tennessee District funding for the period 1979–94. The increase in OFA funds for 1985 and 1986 was due to additional work being carried out at the Oak Ridge Reservation. The decrease in the OFA funds for the following 3 years was due to decreases in funds from Tennessee Valley Authority (TVA), Department of Energy (DOE, Oak Ridge work), and U.S. Army Corps of Engineers (Corps). From 1989 to 1990 funds from DOE, TVA, and the Corps dropped again, but additional or new funds from Arnold Engineering Development Center (AEDC), Arnold Air Force Base at Tullahoma, and the U.S. Environmental Protection Agency more than offset these decreases. The 1993 increase in OFA funds can be attributed to increases from AEDC and the Naval Support Activity (NSA) (formerly Naval Air Station) at Millington and new or additional funds from Fort Campbell Military Reservation and the Army Stormwater Program. Federal Highway Administration and Fort Campbell funds brought an increase in OFA funds in 1994.

In 1993, State funds dropped due to a decrease from the Tennessee Department of Transportation of about $140,000, which was partially offset by other small increases. The decrease in Federal funding in

Tennessee District funds, fiscal years 1979–94

[Source: Administrative Information System for 1979–82, 1986–94; Bob Hudson, Administrative Officer, Southeastern Region, for 1983–85]

FY	Federal	OFA	State	Other	Federal matching	Total
1979	$505,000	$524,800	$700,700		$698,200	$2,428,700
1980	810,000	583,000	797,100	$16,400	813,500	3,020,000
1981	835,300	574,600	885,900		868,300	3,164,100
1982	573,600	657,500	861,200	15,100	876,300	2,983,700
1983	669,000	468,000	790,000	45,000	790,000	2,762,000
1984	625,000	739,000	833,000	22,000	833,000	3,052,000
1985	398,000	1,185,000	976,000	28,000	976,000	3,563,000
1986	330,000	1,673,100	1,050,000		1,050,000	4,103,100
1987	406,000	939,100	1,260,000	50,000	1,310,000	3,965,100
1988	521,000	789,500	1,421,700		1,421,700	4,153,900
1989	600,900	564,800	1,437,500		1,437,500	4,040,700
1990	581,500	1,202,900	1,400,000		1,400,000	4,584,400
1991	520,200	1,499,300	1,450,000		1,450,000	4,919,500
1992	461,800	1,672,500	1,410,200		1,370,000	4,914,500
1993	441,100	2,620,000	1,291,800		1,286,000	5,638,900
1994	417,600	3,151,200	1,257,300		1,255,000	6,081,100

1985 was probably due to the ending of the Coal Hydrology Program.

SUMMARY OF PROGRAMS

Hydrologic Data Collection

The number of data-collection sites includes basic-data-collection sites and some project-data-collection sites, which are noted. There were other project sites that were operated during the period but are not shown here.

With only a few exceptions, the basic data units (Subdistrict Offices) were responsible for installing and operating all data-collection sites. During some years of intense project activity, this put a heavy burden on the resources of these units, in terms of time and manpower. But in general, they handled the tasks in admirable fashion.

Water Use

The Tennessee District has operated a water-use program during the reporting period in cooperation with the Tennessee Department of Environment and Conservation, Division of Water Supply. Detailed accounting of the rate at which water resources are being used and the location where the demands are greatest is needed to develop management strategies that will ensure both sufficient water supply and adequate water quality. A statewide survey of water use is conducted every 5 years. Ground- and surface-water withdrawal and ancillary data are collected for the water-use categories of public supply, industrial, commercial, domestic, agriculture (including irrigation), mining, thermoelectric power, and reservoir operation. Data are compiled at the county, watershed, and aquifer level.

Number of data-collection sites by year and type, 1979–94

Water year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Surface-water stations																
Continuous streamflow	110	108	114	112	96	91	93	96	100	103	94	81	93	76	77	85
Continuous Stage	1	1	1	1	1	2	2	2	6	6	6	6	7		1	1
Flood hydrograph[a]	39		41			10	9	2							12	12
Low-flow partial record[a]	48	73	77	23	83	79	80	78	82	207	77					
Crest-stage partial record[a]	105	127	127	126	116	93	91	90	89	92	94	93	91	90	96	97
Coal hydrology[a]	80	80	81													
Reservoir stage and contents[b]	27	27	27	28	28	28	28	28	27	27	28	28	27	27	27	27
Springs measured[a]	19	6	7	1	1	1	12	16	9	7		1	1		4	4
Seepage investigation sites[a]	149		20	158		44		97	180	78			22			
Miscellaneous sites	25	23	34	30	37	6		31	28	26	12	5	6	5	9	5
Ground-water stations																
Statewide network	27	26	30	30	33	32	32	33	33	32	32	22	22	22	30	30
Subsidence	2		2													
Water-quality sites																
Streamflow gages	80	82	73	70	25	22	25	28	37	25	19	17	14	17	20	18
Ground-water wells	27	21	45	77	49		99	45	149	43	10	12	12	10	12	10
Partial-record and misc. sites						33	39	15							58	58

[a]Data from these sites were mostly from projects but were published in the annual Data Report.
[b]Data furnished by other agencies.

Interpretive Studies

During the 1979–94 period, the number, complexity, and range of subjects of interpretive studies increased in the District. This is at least partly attributable to the hiring and transferring in of highly trained and well qualified personnel. Interpretive studies covered both ground-water- and surface-water-based studies as well as multidiscipline studies. A major focus of ground-water studies was on the Oak Ridge Reservation where possible contamination of ground water and its movement was a concern. A project office was located on the reservation at one time.

Another large multidisciplinary, multiyear (1989–96) project, the Beaver Creek project, was located in west Tennessee near Memphis. It involved the study of possible effects on water quality from agricultural chemicals and practices. This project received funding from many different sources: Tennessee Department of Agriculture; Clemson University; Shelby, Tipton, Fayette, and Haywood County Soil Conservation Districts; Tennessee Department of Environment and Conservation; University of Tennessee; University of Memphis; and Natural Resources Conservation Service. Money from the Farm Bureau Federation was also involved through one of the listed agencies. Several people were Project Chiefs over the duration of the Beaver Creek project, including Robert E. Broshears, Michael E. Lewis, Angel J. Román-Más, and W. Harry Doyle. There were many reports (approximately 20) that came out of this project.

Other subjects emphasized in the District were bridge scour, channel changes due to human activities, and related topics. There were several projects involving these subjects: Tennessee Bridge Scour, Channel Adjustment, Channel Evolution, Geomorphology of Cane Creek, Sediment Deposition in Wetlands, and Potential Critical Scour at Bridges. These projects produced many important reports that advanced the knowledge of how and why channels change. The results of some of these studies also had major effects on the mission of certain agencies and on the regulatory function of others.

Another area that continued to receive a large amount of study and resources was the aquifer systems underlying Memphis, Tenn. Memphis is one of the largest cities in the United States, and perhaps the world, that relies entirely on ground water for water supply. The following projects were conducted in the Memphis vicinity, and most were conducted in cooperation with the Memphis Light, Gas, and Water Division. The Project Chief of most of these projects was William S. Parks.

Chemical Character of Ground Water in the Shallow Water Table Aquifer

Study of Hydrology in Anticipation of Lignite Mining

Geohydrology and Solute Transport in Freshwater Aquifers in the Memphis Area

Chemical Character of Ground Water at the Hollywood Dump

Evaluation of the Magnitude of Leakage Among the Principal Shallow Aquifers in the Urban Area of Memphis

Geohydrology and Pesticide Transport at North Hollywood Dump

Background Water-Quality Data for Selected Trace Constituents and Organic Compounds in the Shallow Water-Table Aquifer in the Memphis Area

Preliminary Assessment of the Potential for Contamination of the Memphis Sand Aquifer in the Memphis Area

Investigation of Ground-Water Quality at the Shelby County Landfill

Flood Investigations

The Tennessee District has had a very vigorous flood-investigations program since about 1954, operated in cooperation with the Tennessee Department of Transportation. It includes documentation of floods at gaged sites as well as miscellaneous sites. During the reporting period, major floods occurred in May 1979 (Nashville and middle Tennessee), August 1982 (southeastern and north-central Tennessee), September 1982 (west-central Tennessee), 1984 (pretty much statewide), December 1987 (northern Memphis), February 1990 (Emory and Hiwassee River Basins), May 1991 (Piney and Duck River Basins), and March 1994 (east Tennessee, Little River Basin). In many cases, the determination of peak discharge for a flood involves indirect methods. During 1979–94, many indirect measurements of peak discharge were made.

An update of the statewide flood-frequency report by J.D. Weaver and C.R. Gamble was published in 1993. This update used data through water year 1986 and used updated techniques developed since the last flood-frequency report was completed.

Droughts

Fairly significant droughts occurred during 1980–92 in central and eastern Tennessee with recurrence intervals of approximately 10–20 years and during 1985–88 statewide with recurrence intervals of 14 to more than 50 years. Some water-supply problems occurred during both events that affected several towns and industries. Water quality was adversely affected also, as indicated by some aquatic life die-offs caused by decreased dissolved-oxygen content and increased carbon-dioxide concentrations.

Energy-Minerals Programs

The USGS and BLM coal-hydrology programs, begun in 1975, ended during the mid-1980's. For this program the District produced five reports and contributed to one other. These included reports to provide information about the regional hydrologic setting in "coal areas" of the Eastern Coal Province.

Regional Aquifer Studies

The District participated in two Regional Aquifer-System Analysis studies, one for the Mississippi Embayment, conducted by J.V. Brahana, and one for the Valley and Ridge subregion of the Appalachian and Piedmont area, conducted by E.F. Hollyday. Several reports came out of each of these projects.

Military Programs

The Tennessee District began doing work for military installations in the late 1980's or early 1990's. The first work was for Arnold Air Force Base near Tullahoma with Connor J. Haugh as Project Chief. Numerous contractors had conducted remedial investigations at individual hazardous-waste sites on the base, but there was no knowledge of the basewide ground-water-flow system and potential for contaminant migration from waste sites. The objective of the project was to try to answer these questions, especially for the Arnold Engineering Development Center, which is located on the base. Numerous data were collected and a ground-water flow model was developed.

The District has also been involved in major activities at the Naval Support Activity (formerly Naval Air Station) at Millington, near Memphis. Basically the same problem exists there as at Arnold Air Force Base. There are a number of solid-waste-management units requiring hydrogeological characterization under the RCRA Corrective Action Program. The general geology and ground-water hydrology of the sites and overall area are not well defined. A basewide ground-water-flow model was developed by John K. Carmichael.

Fort Campbell Military Reservation, which straddles the Tennessee-Kentucky State line, is another installation where work was done by the District. The reservation relies on ground water from Boiling Spring, a karst "rise-pit" spring, as a primary source of drinking water. The broad objective of the project, under the direction of Gregg Hileman, was to understand the occurrence and movement of ground water of the area with a specific objective to delineate the "wellhead protection area," or the area that contributes water to Boiling Spring.

Another sizable activity since about 1993 is the Army Stormwater Program. The Army is required to collect stormflow data to assist Active Army and Army Reserve facilities in meeting Federal and State stormwater requirements. The USGS Water Resources Division contracted with the Army to help with the following on a nationwide basis: (1) Collect and analyze stormwater data at Army installations, (2) assist in preparation of pollution-prevention plans, and (3) assist in training Army staff on stormwater issues. Fred Quinones was the original national Project Chief, assisted by Robert Aycock in Tennessee.

Other Investigations

One of the more interesting projects conducted by the Tennessee District, especially for the geologists, was Hydrogeology and Geochemistry of Deeply Buried Rocks of Low Permeability. The problem involved the lower part of the Knox Group being used to receive injected waste. More information was needed about hydrologic characteristics and geochemistry of the aquifers and confining layer encountered at the injection sites.

A deep test well was drilled in Humphreys County by the I.E. Dupont Company to a depth of about 8,200 feet. Hydraulic tests were conducted for each formation encountered and water-quality samples collected. Geophysical logs were run on the open hole prior to installing casing. A 4-inch core was collected from land surface to basement and described in detail. These data were used to define the hydrology and geochemistry, to evaluate the use of hydraulic testing,

and for parameter estimation, age dating, and isotopic analysis for low-permeability rocks. Mike Bradley directed the District efforts in this project.

Another project that involved elements new to the District was Lebanon, Tenn., Flood Mapping. A significant flood occurred in Lebanon, as well as surrounding areas of middle Tennessee, on February 14, 1989. The District developed a project, in cooperation with the City of Lebanon, to document the flood. The City wanted the inundated area portrayed on topographic maps. Unfortunately, the area is quite flat and no topographic maps with great enough accuracy were available.

The District contracted to have the area flown and topographic maps produced with contour intervals of 2 feet. This was a new experience for the District, and it was learned that the contracting procedures are fraught with unexpected details. However, the work was accomplished and a good product was produced for the City of Lebanon.

CENTRAL REGION

By Don Goolsby

INTRODUCTION

The following is a brief summary of the organization, responsibilities, personnel, and programs of the Central Region Office during the period 1979–94. In 1979, at the beginning of this history, the Region consisted of 15 Districts: Arkansas, Colorado, Iowa, Kansas, Louisiana, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming.

In the years between 1979 and 1994 the composition of the Central Region and responsibilities of the Central Region Office changed significantly. In October 1981 the Arkansas and Louisiana Districts were transferred to the Southeastern Region. In 1982 management responsibilities for the National Research Program and Nuclear Hydrology Program were transferred to WRD Headquarters. In 1991, concurrent with WRD reorganization changes that created four "Area Offices" in the Central Region, the Missouri District was transferred to the Southeastern Region, the Utah District was transferred to the Western Region, and the Minnesota District was transferred into the Central Region from the Northeastern Region. Finally in 1992, management responsibilities for the National Water Quality Laboratory were transferred to the Office of Water Quality in WRD Headquarters. Thus, at the end of the 1979–94 period the Central Region consisted of four Area Offices and 12 Districts. These were: Midwest Area (KS, NE, IA), North Central Area (MN, ND, SD), Rocky Mountain Area (CO, WY, MT), and Southwest Area (OK, NM, TX). In later years the Area Offices would be eliminated, leaving the 12 Districts.

Regional Office Staff: Throughout this period the Central Region Office was housed in Building 25 on the Denver Federal Center in Lakewood, Colorado. Alfred Clebsch, Jr., served as Regional Hydrologist (RH) until his retirement in 1986. James F. Blakey, who was District Chief in Colorado, replaced Clebsch as RH and served through the remainder of this period of history. John P. Monis was the Assistant RH from the beginning of this history until his retirement in 1985. John R. George transferred from the Southeastern Region Office in 1986 to replace Monis. George served as Assistant until his retirement in 1992. This Assistant RH position remained vacant through the end of this history. Hugh H. Hudson was the Central Region Program Officer from the beginning of this history until his retirement in 1980. Hudson remained on the Region staff as a rehired annuitant for several years. Donald L. Coffin, who was District Chief in Missouri, became Program Officer in late 1981 and served until his retirement in 1989. William M. Kastner, District Chief in Nebraska, became Program Officer in 1991 and served in this position through the end of this history. Assistant Program Officers during this period were Jack R. Carter until his retirement in 1980, Saundra S. Duncan from 1980 until 1983, when she left to become Chief of the Denver Central Laboratory, and Richard A. Herbert from 1985 to 1989 when he left to become Subdistrict Chief in Lakewood, Colo. From 1979 until his retirement in 1982, Lee C. Dutcher served as Energy Coordinator for the Region's large program to investigate the hydrology and effects associated with coal and oil shale development. Donald A. Goolsby succeeded Dutcher and served as Energy Program Coordinator until the program's demise in the mid-1980's. As a result of a large expansion of the National Water-Quality Assessment Program (NAWQA), Regional management positions such as Assistant RH were established in 1990. Barbara J. Ryan served in this Central Region position through the end of this

history. Lawrence "Rod" DeWeese served as the NAWQA Regional Biologist and liaison with the Fish and Wildlife Service through the end of this period. In 1990 the Midcontinent Herbicide project was initiated in the Central Region Office to investigate the effects of agricultural chemicals on surface, ground, and atmospheric water in the Midwest corn and soybean belt. Donald A. Goolsby served as Chief of this project through the end of this history. William A. Battaglin assisted on the Midcontinent project from 1990 to the end of this period. Battaglin also was the unofficial Regional expert in geographic information systems (GIS) and helped maintain close coordination between the Region and National Mapping Division (NMD) on the GIS laboratory and related issues.

The four Area Offices created in 1991 were managed by "Area Hydrologists." These were: James E. Kircher, Midwest Area; C.A. "Jerry" Pascale, Rocky Mountain Area; William J. Herb, North Central Area; and Charles R. Burchett, Southwest Area. These Area Hydrologists served through the end of this history. However, the Area Office concept was never fully accepted in the WRD and the positions were later abolished in 1996.

Discipline Specialists: Marion S. Bedinger was the Ground-Water Specialist from the beginning of this history until 1981 when he left to head up the Task I Waste Isolation Studies project. John S. Mclean transferred from Albuquerque, N. Mex., in 1982 and served as Ground-Water Specialist until the end of this period. Mervin S. Peterson was Surface-Water Specialist from 1979 until his retirement in 1980. Kenneth L. Wahl from the California District replaced Peterson and served in this position through the end of this history. Robert C. Averett was the Water-Quality Specialist at the beginning of this history but left in late 1979 to become Regional Research Hydrologist for the Central Region. Donald A. Goolsby transferred from the Quality of Water Branch in Reston in late 1979 and served as Water-Quality Specialist until 1991. Vernon W. Norman, who was already in the Central Region Office, became Water-Quality Specialist in 1992 and served through the end of this period. Saundra S. Duncan also assisted with the Water-Quality Specialist position during 1991–93.

Donald E. Hillier was the Regional Reports Improvement Specialist from the beginning of this period until his retirement in 1992. John V. Flager, who transferred from New Mexico in 1989 to serve as an Assistant Reports Specialist, replaced Hillier in 1993 and served until the end of this period and beyond. Other Assistant Reports Specialists during the period were Larry J. Slack, 1988; George Garklavs, 1989–91; Donald R. Albin, 1989–90; and Glen A. Hearne, 1993 to the end of the period. Slack transferred to the Mississippi District, Garklavs became District Chief in Minnesota, and Albin retired.

Douglas R. Posson was the Regional Computer Specialist from 1980 to 1983 when he transferred to WRD Headquarters. Jeffrey E. Miller transferred from North Dakota in 1984 and served in this position until the end of this history. Debra S. Spahr served as Site Manager for the Central Region computers from 1987 to the end of this period. Human Resources (manpower) duties were handled by Joe R. Wilmon from 1979 to 1983 and by Anthony Buono from 1984 to 1986. Both Wilmon and Buono transferred to the Yucca Mountain Project. In addition to assisting the Program Officer, Richard A. Herbert was Human Resources Specialist from 1988 to 1989. Carole A. Coburn served in that position from 1989 to the end of this period.

Additional duties in the Central Region Office during 1979–94 were handled by various people. Warren E. Hofstra was responsible for Office of Water Data Coordination activities until he transferred to the Nuclear Hydrology Program in 1981. Elizabeth A. Geiser served as Program Analyst from the beginning of the period until retirement in 1988. Saundra S. Duncan coordinated the Central Region's efforts on the Installation Restoration Program (IRP) from 1988 until her retirement in 1991. William R. Hotchkiss assisted in finalizing RASA reports from 1989 to 1994. Vernon R. Norman handled the Water Resources Research Institute activities during 1991–92. Stephen Vandas transferred from the Bureau of Land Management and led the Region's Water Resources Education Initiative from 1992 to the end of this history. Vandas had previously worked for the USGS through a USGS-BLM interagency exchange program.

The Central Region Administrative Officers during the period were Dorothy E. Niles from the beginning of the period until her retirement in 1987; Joanne Schnepf, 1988–90; and Elaine Gockel 1991 to the end of the period. Dorothy L. Burns was the principal Administrative Assistant throughout the 1979–94 period. Others assisting with administrative duties during the period included Kathleen G. Petty, Phyllis N. Burnham, Catherine L. Kraft, Ava Kretschmar, Nancy Nerim Shield, Karin Schellenberg, Susan

Waltzman, Kate Bond, Cynthia Kling, Dee Teasdale, Mary Buchwald, Doris Edmondson, Pamela Kettlehut, Laurie Boyer, Carole Connolly, Deborah Taylor, Marilyn Visconti, Jodene Schlager, and Hal Gerk. The number of administrative services staff positions ranged from 7 to 13 during the period.

The Secretary to the Regional Hydrologist during the period was Carol Curtiss, 1979–84; Virginia Jesser 1985–87; Betty Spahn, 1988–90; and Linda Fritchie from 1991 to the end of this history. Additional secretarial and clerical duties during the period were handled by Marjorie Buteau, Gale Brady, Charlotte "Scottie" Birch, Gladys Fredrickson, Catherine Hambeck, Shirley Harding, Ollie Williams, Marilyn Haller, Gale Saltus, and Laurie Boyer.

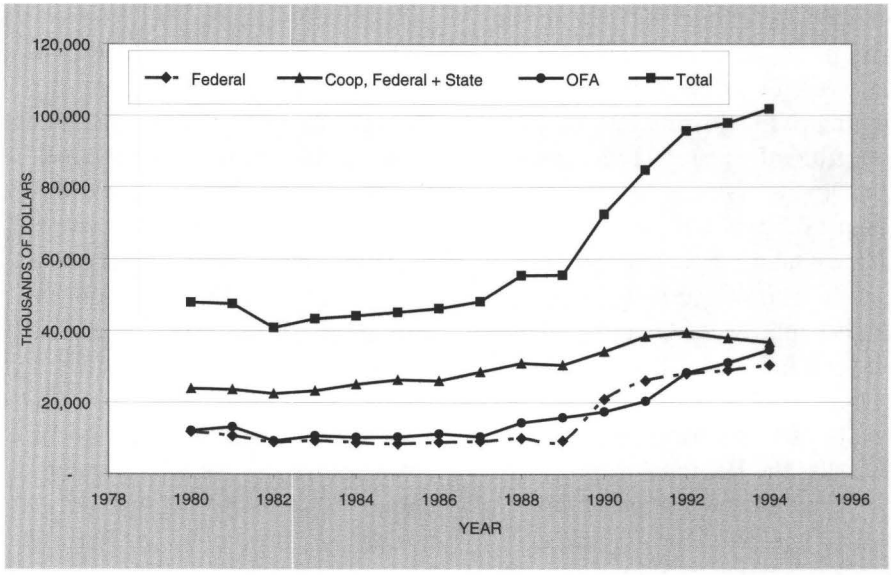
Other Regional Staff: The National Training Center (NTC) was directed by Delbert W. Brown from the beginning of the period until 1982. William R. Hotchkiss transferred from the Montana District in 1983 and directed the NTC until 1989 when he transferred to the Regional Office. Joe R. Willmon ran the NTC from 1990 to end of this period. Other persons who assisted with the NTC included Lucille Foxhoven, Darrell Baldwin, Russel Smith, William Bond, Catherine Hambeck, Cynthia Harris, Carl Cardin, Lan Lieu, and Linda Housel.

John B. Weeks led the High Plains RASA project, Elliot M. Cushing led the Madison Limestone RASA, and George A. Dinwidde led the Northern Great Plains RASA. William E. Wilson was in charge of the Nuclear Hydrology Program while it was a responsibility of the Central Region. Arnold J. Boettcher was in charge of the Borehole Geophysical Services Unit from the beginning of this history until his retirement in 1988.

PROGRAMS AND FUNDING

The Central Region carried out water-resources activities during the 1979–94 period with funding from three primary sources. These were the Federal-State Cooperative (Coop) program, the Federal program, and the other Federal agency (OFA) program. Total funding from all sources more than doubled during the period, increasing from about $48 million in 1980 to more than $100 million in 1994 (fig. 1, table 1). Coop funding increased gradually through this history until 1991 when it leveled off and then declined slightly. This may in part have been caused by the realignment of Districts in 1991. Funding from both the Federal and OFA programs increased significantly between 1989 and 1994 (fig. 1).

Coop Program: The Coop program was the mainstay program of the Central Region and was also the largest of the three funding sources, especially prior to about 1990. It was the source of most of the funding for streamflow-gaging operations, monitoring of ground-water levels, and monitoring the water quality of streams, lakes, and ground water. This



Central Region funding, 1980–94.

Table 1. Central Region funding history, 1980–94

[Data not available for 1979]

Year	Federal	Coop, Federal, and State	OFA	Total	Districts in Region
1980	11,881	23,905	12,138	47,923	15
1981	10,714	23,626	13,194	47,534	15
1982	9,033	22,519	9,284	40,836	13
1983	9,371	23,261	10,709	43,341	13
1984	8,797	25,056	10,276	44,129	13
1985	8,462	26,333	10,333	45,129	13
1986	8,903	26,071	11,198	46,173	13
1987	9,170	28,546	10,427	48,142	13
1988	10,005	30,987	14,374	55,366	13
1989	9,318	30,401	15,811	55,530	13
1990	20,884	34,171	17,435	72,489	13
1991	26,077	38,342	20,322	84,741	12
1992	28,030	39,427	28,304	95,761	12
1993	28,981	37,933	31,068	97,982	12
1994	30,465	36,794	34,599	101,859	12

program also funded most of the hydrologic investigations conducted by the Districts. In this program, designated Federal funds were used to match State or local agency funds, with the caveat that Federal funds could not exceed 50 percent of the total funds for a project or activity. In some instances the cooperator provided personnel or services in lieu of funds. This funding credit was referred to as "direct services." This was particularly true in Nebraska where State employees were collocated with USGS employees to operate streamflow-gaging stations and collect water-quality samples. State agencies in many Districts had water-quality laboratories and received direct-services credit for analyzing water samples collected from monitoring programs and hydrologic investigations. These State laboratories were required to analyze USGS standard reference samples and undergo periodic quality-assurance reviews by USGS laboratory personnel.

In an effort to raise the level of science in hydrologic investigations in the Coop program, the Merit Fund competition was initiated in the early 1980's. Each year, each of the four Regions placed a small amount of Coop funds in a central pool and Districts competed for the funds by submitting proposals for new projects. Funds from the central pool were awarded to the projects judged to have the greatest scientific merit. The Central Region fared well in this competition.

Federal Program: Funds for this program are appropriated by Congress to address issues deemed to be of high national priority. These priorities changed significantly during this 15-year history. At the beginning of this history the high-priority programs in the Region were energy hydrology (coal and oil shale) and Regional Aquifer-System Analysis (RASA). Hydrologic effects of coal mining were of concern in nearly all parts of the Region. Concerns over the effects of oil-shale development were limited to Colorado, Utah, and Wyoming. RASA projects were conducted in the Northern Great Plains, the Madison Limestone, and the High Plains. In the mid-1980's water quality and contamination concerns increased and new programs were initiated that replaced energy hydrology and, in part, RASA.

The Toxic Substances program was initiated to develop an understanding of processes affecting the occurrence and fate of contaminants in surface and ground water. The development of new methods and tools for studying contaminants also was a goal of the program. Funding for this program increased substantially in the latter part of this history. Central Region projects funded by the program included the Calcasieu River in Louisiana (petrochemical wastes), Whitewood Creek in South Dakota (arsenic and other

metals from gold mining), Tar Creek in Oklahoma (heavy metals from abandoned underground lead and zinc mines), Summitville Mine in Colorado (acid mine drainage from open pit mines), Cedar River in Iowa (movement of agricultural chemicals between surface and ground water in the Cedar River alluvium), and the MSEA (Management System Evaluation Areas) project in Minnesota, Nebraska, Missouri, and Iowa. The MSEA project was done in participation with the USDA and USEPA with a goal of reducing the effects of agriculture on surface- and ground-water quality through implementation of improved farming practices. In 1990 the Midcontinent Herbicide project was initiated in the Midwest corn belt of the Central and Northeastern Regions to understand the occurrence, fate, and transport of herbicides in surface water, ground water, and the atmosphere. This was a high-visibility project that attracted much attention at high levels in the USGS, USEPA, and USDA, and the news media. Many new analytical methods were developed at the Kansas organic geochemistry laboratory to detect part per trillion levels of herbicides and herbicide degradation products in water. Several hundred scientific publications resulted from the project.

The National Water Quality Assessment (NAWQA) Program was initiated in 1986 with two pilot studies in the Central Region—a surface-water project in the Kansas River Basin of Kansas and Nebraska, and a ground-water project in central Oklahoma. The goal of the program was to develop an understanding of the conditions, status, and trends in the quality of surface and ground waters of the Nation. Funding for NAWQA increased, and in 1991 the first of three cycles of NAWQA studies was begun with five 3-year projects in the Region. These were the Red River of the North in North Dakota and Minnesota, the Trinity River in Texas, the Rio Grande in New Mexico, the South Platte in Colorado, and the Central Nebraska in Nebraska and Kansas. The second cycle of NAWQA began in 1994. New projects were the Upper Mississippi Basin in Minnesota, the Eastern Iowa Basins in Iowa, South Central Texas, and the Upper Colorado Basin in Colorado. By the end of this history period, NAWQA was the largest Federal program in the Region and in WRD.

The Irrigation Drainage program began in 1985 to investigate the effects of drain water from Department of the Interior irrigation projects on endangered species and migratory birds in wildlife refuges. Of particular concern were the effects from selenium and arsenic that were released from drained soils. Irrigation projects in Colorado, Wyoming, Utah, Montana, and North and South Dakota were investigated under this program. Other Department of the Interior participants in this program were the Bureau of Reclamation, the Fish and Wildlife Service, and the Bureau of Indian Affairs.

Other Federal programs and subprograms in the Central Region during this history were the National Urban runoff program, acid rain program, national water-use program, and monitoring programs such as the National Trends Network (atmospheric deposition), National Stream-Quality Accounting Network, and Hydrologic Benchmark network.

OFA Program: OFA funds are transferred from other Federal agencies as reimbursement for work performed at the request of the agencies. The U.S. Army Corps of Engineers provided funds to many Central Region Districts to operate gages and collect streamflow data on many streams, particularly the Mississippi and Missouri Rivers. The largest source of OFA funds in the early part of this history was the Bureau of Land Management (BLM). The funds were used to conduct hydrologic studies and collect data needed by BLM in order to lease Federal land for coal-mining operations. This work was concentrated in Montana, Wyoming, Colorado, New Mexico, and North Dakota. During the latter part of this history, substantial OFA funds were received for hazardous waste ground-water contamination studies on military bases and other Federal installations. Funding agencies included the U.S. Army, U.S. Air Force, and USEPA. Large-scale studies were conducted at Warren Air Force base in Wyoming and Rocky Mountain Arsenal in Colorado.

OTHER ISSUES

Overall, the Central Region fared well during this period in WRD history, and many advances were made. Computers became commonplace with terminals on nearly every hydrologist's desk. Affirmative Action, EEO, and actions designed to employ more minorities in the Region became commonplace. The role of women in management positions increased significantly as women began to fill District Chief, Assistant District Chief, and Section Chief positions. The Research Grade Evaluation Guide (RGEG) was established in the mid-1980's to provide District personnel an opportunity to advance on the basis of

their performance and scientific output. This system of evaluation and advancement was the same as that used in the National Research Program. Although the RGEG program was completely voluntary in the Region, at the end of the period about 20 District employees were in the program and 2 of them had advanced to the GS–15 level (John Turk, Colorado District, and Michael Thurman, Kansas District. Thurman was later promoted to the ST level). Many scientific advances were made, and the Central Region came to be recognized as the Division's leader in venturing into new areas of investigation such as agricultural chemicals in water resources and groundwater contamination from hazardous wastes. These were made possible by the leadership of the Central Region staff.

COLORADO

By David J. Lystrom, Richard O. Hawkinson, and Linda J. Britton

ORGANIZATION AND PERSONNEL

At the beginning of the 1979–94 period, the Colorado District consisted of a large District Headquarters in Lakewood; Subdistrict Offices in Lakewood, Grand Junction, Pueblo, and Meeker; and a Field Office in Durango. These offices were staffed by approximately 140 employees. As a result of declining energy hydrology programs, mostly in western Colorado, staffing was reduced to about 120 employees by 1985. In the years to follow, with increased Federal funding for the Regional Aquifer-System Assessment (RASA) and the National Water-Quality Assessment (NAWQA) programs, the Department of Army funding at the Rock Mountain Arsenal, and other programs, staffing grew to about 175 employees in 1994.

Office of the District Chief

The Colorado District Office was located in Building 53 at the Denver Federal Center during 1979–94. James Blakey served as District Chief from 1978 to 1985 when he was selected to be the Regional Hydrologist for the Central Region. In 1986, C.A. (Jerry) Pascale transferred from the District Chief position in Alabama to become the Colorado District Chief. In 1991, Pascale was reassigned to the Rocky Mountain Area Chief position, overseeing the activities of the Montana, Wyoming, and Colorado Districts. David J. Lystrom was reassigned from the Associate District Chief for Hydrologic Studies to District Chief in 1991.

Associate District Chiefs were Richard A. Grozier through 1979, Richard O. Hawkinson (1980–89), David J. Lystrom (1990–94), and Zelda Bailey (1992–94).

District secretaries in chronological order were Anna M. Songe, Eleanor L. Simpson, Virginia R. Jesser, Betty M. Spahn, Marilyn R. Visconti, Dorothy Westerfield, Yolanda L. Clausen, and Karen Soergel. Secretarial staff also included Lula M. Smith, Helen M. Ortega, Betty Jo Vitry, Julie C. DeNuzzi, Donna S. Hoyt, and Lucy A. Heinicke.

Beverly J. Tirrell was Chief of the Administrative Services Section until 1988. She was succeeded by Joseph P. Piro (1988–90), Doris Adair (1990–92), and Sharon S. (Kuhnlein) Goss (1992–_). Others serving in the Section were Joan J. Olsen, Marjorie M. Bisant, Wendy (Joachim) Maura, Debora K. Zell, Jacqueline D. Evans, Jean Asper, Beverly Buck, Marilyn R. Visconti, Suzanne Chicholski, Denise Dennett, Joan Simms, Kathy J. Montoya, Betty Jo Vitry, Virgiline L. Lowe, Gabina R. Sosa, Paula Leshinski, and Paula S. Thomsen.

The use of computers in the Colorado District evolved from the data point system to minicomputers, allowing computer terminals on most desks by 1983. Workstation computers arrived in 1991. The minicomputer overlapped the workstations until 1997 for the purpose of computing hydrologic data records for publication. In addition to the workstations, the use of personal computers (PC's) by project personnel expanded into the 1990's. Charles D. Nethaway was Chief of the Computer Unit at the beginning of this period. Succeeding Chiefs of the Computer Unit/Computer Services Section were Robert F. Wakelee (1981–85), Sandra R. Turner (1985–87), Robert F. Middelburg, Jr. (1988–91), and Scott McEwen (1991–__). Norman E. Spahr was in charge of a Programming and ADP Support Unit in 1986–87. Others who served in the Computer Unit were Pauline Juarez, Mary K. Namba, Rocky J. Riviera, Vickie K. Clark, Martha M. Vaught, Helen Ortega, Debra S. (Leonard) Spahr, Betty Jo Vitry, John P. Crisci, Deborah C. (Longs) Hines, Elizabeth A. Anderson,

Dorris L. Jackson, Lynn D. Jackson, Gary Krammes, Scott A. Townsend, and Mark S. Bailen.

A Hydrologic Equipment and Laboratory Services Unit, located in Building 82 on the Federal Center, was in operation until 1986. This Unit provided laboratory services for sediment concentrations and size analysis. The Unit also calibrated, repaired, and maintained field instruments. Albert C. (Jerry) Duncan served as Chief of the Unit until 1985, and Jennie T. Steinheimer led the Unit from 1985 to 1986. Others serving in the Unit were Stanley Breshears, Kim Clemmer, Michael J. Paulsen, Curtis W. Roberts, Patricia K. Bishop, and Michael J. Werito.

NAWQA Study Units

The National Water-Quality Assessment (NAWQA) Program supported two study units in the Colorado District. The South Platte River study unit, beginning in 1991, was headed by Kevin F. Dennehy. His staff was composed of Peter B. McMahon, David W. Litke, James E. Paschal, Kathy M. Tate, Janet S. Heiny, Jorge R. Ortiz, Robert A. Kimbrough, Breton W. Bruce, Ellen Montague, Jonathan B. Evans, Sharon L. Qi, and Karla S. Pfenning.

The Upper Colorado River Study Unit, which began in 1994, was headed by Nancy E. Driver. Her initial staff included Lori Apodaca and Sherry C. Gee.

Hydrologic Surveillance (Records) Section

The Section was composed of a small support group in the District Office to provide technical oversight of the data-collection programs and to manage the annual publication. Section Chiefs were Richard U. Grozier until he retired in 1980, Richard O. Hawkinson (1980–83), Robert F. Middelburg, Jr., (1983–87), Sherman R. Ellis (1987–89), and Kathleen R. Wilke (1989–__).

Others assigned to the Surveillance Section were Robert Brennan, Theron R. Dosch, Rulon C. Christensen, Michael W. Gaydos, Sherman R. Ellis, John R. Little, Harold E. Petsch, Thomas J. Major, Charles H. Onions, Larry L. Jones, Johnnie W. Gibbs, Steven R. Blakely, Phillip J. Karper, Dana Q. Coffield, Kim A. Clemmer, Susan I. Kinney, Elizabeth Anderson, Nancy L. Nickerson, Julie C. DeNuzzi, Steven M. Sober, Jennie T. Steinheimer, Helen M. Ortega, Betty Jo Vitry, David J. Edrich, Kristine Moreland, Carter E. Hutchinson, John L. Ebling, Terence Dragoo, Robert C. Ugland, Albert C. Duncan, David W. Litke, James M. Norris, Curtis W. Roberts, Michael J. Werito, Earl W. Cassidy, Betty J. Cochran, Ann V. Paillet, Lynn D. Jackson, and Raymond Reed.

Hydrologic Investigations (Studies) Section

Hydrologic studies were conducted in the District Office Studies Section and in Studies Sections in each Subdistrict. The District Studies Section Chief provided overview of studies conducted in Subdistrict offices but did not provide supervision. District Studies Section Chiefs at the beginning of the period was Jerald F. McCain (1979–80), followed by David J. Lystrom (1981–91), and Zelda Bailey beginning in 1992. Due to program growth, the District Studies Section was reorganized in 1989 into separate units under the direction of the District Studies Section Chief. Hydrologic Research Unit Chiefs were David J. Lystrom (1989–91) and Zelda Bailey beginning in 1991. The Hydrogeologic Unit Chief was Stanley G. Robson (1989–93).

The Environmental Assessment Unit Chiefs were Sherman R. Ellis (1989–90), Robert S. Williams (1991–1992), and Leo House beginning in 1992.

The Northeastern Colorado Hydrologic Unit Chief was Robert F. Middelburg beginning in 1991. The Unit included the Rocky Mountain Arsenal Project Office, located north of Denver at the Rocky Mountain Arsenal.

Other personnel serving in the District Hydrologic Studies Section were Elizabeth Anderson, Edmund D. Andrews, Anthony Arnett, Edward R. Banta, Daniel P. Bauer, Denise A. Bieerley, Ronald G. Borman, Clifford R. Bossong, Linda J. Britton, Robert E. Broshears, Alan W. Burns, Donald H. Campbell, Earl W. Cassidy, Dan Chafin, Thomas H. Chaney, Stephen J. Char, Ann F. Choquette, Rulon C. Christensen, Gregory M. Clark, David W. Clow, Betty J. Cochran, Stanley R. Cole, John E. Costa, Richard M. Crowfoot, William F. Curtis, Katherine Walton-Day, Dennis A. Wentz, Joseph J. D'Lugosz, Theron R. Dosch, Terence E. Dragoo, Nancy E. Driver, Albert C. Duncan, John L. Ebling, John G. Elliott, Sherman R. Ellis, Jennifer Flynn, Jeffery B. Foster, Ronald A. Funkhauser, Warren J. Gaal, Neville G. Gaggiani, Arthur L. Geldon, Douglas Geller, Carol N. Gerlitz, Richard L. Goss, Jeanne E. Hackbart/Boyle, Stephen E. Hammond, Kathleen N. Hayden, Glenn A. Hearne, Frederick J. Heimes, Richard A.

Herbert, Donald P. Hillier, Scott A. Hogan, Theodore R. Hurr, Carter E. Hutchinson, George P. Ingersoll, Robert D. Jarrett, Clifford T. Jenkins, David A. Johncox, William P. Johnson, Amy Johnson, Sharon M. Johnson, Larry L. Jones, Benedict E. Kelley, Briant A. Kimball, Robert A. Kimbrough, James E. Kircher, Roy W. Koch, Gerhard Kuhn, Juli B. Lindner, Timothy D. Liebermann, David W. Litke, Kenneth J. Lull, Alisa M. Mast, David P. Mau, Wendy S. Maura, Thomas S. Meredith, Paul (Mickey) Messer, David K. Mueller, James M. Norris, Richard A. Orr, Lisa L. Osen, Ann V. Paillet, Randolph S. Parker, James E. Paschal, Diane M. Perry, Harold E. Petsch, Michael J. Paulsen, Tony Ranalli, Curtis W. Roberts, Frederick J. Rossi, Barbara C. Ruddy, Robert L. Runkel, Leslie A. Sakumoto, Donald E. Schild, Paul A. Schneider, Jennifer Sieverling, Cecil Slaughter, Gregory J. Smith, Dennis E. Smits, Gabina R. Sosa, Norman E. Spahr, Timothy D. Steele, Cory Stephens, James O. Stull, Amy Swancar, Cathy M. Tate, James O. Taylor, Ralph W. Teller, Douglas J. Trieste, John T. Turk, Sandra R. Turner, Robert C. Ugland, John W. Unruh, William P. Van Liew, James W. Warner, Emanuel J. Weiss, Michael J. Werito, Gregory A. Wetherbee, Helen Wharry, and Tracy J. Yager.

During 1991 to 1994, the District Studies Section supported a Drilling Unit headed by Roger W. Nichols with Anthony J. Shanahan and Dave E. Rehder as principal assistants. The Drilling Unit provided drilling services for the Colorado District and the Water Resources and Geologic Divisions nationally.

Other staff positions during the period were Frank Cooley, Arkansas River Compact Administration and Alex A. Fischback, Jr., Rio Grande Compact Commission.

Publications Section

During this 1979–94 history period, the Colorado District Publications Section was reflective of the major changes in technology from a manual operation (typewriters and magnetic cards) to typesetting equipment supported by a dedicated word-processing system to a desktop publishing system supporting computer stations on every author's desk. The Graphics Unit began this period primarily using hand-scribing tools and techniques and progressed to full use of digital graphics and multimedia production. This period also was a time of extensive growth (personnel and budget) as the Section changed from one of only internal District support for reports to become one of the leaders within the WRD in providing publications support for all types of media production throughout the Division.

At the beginning of the period, the Publications Section consisted of a Manuscript Preparation Unit headed by Lucy Laughlin and an Illustrations Unit headed by Xava W. (Billie) Dutton with oversight of a staff of about five. Donald E. Hillier was the District Reports Specialist. In 1980 Hillier transferred to the Central Region to become the Regional Reports Specialist and Bill Price became the District Reports Specialist. In order to maximize fiscal and technology resources, including computer resources, the Central Region Research Publications staff merged with the District Publications and Computer staff in 1984. Under a new organizational framework titled the Publications and Computer Section (PACS), James E. Kircher became the Chief, and Linda J. Britton became the District Reports Specialist following Bill Price's retirement. The advent of the "Corporation" approach to providing publications and computer services to other organizational entities outside the Colorado District had begun with this internal reorganization, followed by support to the Yucca Mountain Project, National Training Center, National Water Quality Laboratory, Quality Assurance Branch, Central Region Office, and other Districts, Divisions, and Federal agencies.

In 1987, after Kircher transferred to Wyoming as District Chief and as publications support from the District expanded to include National Program entities under the Scientific Information Management Program at Headquarters, the Publications and Computer Sections reorganized once again and Linda Britton became Chief of the Publications Section and District Reports Specialist. The years 1987 to 1994 were notable as a time of great change for the Section, as it was informally labeled as one of WRD's "Centers of Publications Excellence," along with the Cartographic and Publications Program (CAPP) in Wisconsin. The moniker was applied primarily because of the support that the Section provided in production of the National Water Summary reports and designation as a Federal Series Reports Unit for the Division. As a result of this publication support, the Section had a budget totaling more than $2 million, much of it from standard voucher income and Federal funds provided by entities outside the Colorado District. In addition, the District Publication Section's

role as a "Publication Center" for the Division brought additional resources to the Section and District in terms of skilled staff and state-of-the-art equipment and computers, which helped the Section maintain a leading position in publications technology and resulted in higher quality products.

In the late 1980's and early 1990's, the advent of Total Quality Management practices and external customer input regarding needs and concerns relating to overdue reports throughout the Division and in the Colorado District led to extensive restructuring demonstrating a team approach in the Publications Section. A District goal of reducing the time from approval to publication led to a design approach of Publications Section staff working as a team with authors at the beginning of the publication process rather than at the end. As a result of this implementation of new approaches, report-production time decreased substantially and led to a significant reduction in overdue reports and length of time from approval to publication in 1994, the first time in several years that goal had been accomplished.

Beyond the more than 500 or so reports and other media products processed by the Publications Section during this history period, some of the more significant publications prepared included a number of formal-series reports associated with the RASA, Coal-Hydrology, Ground-Water Atlas, and National Water Summary programs for the Colorado District, as well as other Districts and Headquarters. In addition, the technology capabilities allowing for easy merging of FrameMaker documents with various colored computer graphics and photographs led to enhanced use of outreach products, such as posters, brochures, and lay-reader Fact Sheets, all of which contributed to healthy program development within the District and higher internal and external customer satisfaction.

The Publications Section, which had a staff of about 5 at the beginning of this period, increased to as many as 30 (including students) at times during the entire period with a combination of hydrologists, editors, illustrators, editorial assistants, and a full-time librarian. The Publications Staff were the following: Lucy L. Laughlin, Bernice R. Canzona, Joy L. Anderson, Martha M. Vaught, Judith Cornwell, Virginia R. Jesser, Brenda L. Short, Xava, W. (Billie) Dutton, Margaret E. Olsen, Robert J. Olmstead, Barbara J. Condron, Noel B. Cummings, Mary A. Kidd, Patricia A. Griffith, Sharon M. Powers, Julie M. Stewart, Carol L. Anderson, Martha A. Crawford, Patricia I. Morrisette, Betty Pedersen, Edward J. Swibas, Richard K. Tucker, Kurt A. Homan, Margo J. (Rosenfield) VanAlstine, William R. Stephens, Leslie Martinez, Theresa J. Lane, Judith M. Brown, Anthony G. Sanchez, Jayne Griego, Deanna Geisler, Lucy A. Heinicke, Christine R. Canfield, John S. Williams, Tracy J. Yager, John M. Evans, Steven H. Denowski, Derald Dunagan, Douglas G. Shubert, Dianne A. Shugrue, Albert D. Romero, John E. Atencio, Hyla H. Strickland, James R. Garcia, April A. Kobayashi, Dorothy C. Westerfield, Alene J. Brogan, Joyce E. Dickey, Ann Marie Squillacci, Loretta J. Ulibarri, Sharon A. Rafferty, Alan M. Duran, Ann V. Paillet, Nancy L. Powers, Joy K. Monson, and Linda Britton.

Subdistrict and Field Offices

As the period began, the responsibility for collection of hydrologic data in Colorado was distributed among four Subdistrict Offices and one Field Office that were organizationally part of the Hydrologic Records Section. "Data with a purpose" was the primary goal applied to the implementation of new program activities as well as in the collection of data at existing sites. Personnel assigned to the data-collection sections in each of these offices were generally responsible for the collection and timely computation of data for both investigative as well as longer term hydrologic data reports.

During the period, no offices were closed; however, two Subdistricts (Meeker and Lakewood) were reclassified as Field Offices. As a Field Office, the primary responsibility was for collection of hydrologic data, and no investigative project responsibilities were maintained in the office. The reclassification of the Meeker office in 1986 was necessitated by a decline in interest and funding for energy-development-related programs in the early 1980's on the part of all Federal agencies. The change in status of the Lakewood office in 1991 was the result of a management decision to create a more functional and efficient hydrologic studies team in the District Office to respond to investigative and research needs in the Denver metropolitan area and northeastern Colorado. After these changes occurred, the data-collection responsibilities in Colorado were assigned as follows. The Western Slope Subdistrict Office in Grand Junction had responsibility of all data collection west of the Continental Divide with assistance from the Meeker and Durango Field Offices for data collection in northwestern and southwestern Colorado; the Pueblo

subdistrict office had responsibility for data collection in southeastern Colorado as far north as Colorado Springs; and the Lakewood Field Office had data collection responsibility for northeastern Colorado including the Denver metropolitan area.

Pueblo Subdistrict Office.—In 1979, the office was located in the First National Bank (Thatcher) Building at 5th and Main Streets in Pueblo. The office was relocated in 1991 to the United (Norwest) Bank Building at 201 W. 8th Street. During the period 1979–84, the following Subdistrict Chiefs provided leadership and service for USGS programs in southeastern Colorado: Richard Fidler (1979 and before), Jerry L. Hughes (1980–83), Russell K. Livingston (1984–88), and Doug L. Cain (1989–__).

Other staff during the period: Peggy L. Sutton (Herman), Cheryl Curran, Tom M. Crouch, Guy J. Leonard, Ronnie D. Steger, Stanley T. Green, Robert D. Penley, Charles T. Warren, Patrick F. Edelmann, Alan P. Hall, Bernard M. Jesik, Edward L. Nickerson, William F. Payne, Timothy C. Cheatum, Joanne S. Housh, Mark W. Eddy, Gerald G. Hesseltine, Kenneth N. Nellson, Mark D. Klock, Peyton O. Abbott, Fred H. Smith, Arthur Geldon, Steven M. Sober, Paul von Guerard, Joseph R. Sullivan, Jr., William D. Bemis, (1986), Gerhard Kuhn, Kenneth R. Watts, John M. Kuzmiak, Michael J. Haley, Mark A. Salay, Daniele T. Chafin, David A. Johncox, Susan C. Rishel, Russell G. Dash, Gregory A. Nelson, Roderick (Rodger) Ortiz, Gary S. Krammes, Eva M. Morrell, Michael E. Lewis, Mary Jo Radell, Jeffrey B. West, Ellen L. Samuels, Marjorie A. Penrod, William B. Weiss, Nick O. Young, Rodney H. Munson, Timothy J. McCollum, George D. McElhany, Rick L. Schmidl, Robert M. Moquino, Timothy Parcher, William A. Swenson, and Monique L. Gerken.

Lakewood Subdistrict/Field Office.—The Lakewood office was located in Building 82 on the Denver Federal Center for the entire period 1979–94. During this period the following Subdistrict and Field Office Chiefs provided leadership and service in the Lakewood office: Russell K. Livingston (1979–81), Douglas B. Manigold (1982–85), Kathleen R. Wilke (1986–89), Richard A. Herbert (1990–91), Millard M. Hiner (1991–93), and Gregory B. O'Neill (1994–__).

Other staff during the period: Sharon M. Powers, Ronald G. Borman, Dennis C. Hall, Joe L. Blattner, Donald R. Minges, Harold Hodges, Eugene J. Charbonneau, Neville G. Gaggiani, Gerhard Kuhn, Martha H. Mustard, Robert L. Einarsen, Johnnie W. Gibbs, Charles W. Reeter, Richard M. Neam, Betty J. Cochran, James D. Martinez, Kerry N. Howey, Phillip J. Karper, Bruce F. Rasmusson, Michael J. Werito, Benedict E. Kelley, Sherman R. Ellis, Juli B. Lindner, Leslie R. Murray, Thomas A. Meredith, Raymond L. Reed, Lynn M. Achord, Dolores P. Chavez, Steven R. Blakely, Kurt Homan, Louetta A. Walsh, Barbara C. Ruddy, Robert S. Williams, John L. Ebling, Kathleen G. Petty, William P. Van Liew, David Mueller, Zachary D. Hill, David A. Johncox, Robert A. Kimbrough, Jennie T. Steinheimer, Kenneth J. Lull, Michael R. Stevens, Matthew S. Lauffer, Jim A. Collins, Michael D. Corse, Mark A. Wells, Robert J. Brandle, Douglas G. Shubert, Dennis E. Smits, Steve V. Muro, Melissa M. Trujillo, and Hoa Dang.

Grand Junction Subdistrict Office.— was renamed Western Slope Subdistrict in 1987, and was located in room 223 of the Wayne Aspinall Federal Building at 4th Street and Rood Road during the period 1979–94. During the 1990–94 period, the following Subdistrict Chiefs provided leadership and service for USGS programs in the Grand Junction Office: Dannie L. Collins (1979–93), and Paul B. von Guerard (1994–__).

Other staff during the period: Daniel J. Ackerman, D. Briane Adams, Kimball E. Goddard, Ralph O. Patt, Robert G. Kretschman, Charles E. Keliher, Carl E. Lesher, Robert A. Jenkins, Clyde H. Corneille, Michael E. Whiteman, Kenneth C. Galyean, Kurt A. Homan, Thomas A. Sadowski, Thomas W. Hale, Mark A. Leslie, Steve R. Sturm, Joseph R. Sullivan, Beverly Collett, Richard C. Woodring, and Patricia M. Houser, Dennis J. Plog, Rand R. Evett, Kenneth N. Butcher, Lenora A. Davis, David T. Kendrick, Joseph D. Steinkirchner, James R. Buzzell, Beverly Collett, Michael J. Gardner, Paula J. Nichols, Lillian Roybal, Thomas D. Brooks, David L. Butler, Daniel E. Hitch, Linda C. Barwick, Valerie D. Briggs, Alzo L. Jones, Cynthia L. Appel, Dale A. Loucks, Merrilyn Simpkins, Jerry (Ed) Vaill, Jr., Robert W. Boulger, Jr., Winfield G. Wright, Eddie A. Wilson, James M. McCormack, Janet C. Ray, Timmee C. Wild, Barbara K. McNure, David M. Hartle, Frank C. Crenshaw, Lorrie Nutter, Darrin A. Miller, and Troy Taylor.

Meeker Subdistrict/Field Office.—The Meeker office was located at 321 Seventh Avenue during the period 1979–94. Office leadership and service were provided by the following personnel: Vernon W. Norman, Subdistrict Chief (1979–81), Robert L. Tobin, Subdistrict Chief (1982–86) and

Field Office Chief (1987–93), and Richard G. Carver, Office Leader (1994–__).

Other staff during the period: Frank A. Welder, Kenneth J. Covay, Eddie A. Wilson, Robert W. Boulger, Jr., Paul von Guerard, Phyllis G. Mann, Caroline Pease (Hollowed), Donald Hayes, Patrick F. Key, William D. Mecham, Judy A. Tackman (Ludwig), Ralph O. Patt, Thomas A. Herrett, Donald J. Hays, Helen E. Stranathan, Carol Sue Kent, William P. Van Liew, Ralph W. Teller, Michael P. McCarty, Deborah A. Pettijohn, Barbara P. Leet, Catherine Dolan, and Joseph R. Dungan.

Durango Field Office.—In 1979 and before, the Durango office was located at 701 Camino del Rio. The office was relocated to the Hunt Building, 1474 Main Street, during the period 1981–86. During the 1986–87 timeframe, the office moved back to the Federal Building at 701 Camino del Rio, Room 210. During the period, Office leaders were Harold E. (Sandy) Burch (1979–83) and James D. Bennett (1984–__).

Other staff during the period were Daniele T. Chafin, Mark Gress, David W. Grey, and David M. Swanson.

FUNDING AND COOPERATION

As indicated by the funding table, the total funding more than doubled during the period. However, significant declines in Federal and other Federal Agencies (OFA) sources of funding occurred between FY 1981 and FY 1985 due to the fall in worldwide oil prices and the decreasing interest in hydrology programs related to coal and oil shale in western Colorado.

At the beginning of this period, the Colorado District's Federal-State program (Coop) included cost sharing with the Colorado State Engineer, the Colorado River Conservation District, and the Denver Regional Council of Governments (DRCOG), and more than 40 other cooperating agencies including State agencies, conservation districts, counties, and cities. Coop funds largely supported stream-gaging stations, flood studies, ground-water studies, and a large urban hydrology water-quality study. By the mid- to late 1980's, the urban hydrology study with DRCOG was completed and the program with the State Engineer declined as the State operated more of their own stream gages.

The Denver Water Board, the Colorado Springs Department of Public Utilities, and several conservation Districts increased funding for stream gages and studies related to water supply and water quality. The Coop program continued to diversify into the early 1990's with 65 or more cooperating agencies.

Through the early 1980's, the Federal program was predominated by the coal and oil-shale programs directed to study the potential hydrologic effects of

Colorado District funds, fiscal years 1979–94

[FY, fiscal year; OFA, other Federal agency]

FY	Federal	OFA	State	Federal matching	Total
1979	$1,771,312	$1,497,589	$1,450,728	$1,338,177	$6,057,806
1980	$2,140,500	$1,523,351	$1,532,378	$1,408,323	$6,604,552
1981	$2,973,944	$1,996,716	$1,521,313	$1,351,373	$7,843,346
1982	$2,201,520	$1,391,329	$1,560,017	$1,613,702	$6,766,568
1983	$1,669,823	$1,282,714	$1,182,104	$955,320	$5,089,961
1984	$1,281,111	$939,788	$1,153,768	$706,504	$4,081,171
1985	$1,176,417	$844,203	$1,036,242	$987,332	$4,044,194
1986	$1,949,085	$1,464,200	$1,632,774	$1,564,800	$6,610,849
1987	$2,009,310	$978,950	$2,015,993	$1,910,686	$6,610,859
1988	$1,876,266	$1,846,224	$2,114,693	$1,906,110	$7,743,293
1989	$2,107,680	$1,596,630	$2,105,991	$1,886,000	$7,696,301
1990	$1,982,010	$1,857,600	$1,987,027	$1,913,500	$7,740,137
1991	$2,748,290	$3,050,311	$2,113,611	$2,112,315	$10,024,527
1992	$3,388,304	$4,022,076	$2,239,898	$1,978,300	$11,628,578
1993	$4,642,453	$6,125,668	$2,128,763	$1,959,826	$14,856,720
1994	$4,910,695	$7,152,144	$1,956,298	$1,940,145	$15,959,282

large-scale development and extraction of coal and oil shale in western Colorado. These programs peaked in FY 1981 with almost $2.5 million funding, and programs were phased out in the mid- to late 1980's. During this time, the Federal program initiated and supported RASA and hazardous-waste studies in Colorado. By 1994, the Federal program grew substantially, including about $1.8 million for NAWQA studies. The Federal program support for collection of basic records (CBR) grew from about $300,000 in 1979 to about $600,000 in FY 1994.

During the early 1980's, the Bureau of Land Management (BLM) funded coal hydrology studies in Colorado that peaked at about $1 million in 1981 and then phased out into the mid- to late 1980's. Other major OFA funding sources during the late 1980's was the U.S. Army at Fort Carson with over $400,000 in FY 1988. The OFA program grew substantially in the 1990's with a large hazardous waste study at the U.S. Air Force Academy peaking in FY 1991 with nearly $800,000. In addition, a hazardous-waste studies program at the Rocky Mountain Arsenal grew to over $3.5 million in FY 1994 and was funded by the Department of the Army.

Summary of Programs—Hydrologic Data Collection

During the 1979–94 period, the data program was faced with the following negatives and positives that influenced program development opportunities and the overall structure of the program. The negatives included the discontinuation of Federal energy programs, which resulted in an immediate loss of USGS program funds in 1982 and a gradual phase-out of other Federal agency (OFA) funds particularly from BLM between 1982 and 1985. Also during this period, State cooperator funds were very tight, thereby creating a negative growth condition for hydrologic data programs. The positives during the period included cooperative programmatic opportunities with local agencies, councils of governments, and water conservation districts. Also, federally supported opportunities were provided by the USGS Ground Water Toxics program, NAWQA, and the Irrigation Drainage Program. From OFA programs, support was provided for projects at the Air Force Academy, the Pueblo Army Depot, and the Rocky Mountain Arsenal. Data collection associated with project work at these military installations provided the basis from which a better understanding of local flow systems and transport of contaminants could be gained. A summary of the hydrologic data-collection program in Colorado, by discipline activity, is provided in the following table.

The year-to-year changes in the various activities are associated with the sequencing of the just-discussed negative and positive program opportunities and the ability of various office managers to react to changing program needs of our numerous customers. Overall, the Colorado District did well in responding to changing needs. The largest reduction of $2.5 million in 1982 from a total budget of about $8.5 million was met by conservative management, and fewer than six persons were offered transfers out of the District. From the late 1980's on the surface-water and

Colorado District data collection by discipline activity for selected years 1980–94

[NA, not applicable]

Activity	Years					
	1980	1983	1987	1991	1993	1995
Surface-water continuous record discharge	[4]446	357	283	250	286	291
Reservoir stage	22	27	20	22	31	35
Surface-water quality[1]	163	111	86	100	169	97
Ground-water levels[1]	NA	2,226	1,771	1,460	1,350	855
Ground-water quality[1]	NA	28	28	32	26	685
Precipitation	NA	30	33	26	25	38
Data-collection platform sites[2]	NA	25/NA	34/71	48/61	92/73	127/45
Fluvial sediment[3]	NA	13/37	11/32	7/26	7/28	8/29

[1]Includes both long-term operational and short-term project stations.

[2]Operated by USGS/operated by others (Colorado State Engineer's office).

[3]Number of daily sites/number periodic sampling sites.

[4]Includes about 100 Colorado State Engineer's office-operated gaging stations for which USGS publishes the record.

water-quality activities have generally shown an upward trend. Ground-water-level programs tended to decline due to the fact that sufficient information had been collected to fulfill program objectives—or in some cases, cooperators had taken over the data-collection activities. Throughout the entire period a more timely availability of data was a goal. In addition to meeting or bettering target dates set for publication of the annual data reports, the District was committed to the installation of data-collection platforms (DCP's). The success of this program is illustrated by the upward trend in DCP units in operation, coupled with the fact that the District purchased and installed a DRGS (direct readout ground station) in 1985 to facilitate the receipt and redistribution of streamflow information. Credit for the success of this activity goes to the field personnel involved in installing and maintaining the equipment, to the District Data Unit staff who worked to review and quality control the data, and to the Computer Section staff who hooked the correct wires together and developed programs to facilitate data flow and distribution.

To summarize data-collection programs in Colorado, they were responsive to customer needs, and much of the data collected was used to characterize or describe hydrology on a regional or statewide basis, to assist in forecasting extreme events, or as the basis for hydrologic investigations and research (additional discussion regarding hydrologic studies is provided in a following section). Finally, the hydrologic information needs varied on an area-by-area basis. The following summary lists some of the driving forces that provided the basis for hydrologic data programs and projects in each office:

Lakewood Subdistrict/Field Office

- Urbanization in Denver metropolitan area—data to assess the effects of development on quantity and quality of runoff. Also, data to document impacts of past land use as well as remediation activities on surface- and ground-water resources.
- Denver Basin water supplies—data to assess ground-water availability from Denver Basin aquifers with respect to metropolitan-area demand.
- South Platte River—data to document and describe water-quality conditions throughout the river basin and the waste-assimilative capacity of the river.
- Water rights—data to document West Slope to East Slope diversions to meet East Slope water demands.
- Flood hazards—data to document and assess flood potential from urban and mountain regions in Denver Metropolitan area.

Pueblo Subdistrict Office

- Military installations (Air Force Academy, Fort Carson, Pinon Canyon)—data to assess past and current military base activities on area water resources.
- Urban impacts of Colorado Springs—data to assess the municipal and industrial effects of water management and use on water resources in Fountain Creek.
- Arkansas River water rights—data to assess surface- and ground-water distributions and availability within the river basin.

Grand Junction (Western Slope) Subdistrict Office

- Salinity control—data to assess impacts of implemented technologies.
- Water rights/water allocation—data to assess availability versus demands.
- Coal lease assessments—data to document viability of lease applications.
- Reservoir construction—streamflow and sediment data to assess suitability of various locations for reservoir construction.
- Military installations (Air Force Academy, Fort Carson, Pinon Canyon)—data to assess past and current military base activities on area water resources.

Meeker Subdistrict/Field Office

- Coal lease assessments—hydrologic data to document viability of lease applications.
- Shale-oil development—data to document water availability with respect to projected water

needs. Also, data to assess development impacts on water quality and quantity.

- Water rights—data to document water quantity and quality as related to Colorado, downstream, and environmental demands and regulations.

Durango Field Office

- Water rights—water availability data in southwestern Colorado streams and rivers.
- Salinity issues—data to document water-quality conditions related to various land uses.
- Mining activities—data to document and assess water quality and methane issues associated with past coal mining.
- Land development impacts—runoff, water quality, and sediment data to assess possible effects of conversion of forest area to more intensively used recreational areas.

Hydrologic Studies

The Colorado District initiated and completed more than 150 hydrologic studies during this period. The following is a brief summary describing a small portion of these studies that were considered major programs.

Energy Minerals Programs

The USGS and BLM funded oil-shale and coal studies that began in the mid-1970's and continued into the mid-1980's. These programs provided the core funding and support of the Meeker Subdistrict. Observation wells were monitored and aquifer tests were conducted by Welder and Teller to support ground-water assessments of the rich oil-shale deposits in the Piceance Basin. A three-dimensional Piceance Basin ground-water model was developed and calibrated by Taylor. The biota and water quality of streams in the Piceance Basin were characterized and published by Covey, Stranathan, and Tobin. Watershed (rainfall runoff) models were calibrated for Roan and Parachute Creeks by Adams and Norris. Norman, von Guerard, and Kircher collected and summarized sediment yield data in the Piceance Basin.

Large coal deposits in northwestern Colorado precipitated a number of hydrologic studies to evaluate the existing and potential effects of coal extraction primarily from surface mines. A series of studies evaluating the effects of coal-mine spoil piles on surface- and ground-water quality was conducted by Robert Williams. Surface-water precipitation-runoff models were developed and calibrated for small streams in the Yampa River coal areas by Parker and Norris. A series of Coal Area Characterization reports were published in 1983–85. Principal authors were Abbott, Kuhn, Gaggiani, Driver, and Chaney. Water quality and aquatic biology of streams in the coal-rich areas of northwestern Colorado were characterized in publications by Britton and others. Parker and Litke developed a dissolved-solids transport model to show effects of coal mining in the Yampa River Basin. A study of the potential subsidence in proposed coal lease tracts in Delta County was conducted by Brooks. A summary of the coal hydrology program in Colorado was written by Britton.

Ground-Water Investigations

Availability of water for irrigation and the long-term effects of withdrawals were the focus for numerous ground-water studies in Colorado. A digital model was developed for the San Luis Valley (Leonard and Watts) to evaluate the availability of withdrawals from the closed-basin confined aquifer. The Regional Aquifer-System Analysis (RASA) program of the WRD supported all or parts of three major ground-water investigations in Colorado. RASA program studies addressed comprehensive geohydrology and geochemical aspects of major ground-water basins. Taylor, Kimball, and others conducted the Upper Colorado River Basin RASA study in the mid-1980's. Robson and Banta investigated the deep bedrock aquifers in eastern Colorado as part of the Central-Midwest RASA study. The upper Rio Grande part of the southwestern alluvial basins RASA was characterized by Crouch and Hearne. A model of the Black Squirrel Basin was developed by Buckles and Watts in the mid-1980's. A study of the deep bedrock in the Denver Basin aquifers was conducted by Robson and Banta in the early 1980's. Ground-water levels and potential yields were characterized for several areas in Colorado, including Larimer, Logan, Sedgwick, and Weld Counties (Borman and Gaggiani); west-central Colorado (Giles); Larimer-Fox Hills aquifer

(Schneider); Boulder-Fort Collins area (Schneider); lower Gunnison River Basin (Brooks and Ackerman); White River Valley (Van Liew); North Fork Gunnison (Ackerman and Brooks); and Arkansas River Valley fill areas in Pueblo County (Nelson, Hurr, and Moore).

Surface Water Investigations

A number of studies were conducted to characterize surface-water availability and flood frequency. Principal investigations include rainfall-runoff modeling of flow characteristics in the Arkansas River Basin (Livingston); estimation of streamflow characteristics in western Colorado (Kircher, Choquette, and Ricten); hydraulic geometry and streamflow in the Piceance Basin (Elliott and Cartier); verification of Manning's roughness coefficients (Jarrett and Petsch); transit loss in Fountain Creek (Kuhn); and estimating regional flood characteristics of small watersheds in eastern Colorado (Livingston and Minges).

Water-Quality Investigations

Concerns regarding water quality of streams and ground water grew steadily through this period. Investigations commonly were done in response to the effects of mining and land-use changes. Some of the principal investigations include urban runoff-quality studies (Ellis and others); stream quality in the Yampa River Basin (Steele and Wentz); waste assimilation of the Arkansas River in Pueblo County (Cain and others); effects of feedlots on ground-water quality (Borman); quality of ground water in the San Luis Valley (Edelmann and Buckles); rainfall-runoff-quality models in Denver (Lunsford, Ellis); trend analysis of salt loads in the Gunnison and Dolores Rivers (Kircher, Dinicola, and Middelburg); simulated effects of water-quality in proposed reservoirs on the White River (Kuhn and Ellis); effects of wastewater effluent on the South Platte River from Littleton to Denver (Spahr and Blakely); surface-water-quality characteristics in the North Fork Gunnison River (Norris); estimating natural dissolved-solids discharge in the Upper Colorado River (Mueller and Osen); interactive dissolved-solids accounting model of the Arkansas River Basin (Burns); effects of sediment transport on benthic invertebrates in the Fountain Creek Basin (von Guerard); effects of wastewater effluent on the South Platte River through Denver (Paschal and Mueller); sediment transport and water-quality characteristics in the White River Basin (Tobin); model development and solute-transport simulations in Saint Kevin Gulch (Broshears); and effects of sewage sludge disposal on ground-water (Gaggiani). A major study of water quality in the South Platte River Basin was conducted by Dennehy and others under the National Water-Quality Assessment Program (NAWQA).

Irrigation Drainage

A series of studies investigating the effects of irrigation drainage on surface-water quality, bottom sediments, and biota was conducted in Colorado under a national program. These studies included the Middle Arkansas River Basin in Colorado and Kansas (Mueller and others); the Gunnison and Uncompahgre River Basins (Butler and others); the Pine River area of the Southern Ute Indian Reservation (Butler and others); and the Dolores River project area of southwestern Colorado (Butler and others).

Environmental Assessments

A considerable part of the growth in the Colorado District's programs in the late 1980's and early 1990's was attributable to investigations of hazardous wastes. An investigation of the effects of fuel spills and hazardous-waste materials on surface water and ground water was conducted at the U.S. Air Force Academy by Ellis and Norris. A large ground-water-quality monitoring study was done by Steger and others at the Pueblo Army Depot to evaluate the effects of munitions and fuel storage. In 1991, a major program of data monitoring and investigations was initiated at the Rocky Mountain Arsenal near Denver under the leadership of Robert Middelburg. These investigations characterized the effects of waste disposal and storage of military munitions and chemicals.

Research Investigations

The Colorado District participated in the National Research Program (NRP) of the WRD by financially supporting 10 or more researchers that conducted studies meeting goals of the NRP. A hydroclimatic research unit was reorganized as part of the

Studies Section in 1990. Turk, Campbell, Spahr, Clow, Ranalli, Ingersoll, Mast, and others conducted research investigations of the effects of smokestack-related acidic precipitation on snowfall and lakes in the high mountainous areas of Colorado and the Western United States. Elliott conducted geomorphology studies of river channels and unstable land-surface areas related to surface mining. Kimball studied the geochemistry of metals transport in streams affected by metal mining. Parker studied potential effects of climate change on the hydrology of the Gunnison River Basin.

Publications

District authors completed about 100 data reports and 400 interpretive reports during 1979–94. The loss of funding for energy-hydrology programs in the early and mid-1980's resulted in a backlog of unfunded and overdue reports. Through diligent efforts and numerous reassignments of personnel, the number of overdue reports was reduced from more than 25 to 5 by the end of the period.

IOWA

By Richard A. Engberg, *including information provided by* Robert C. Buchmiller *and reviewed by* Robert C. Buchmiller

ORGANIZATION AND PERSONNEL

In 1979, the Iowa District consisted of a Headquarters Office in Iowa City, a Subdistrict Office in Council Bluffs, and a Field Headquarters in Fort Dodge. The total number of employees, including full- and part-time personnel, was 40 including 4 at Fort Dodge, 6 at Council Bluffs, and the rest at Iowa City. The principal occupation of the office in 1979 was hydrologic surveillance with an emphasis on surface-water data collection and records computation. Eight persons were attached to the Hydrologic (areal) Studies Section. During the years between 1979 and 1994, the number of employees fluctuated slightly on an annual basis but with a gradual increase to a total of 57 full- and part-time employees in 1994. This accompanied a significant increase in budget at about the midpoint of the period, and a large increase in hydrologic studies. In 1994, 20 persons were involved in some form of hydrologic studies, a greater than 100-percent increase in hydrologic studies personnel during the 15-year period. The same offices at the same locations were still present in 1994, although the Council Bluffs office (six employees) and the Fort Dodge office (four employees) were collectively titled the Western Field Unit.

For most of the period, the District was under FTE (Full Time Equivalent) ceilings imposed by national Headquarters at the behest of the Office of Personnel Management. To get the job done in the late 1980's, in times of increasing budget but with FTE limitations, the District found it necessary to increase greatly its reliance on student employees under the Stay in School program. These employees did not count against FTE ceilings. Because it was able to find and employ outstanding students, the District met its programmatic requirements during the period. The number of Stay in School employees reached a maximum in 1989 when 22 of the 56 employees on District rolls (39 percent) were student employees.

District Headquarters, Iowa City

Office of the District Chief.—In 1979, the Iowa District Office was located in Room 269, Federal Building, 400 South Clinton Street in Iowa City. The Administrative Services Section, the Areal Studies Section, the Automated Data Processing Unit, the Special Studies Section, the Basic Data Section, the Records Collection, Compilation and Publications Unit, and the Sediment Unit all were located at the same address. The District Office remained in the same location throughout the period.

Donald K. Leifeste was District Chief in 1979. He was the second Iowa District Chief, replacing Sulo Wiitala in late 1978. Leifeste served as District Chief until 1982 when he transferred to Reston, Va. He was replaced the following year by John M. Klein, who moved to Iowa from the Washington District. Klein transferred to California in early 1986 and was replaced the same year by Richard A. Engberg, who transferred from the Nebraska District. Engberg left the USGS in 1990 to take a position with the U.S. Department of the Interior in Washington, D.C. He was replaced by Norwood B. (Nick) Melcher, who had previously served as Iowa District Hydrologic Studies Chief and before that as Hydraulic Surveillance Section Chief. Melcher served as District Chief through the remainder of the period.

Each District Chief left his mark on the District. Leifeste, Klein, and Engberg all came from water-quality backgrounds, a major change for the District. Leifeste investigated personnel and operations that the District needed in order to move to a more varied program. Klein initiated a cooperative agreement with the University of Iowa Hygienic Laboratory and brought in new, energetic employees. Engberg developed new programs including the Midcontinent Herbicide Initiative and expanded the cooperative (Coop) program and programs with other Federal agencies (OFA). Melcher continued program development and performed in an outstanding fashion during the disastrous floods of 1993.

Oscar G. Lara served as Assistant District Chief from 1981 to 1986. Those were the only years during the period that the position was occupied.

During the period, the District underwent several minor reorganizations that mostly included changing the names of sections. Despite these name changes, District organization was essentially the same during the period and included, in addition to the Office of the District Chief, an Administrative Services Section, a Computer Section, a Hydrologic Surveillance (Data) Section, and a Hydrologic Studies Section. A Sediment Laboratory and the Council Bluffs and Fort Dodge Offices were attached to the Hydrologic Surveillance Section. In 1993–94, a National Water-Quality Assessment (NAWQA) Study Unit was attached to the Hydrologic Studies Section. In 1986 the Senior Staff, consisting of the District Chief and the Chiefs of the Hydrologic Studies Section, the Hydrologic Surveillance Section, the Administrative Officer, and the Chief of the Computer Section, began regular meetings as the management staff of the District.

The Administrative Services Section reported directly to the District Chief. Elaine A. Gockel was Administrative Officer from 1979 through 1984. The position was vacant in 1985. Kathleen A. Miller became Administrative Officer in 1986 and served in the position for the rest of the period. In addition to administrative duties, the Administrative Services Section provided secretarial assistance for the District Chief. Other persons who served in the Section were, in chronological order, Gary R. King, Luann Turecek, Joan Tujetsch, Betty J. Sterns, Cheryl A. (Dixon) Patterson, Yvonne B. Schulte, Valerie J. Miller, Diane A. Rudkin, Kelly D. (Gaines) Huddleston, Melanie M. Cook, Mary K. (Kate) Smith, Elizabeth F. Harris, Stephanie C. Hassler, Kandis K. Hildreth, Mary L. Shumaker, Gloria A. Hartman, Kaylene F. Carney, J. Vance, and K. Kuhar.

The Computer Section was also known variously as the ADP Unit, the Project Services Unit, and the Computer Services Unit. The Computer Section reported directly to the District Chief. Functions of this Section changed greatly during the period. In 1983, a minicomputer replaced the Datapoint terminal, and from this time on, nearly everyone in the District had a terminal on their desk. In 1989, a workstation was acquired by the District and was followed in 1991 by updated workstations. By the end of the period, personal desktop computers and laptop computers were being used in the District. Daniel J. Gockel headed the Computer Section from 1979 through 1984. Others who headed the Computer Section were James J. Majure, Matt P. Donath, Edward E. Fischer, and Shawn C. Noble. Others who served in the Section, in chronological order, were Donna Runkle, Roberta C. Klosterman, Susan J. Lenker, Kathleen A. Miller, Robert W. Lane, Pamela K. B. Hunt, Donna J. Rayner, Patricia Maher, Sandra Simmons, Cynthia Provow, Kay M. Carpenter, Latonya M. Barksdale, Kirby L. Jewett, Christopher R. Hamernick, Loren D. Miller, Larry R. Wilford, James R. Tyer, Doug D. Mermier, Loren G. Kloft, Thuy Diem Pham, Van Hong Nguyen, Wendy L. Driscoll, Jeremy B. Faden, Jan Waterhouse, and B. Sponcil. Majure, Donath, and Noble all worked in the Section prior to heading it.

The District did not have a publications unit as such during the period. The annual basic-data report was the responsibility of the Chief of the Hydrologic Surveillance Section, aided by staff and by the Computer Section. From 1979 to 1986, interpretive reports were the responsibility of the Chief of the Hydrologic Studies Section, who also served as District Reports Specialist. The Reports Specialist was aided by staff members, by the Computer Section, and on occasion, by staff members of the Administrative Services Section. In 1987, the District began contracting out all interpretive report publication work to the Missouri District.

Hydrologic Surveillance (Data) Section.—The Hydrologic Surveillance Section was called the Basic Data Section in 1979–80 and the Hydrologic Surveillance Section thereafter. It was composed of the Section Chief, several support personnel, field personnel responsible for hydrologic data collection in eastern Iowa, and a Sediment Unit (retitled Water

Quality Unit in 1981 and again retitled Sediment Laboratory in 1987). Section Chiefs during the period were Ivan L. Burmeister, who retired in 1985; Norwood B. (Nick) Melcher, 1986–89; Delmar J. O'Connell, 1990–92; Jayne May, 1993; and Rodney A. Southard, 1993 to early 1994. Others assigned to the section in Iowa City were, in chronological order, Robert E. Hansen, Gloria A. Johnson, Dana W. Kolpin, Richard A. Karsten, David W. Wolf, Rebecca B. Lambert, Scott P. Kluesner, Kimberlee K. Barnes, Julee M. Melichar, Robert W. Baebenroth, Brian D. Schaap, and B. Nations. This list does not include the field personnel from the Iowa City office. Those employees are listed in the discussion of Field Offices.

Sediment Laboratory Chiefs were Wilbur J. Matthes, Jr., until his retirement in 1988; Carol A. Anderson, 1988–93; and Von E. Miller, 1994. Others assigned to the Sediment Laboratory, in chronological order, were Shirley A. Dvorak, Louise E. Hotka, Carol J. DeHague, Lauren K. Amspoker, David C. Pedersen, Rebecca B. Lambert, Latonya M. Barksdale, Scott P. Kluesner, Beth A. Ellsworth, Paul S. LaFauce, Curtiss W. Johnson, Pam K. Smith, Todd M. Kluesner, Shurice Robinson, Mario A. Buendia, C. Boge, H. Deininger, and J. Noe.

Hydrologic Studies Section.—The Hydrologic Studies Section (called Areal Studies in 1979–80) conducted ground-water, surface-water, and water-quality interpretive studies. A Special Studies Section in 1979–80 carried out surface-water hydrologic studies independently of the Areal Studies Section. Beginning in 1989, a program entitled the Midcontinent Herbicide Initiative Project was created and for 3 years carried out hydrologic studies independent of the Hydrologic Studies Section. In 1993, the Hydrologic Studies Section was subdivided into the Hydrologic Research Unit, the Environmental Assessment Unit, and the National Water-Quality Assessment (NAWQA) Unit. The Hydrologic Studies Section was headed by Kenneth D. Wahl from 1979 to 1981, by Michael R. Burkart, 1983–89, Norwood B. (Nick) Melcher, 1989–90, and Robert C. Buchmiller from 1991 on. Oscar G. Lara headed the Special Studies Section in 1979–80 and Michael R. Burkart headed the Midcontinent Herbicide Initiative Project in 1989–92. Robert C. Buchmiller, in addition to his duties as Hydrologic Studies Section Chief, headed the Hydrologic Research Unit in 1993–94. Keith J. Lucey headed the Environmental Assessment Unit in 1993–94, and Steven J. Kalkhoff headed the NAWQA Unit in 1994. The Section more than doubled in size from 1979 to 1994, a reflection of the increased importance of interpretive studies in Iowa.

Others assigned to the Hydrologic Studies Section and its various entities, in chronological order, were Larry J. Slack, Joseph W. Cagle, Jr., Harvinder S. Ahuja, Mark G. Detroy, Richard A. Karsten, John D. Logel, Albert J. Heinitz, Donald E. Riddle, Gary Gaillot, Donna Runkle, Robert W. Lane, Pamela K.B. Hunt, Robert E. Hansen, Philip J. Soenksen, Carlos E. Ruiz, Ronald L. Kuzniar, Paul J. Squillace, Joanna Newman, Carol L. Schnell, Melanie L. Clark, David A. Eash, David A. Cardwell, Abigail L. Rankin, James J. Majure, Maureen A. Holub, Robert W. Baebenroth, Michael J. Liszewski, Phillip R. Bowman, Daniel J. Berte, Edward E. Fischer, Peter M. Schulmeyer, Dana M. Kolpin, Van Hong Nguyen, Randall F. Hedegaard, Craig A. Harvey, Joseph M. Pohl, James P. Caldwell, Scott P. Kluesner, Kimberlee K. Barnes, Wuncheng (Woodrow) Wang, Bryan D. Schaap, R. Einhellig, M. Bobier, Douglas Schnoebelen, and P. Green. In addition, Burkart, Buchmiller, Lucey, and Kalkhoff worked in the Section prior to being selected for supervisory positions.

Iowa City Field Headquarters.—The Iowa City Field Headquarters, for organizational purposes, was part of the Hydrologic Surveillance Section until 1988 and reported directly to the Section Chief. In 1988, it was recognized as a separate entity with Von E. Miller as Lead Hydrologic Technician through 1993. The office was located in the District Office in Iowa City. Personnel were responsible for all data-collection operations in the eastern half of Iowa and the Mississippi River. Others assigned to the Iowa City Field Headquarters, in chronological order, were Robert L. Richards, Robert D. Goodrich, Gloria A. Johnson, Richard L. Kopish, Louise L. Hotka, Dana W. Kolpin, Bob D. Rowden, Douglas Ott, David W. Wolf, James J. Wellman, James F. Cerveny, Debra S. Sneck-Fahrer, Dennis A. Steil, Michael Linhart, D. Wydra, Mario Buendia, T. Hazlett, and N. Miller.

Fort Dodge Field Headquarters.—The Fort Dodge Field Headquarters was located in Room 456 of the Federal Building in Fort Dodge at 205 South 8th Street during the entire period. From 1979 to 1984, Philip J. Soenksen was Supervisory Hydrologist in Charge. From 1985 through the end of the period, Alvin R. Conkling, Jr., was Lead Hydrologic Technician. The office was responsible for all data-collection operations in northwest and north-central Iowa. Other

persons assigned to the office, in chronological order, were Kathryn M. Svaleson, Neal V. Fish, David T. Conell, Ann M. Berte, Leann A. Berte, Sheridee M. Jorgenson, Melissa L. Stalzer, Michael S. Rector, Danielle J. Fiala, and J. Colyer.

Council Bluffs Field Headquarters.—The Council Bluffs Field Headquarters began the period as the Council Bluffs Subdistrict Office. Throughout the entire period, the office was located in Room 250 of the Federal Building at 8 South 6th Street in Council Bluffs. Orlando J. Ramsvick was Supervisory Hydrologist until his retirement at the beginning of 1981, at which time the office was renamed the Council Bluffs Field Headquarters. He was succeeded as Supervisory Hydrologist by Virgil L. Spiers, who in turn was succeeded by Robert W. Baebenroth in 1986. Upon Baebenroth's transfer to Iowa City in 1989, Joseph G. Gorman was made Lead Hydrologic Technician then in 1990 Supervisory Hydrologic Technician, a position he held through the rest of the period. In 1994, the Council Bluffs Headquarters and the Fort Dodge Headquarters were designated the Western Field Unit, with Gorman in charge. Other persons assigned to the office, in chronological order, were Eugene D. Stenstadvold, Raymond D. Burkey, Gary K. Lyke, Viola S. Taylor, Hugh B. Lynch, Richard L. Kopish, Patrick D. Lustgraaf, James J. Sondag, James J. Wellman, Angela M. Brayman, Vergarie Sanford, Greg E. Albertus, Antoine J. Bedard, Richard W. Jones, Charles R. Jordan, Philip N. Straight, Michael T. Smith, Arlyn S. Jensen, Daron Tanko, and B. Porter.

Funding and Cooperation

District funding varied greatly during the period from a little over $1.5 million in 1979 to over $4.3 million in 1994. Low funding totals for 1983–85 may reflect incomplete records. Iowa District funds for fiscal years 1979 to 1994 are shown in the following table. The source of the funding information is from District program review documents. Funds are in thousands of dollars.

The 1980's were turbulent times for the Iowa District, both financially and programmatically. At the beginning of the period, most District revenue was for support of the surface-water CBR (collection of basic records) program, both in the OFA program and the Federal-State matching-funds program. Even the Special Studies Section (1979–80) carried out surface-water-related areal studies. Direct Federal funding supported a Regional Aquifer-System Analysis (RASA) study in eastern Iowa. Prior to the period, only one water-quality-related report had been produced by the District. As the 1980's progressed, political decisions dictated that other Federal agencies that were providing budget to the District to operate stream-gaging and sediment stations consider contracting the station operation to non-Federal enti-

Iowa District funds for fiscal years 1979–94

Fiscal year	Federal	Other Federal agencies	State	Federal matching	Total
1979	236.9	425.8	438.2	435.6	1,636.6
1980	342.8	427.1	456.2	455.2	1,681.3
1981	327.3	447.2	498.1	494.7	1,767.3
1982	187.4	400.4	499.4	491.7	1,578.9
1983*	80.9	369.3	431.9	296.8	1,178.9
1984*	82.0	284.3	467.8	233.5	1,067.6
1985*	57.4	206.1	460.0	316.4	1,040.0
1986	100.4	765.3	679.2	656.4	2,201.3
1987	186.8	658.0	676.4	706.2	2,227.4
1988	441.8	682.1	823.8	810.0	2,757.7
1989	624.3	704.0	814.3	800.0	2,942.6
1990	726.2	737.3	802.6	785.7	3,051.9
1991	686.8	747.3	925.4	872.5	3,232.0
1992	558.3	713.1	995.4	854.7	3,121.5
1993	717.0	839.8	1,020.6	847.6	3,425.1
1994	910.1	1,591.7	960.9	844.0	4,306.8

*Funding totals for these years may be incomplete.

ties, and funding for the OFA (other Federal agencies) program decreased significantly. The Federal-State Cooperative (Coop) program also decreased during the period. At the same time, funding decreased substantially in the direct Federal program as the RASA study was completed. By 1984–85, serious consideration was being given by the Central Region and Headquarters to combining Districts to reduce overhead.

A significant turnaround occurred in 1986 when the OFA program was restored substantially with a 1-year increase of more than $0.5 million. By this time also, the District was active in water-quality-related studies in the Iowa River Basin. The first big jump in the direct Federal program came in 1988 with a more than 100-percent increase in funding over 1987. At this time, direct Federal funding began to flow to the District for the Midcontinent Herbicide Initiative and for additional water-quality-related programs in the Cedar River Basin and elsewhere. A study funded through the Federal/State Coop program in the karst area of northeast Iowa also began at about this time. In the 1990's, substantial direct Federal funding was provided to the District through the NAWQA Program. The large increase in OFA funding in 1994 was for replacement of gaging stations and equipment lost in the disastrous flooding the previous year. Since 1989, the four funding components of the of the District Program have been nearly equal on an annual basis, which has created a very healthy situation for the District.

The principal cooperator in the Federal-State Coop program during much of the period was the Iowa Geological Survey, which in the mid-1980's was assimilated into the Iowa Department of Natural Resources as the Geological Survey Bureau (GSB). The GSB served as cooperator for ground-water and water-quality-related interpretive studies throughout the State, including the karst area studies in northeast Iowa. Midway through the period, the University of Iowa Hygienic Laboratory became a major cooperator. Beginning in 1985, the Hygienic Laboratory performed water-quality analyses from all stations in the Federal-State Coop program and for all samples collected as part of interpretive studies. In fact, for several years the only samples that the District submitted to the USGS Central Laboratory were from NASQAN and Hydrologic Benchmark stations.

Several other State and local agencies or municipalities also provided funding and(or) direct services support during the period, for such things as gaging and sediment stations important to municipalities, for crest-stage gages, and for ground-water-level observation wells. All cooperating organizations for the period are listed below.

City of Cedar Rapids
City of Des Moines
City of Fort Dodge
City of Charles City
City of Marshalltown
City of Sioux City
City of Waterloo
Union Electric Company
Carroll County Health Department
Guthrie County Health Department
Iowa Department of Transportation Highway Division
Iowa Department of Natural Resources, Geological Survey Bureau
Iowa State University Department of Agricultural Engineering and Biosystems Engineering
Iowa State University Department of Contracts and Grants
Iowa State University Water Resources Research Institute
Muscatine Power and Water
University of Iowa Institute of Hydraulic Research
University of Iowa Hygienic Laboratory
University of Iowa Physical Plant
University of Iowa Sewage Disposal Plant

The U.S. Army Corps of Engineers (Corps) was the principal agency supplying funding for the OFA program. Four separate Corps offices provided funding, with the Omaha, Nebr., office providing funding for streamflow stations in the Missouri River Basin and for stations on the Missouri River main stem. The Rock Island, Ill., office provided funding for stations on streams that drained to the Mississippi River and for stations on the Mississippi River main stem. The St. Paul, Minn., and Kansas City, Mo., offices provided funding for a few additional streamflow stations. Omaha and Rock Island also provided funding for sediment collection and analysis at some streamflow stations and for sediment-sample collection at Corps reservoirs in the State.

Summary of Programs

Hydrologic Data Collection

Numbers of stream-gaging stations and sediment stations operated by the District during the

period remained remarkably constant from 1979 to 1994. Numbers of crest-stage gages declined somewhat during the same period, and the number of gaging stations at which water-quality samples were collected declined substantially during the period. From 1980 to 1984 the number of ground-water-level observation wells more than doubled and stayed fairly constant after 1984. These and other categories of hydrologic data are listed in the table below for the years 1980, 1984, 1988, and 1994, which are representative of the entire period.

Throughout its early history as a District, the Iowa District was known primarily as a surface-water District. By 1979 the District considered itself to be the premier District in the Nation for producing quality hydrologic data in a timely manner. For several years prior to 1979 and after 1979, the District was the first to complete and publish the annual basic-data report. In fact, this was such a source of pride for the District that for the period at the beginning of each new water year (October and November) when work on streamflow-gaging-station records for the previous water year were being completed, the District detailed persons from other Sections to help complete the records. Additionally, maintenance on gaging stations was scheduled prior to or after the period, and only routine stream-gaging and sample-collection trips were scheduled so field personnel could maximize their time on records computation. Annual leave was granted to those employees engaged in records computation only for emergencies until the records work was complete. Generally, the target date for delivering the annual data report to the printer was December 1. The Iowa District continued to be the first or second District to complete its annual report through about 1986–87 when the overall District program became diverse enough that priorities changed and personnel from other sections no longer were detailed to the Data Section to complete the records. Through 1994, the District's completion of the data report remained very timely.

Streamflow Stations.—Approximately 80 of the streamflow stations operated by the District were funded by the Corps. The rest were funded by the Federal program, the Federal-State Coop program, or by other State cooperators. The 93 to 120 crest-stage gages were funded either by the Iowa Department of Transportation or the National Weather Service. Lake and reservoir stage or contents stations were located at Corps reservoirs in the State. At the beginning of the period, all streamflow stations were equipped with water-level recorders. By 1994, 89 of the 115 streamflow stations were equipped with data encoders. Encoders and an ever-increasing number of data-collection platforms (DCP's), by which river stage and other data were beamed to a satellite and could be recovered on a real-time basis, provided great assistance to the Corps, the National Weather Service, and other cooperators for the purpose of flood forecasting. Whereas most gaging stations were visited on a 3-week basis for actual water-discharge measurements, four stations on the Missouri River main stem were visited by personnel from the Council Bluffs Field office twice weekly for discharge measurements. Results of the measurements were reported to the Omaha District of the Corps on the day they were made. The Missouri River channel shifts greatly, and the Corps needed the frequent discharge measurements because for about 7 months of the year the river is used for navigation. Channel-shift information was provided to barge operators on a regular basis by the Corps.

Surface-Water-Quality Stations.—In 1980, the District collected water-quality data on a monthly or quarterly basis at 25 stream-gaging stations. By 1994, this number was reduced to six stations. In 1980, the program consisted of one Hydrologic Benchmark Station and eight National Stream-Quality Accounting Network Stations (NASQAN) funded by the Federal program. The other water-quality-sampling sites were funded through the Federal-State Coop program. By 1994, only the Hydrologic Benchmark station, four NASQAN stations, and one other site remained as active stations. The NASQAN program changed, primarily by the elimination of main-stream sampling sites on the Mississippi and Missouri Rivers.

Sediment Stations.—Sediment data were collected at 14 stream-gaging stations in 1980. Suspended-sediment concentrations were determined daily at six stations. The daily stations were part of the Corps program. Sediment discharges and the sand/silt-size fraction break were determined on monthly samples from NASQAN stations and on samples collected six times per year at the Hydrologic Benchmark station. The sediment program remained remarkably constant during the period. In 1994, sediment data were collected at 13 sites. Suspended-sediment concentrations were determined daily at 12 stations, and sediment discharges and the sand/silt-size fraction break were determined four times for the Hydrologic Benchmark station.

Type of data	1980	1984	1988	1994
Gaging stations	117	115	117	115
Lake or reservoir stage or contents	7	7	8	8
Water quality at gaging stations	25	12	8	6
Sediment stations	14	13	15	13
Water-level observation wells	34	90	108	234
Crest-stage gages	126	120	113	93
Water-quality data for municipal wells	--	--	197	101
Precipitation-quality sites	--	2	2	2

Ground-Water Levels.—The ground-water-level program grew substantially during the period. In 1980, water levels were measured in only 34 observations wells statewide by the District. Five of the wells were equipped with continuous recorders. By 1984, water levels were measured in 90 observation wells and 12 were equipped with continuous recorders. Measurements in the other wells were made on a monthly, quarterly, or intermittent basis, depending on the needs of the cooperating agency. By 1994, water levels were measured monthly, quarterly, or intermittently in 232 wells, none of which were equipped with continuous recorders.

Quality of Municipal Wells.—In the mid-1980's the District established a cooperative program with the University of Iowa Hygienic Laboratory and later the Iowa DNR–Geological Survey Bureau to evaluate the quality of water in municipal wells across the State for communities that depended on ground water for their drinking-water supply. The District collected the samples and the laboratory performed the analyses. Approximately 300 municipal wells were inventoried, and the wells were sampled on a rotating basis of about 100 wells per year.

Quality of Precipitation Sites.—Two precipitation-quality stations were located in northeast Iowa. They were part of a national atmospheric water-quality program and were started in 1984.

Interpretive Studies.—Interpretive studies at the beginning of the period mostly were related to surface water. By the end of the period, the principal thrust of the interpretive program had shifted to studies with significant water-quality components. Nearly 90 percent of Iowa is under cultivation. In the mid-1980's it was common knowledge that more pesticides and fertilizers were used in Iowa for crop production, primarily corn and soybeans, than in any other State. District management and State cooperators recognized the need to conduct investigations concerning the effects of agricultural chemicals on the quality of both the surface water and ground water in Iowa. About the same time, several persons with expertise in water-quality-related investigations were added to the staff, enabling the District to meet the needs of the cooperators for conducting these studies. Selected interpretive studies completed by the District are discussed below.

Surface-Water-Quantity Studies.—Al Heinitz prepared reports documenting Iowa floods in 1985 and 1986. David Eash and Oscar Lara produced a flood report for Iowa streams in 1987, and Eash and Heinitz described floods in the Nishnabotna River Basin in a report published in 1991. Eash produced a report in 1993 on floods that occurred in south-central Iowa in September 1992. The year 1993 produced the greatest flooding in Iowa that had occurred in the 121 years of record keeping, on the Mississippi and Missouri River main stems and for many other Midwestern locations. Melcher and many others of the District Hydrologic Surveillance Section produced reports documenting the disastrous flooding on nearly every river in the State and in the Upper Mississippi River Basin. Melcher produced a report in 1991 that evaluated methods for determining discharge during periods of ice effect. Eash prepared a report in 1994 on a GIS procedure to quantify drainage-basin characteristics.

Between 1987 and 1989, Heinitz produced 11 reports on discharge ratings for the control gates of Mississippi River locks and dams. In 1987, a report by Lara detailed methods for estimating the magnitude and frequency of floods in Iowa. Earlier, in 1984, Ivan Burmeister and Lara authored reports on the effectiveness of streamflow data collection and on the cost effectiveness of the stream-gaging program in Iowa. In the same year, Lara and Robert W. Lane coauthored a report with a University of Iowa scientist on the effects of visitation frequency and instrument reliability on the accuracy of estimates of river discharges.

Regional Aquifer-System Analysis (RASA). —During much of the early part of the 1980's Michael Burkart was involved in a RASA study of the St. Peter–Jordan aquifer system in Iowa and southern Minnesota. In 1990, a final report of the study authored by Burkart and Robert Buchmiller was published. Burkart also authored a report on water in the Dakota aquifer in 1984.

Karst Area Studies in Northeast Iowa.—Steven Kalkhoff led a surface water/ground-water interaction study in the karst area of northeast Iowa during the late 1980's and early 1990's. The study also

had a large water-quality component. Kalkhoff produced several reports including one in 1992 on hydrologic data for the Big Springs Basin that was coauthored by Ron Kuzniar and Dana Kolpin, one in 1993 coauthored with Kolpin on time of travel and dispersion in Roberts Creek, and one coauthored with Kolpin in 1993 on atrazine degradation in a small Iowa stream. Kalkhoff authored a GIS report on Roberts Creek in Clayton County in 1993. In 1992, with Mark Detroy and a State coauthor, Kalkhoff authored a report on herbicide and nitrate variation in alluvium.

Water-Quality Studies.—Detroy was involved in several water-quality and other studies in the early and mid-1980's. With a coauthor from the Missouri District, he published a report in 1982 on the hydrology of a coal area in south-central Iowa and in Missouri. In 1984, he published a report on the ground-water-monitoring program in Iowa and followed this with a report, published with coauthors Pam Hunt and Maureen Holub, on the same subject, which dealt specifically with nitrate and pesticides in shallow aquifers.

The Midcontinent Herbicide Initiative.—From a relatively inauspicious beginning as a result of a series of meetings in 1987, the Midcontinent Herbicide Initiative grew into a major program in the midcontinent area in the late 1980's and the 1990's. In addition to personnel from Iowa and other Midwestern States, personnel from Headquarters and the Central Region were active in herbicide studies. Much of the pioneering work in the initiative took place in Iowa and was performed by District personnel. Burkart headed the initiative project in Iowa. In 1988 and again in 1990, Burkart coauthored reports on agrichemical research in the midcontinent area. In 1991, he authored a report on agricultural research to improve water quality. In 1993, Kolpin and Burkart authored a report on hydrologic and land-use factors associated with herbicides and nitrate in shallow aquifers. Kolpin, Burkart and others authored a report on water-resource implications of Midwest agroecosystems in 1994.

Cedar River Studies.—While the Midcontinent Herbicide Initiative primarily was a study of ground-water quality, studies on pesticides in streamflow and the movement of pesticides into and out of bank storage in the Cedar River Basin were conducted at the same time. These studies were headed by Paul Squillace and began in the late 1980's. Squillace's first Cedar River report on the occurrence and transport of herbicides in the Cedar River, coauthored by Richard Engberg, was published in 1988. In 1993, Squillace and others published a report on ground water as a nonpoint source of atrazine and deethylatrazine in a river during base flow. In 1993, with coauthors Michael Liszewski and Michael Thurman, and again in 1994, with coauthors James Caldwell and Peter Schulmeyer, Squillace published reports on movement of agricultural chemicals between surface water and ground water in the lower Cedar River Basin. A related report on herbicide interchange between streams and adjacent alluvial aquifers was authored by Woodrow Wang and Squillace also in 1994.

Ground-Water Studies.—Ken Wahl, Richard Karsten, and a coauthor published a report in 1981 on the hydrology of the surficial aquifer in the Floyd River Basin of Iowa. Hunt and Donna Runkle, in 1985, published ground-water data for alluvial, buried channel, basal Pleistocene, and Dakota aquifers in west-central Iowa. In 1988, Runkle published a report on the hydrology of the same area. In 1989, Robert Buchmiller authored a report on the screening of ground-water samples for volatile organic compounds by using a portable gas chromatograph. He published a report in 1993 on ground water in the Walnut Creek management system and a report in 1994 on agricultural chemical data in the South Skunk River Basin. In 1992, Keith Lucey published an analysis of the ground-water flow system in the vicinity of Red Rock Dam. Also in 1992, Phillip Bowman authored a study on the pre-Illinoian glacial till in Linn County.

Other Studies.—In 1986, Runkle together with Joanna Newman and a coauthor produced a report on permitted water use in Iowa in 1985. Buchmiller authored a hydrologic reconnaissance report of the Missouri River Valley in 1986. Also in 1986, Lara and Wilbur Matthes published a report on the use of the sedigraph as an alternative method to the pipet for the analysis of fluvial sediment. In the mid-1980's, Buchmiller conducted studies at the Des Moines Air National Guard Base as part of the Department of Defense Environmental Conservation program.

The Storms of the Century

The major hydrologic event of the 20th century for Iowa and other Midwestern States occurred in 1993. This was the wettest year in 121 years of record keeping in Iowa, with average precipitation for the State of 52.93 inches. Major storms began in April. They also occurred in May, June, July, and August. In

April, major flooding occurred in Des Moines and in the Turkey, Wapsipinicon, and Cedar River Basins, with a record flood peak in the Cedar River Basin. Intense rainstorms pounded Iowa May 3–7. June precipitation was 183 percent of normal for the State. July precipitation was 254 percent of normal, the wettest month ever recorded in Iowa. Thirty-four gaging stations exceeded their previous peak discharges during 1993 with the majority occurring in July. Eleven stations with 10 or more years of record experienced 100-year floods. Record outflows occurred at Corps reservoirs at Saylorville, Red Rock, and Coralville. A total of 250,000 persons in greater Des Moines were without a water supply for 19 days as a result of flooding of the Des Moines water-treatment plant. The rain continued. August precipitation was 204 percent of normal for Iowa, the wettest August on record. Throughout the entire period, District hydrologists and hydrographers worked record numbers of hours, many times under dangerous or life-threatening conditions, measuring swollen streams, rescuing equipment, collecting samples, performing indirect measurements, and finally when it was all over, rebuilding damaged and destroyed gages and other equipment and authoring reports describing the flooding. All this was accomplished with care and safety and an outstanding level of competence. The District truly did itself proud during this highly stressful period.

KANSAS

By Jesse M. McNellis

DISTRICT OFFICES AND LOCATIONS

The Water Resources Division (WRD) Kansas District began the period with the District Office on the west campus of the University of Kansas in Parker Hall in Lawrence. Parker Hall was named after H.N. Parker, an early-day WRD chemist from Kansas. There were Subdistrict Offices located in Garden City and Salina and a Field Office in Lawrence. The District Office was moved from the campus to 4821 Quail Crest Place in west Lawrence in 1988. There was an office in Garden City throughout the period, but the Salina office closed in 1983, and an office opened in Wichita in 1993.

The District has a history of strong and comprehensive cooperative programs with several agencies of the State of Kansas. In fact, the U.S. Geological Survey and agencies of the State of Kansas have had cooperative agreements for the collection of water-resources information since 1895. Cooperating State and local agencies in 1993 included the Kansas Geological Survey; Kansas Water Office; Kansas Department of Transportation; Kansas State Board of Agriculture, Division of Water Resources; Kansas Department of Public Works, Johnson County; and City of Hays. Other Federal agencies included the U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and U.S. Fish and Wildlife Service.

The District Chief and nature of the projects dictated the personnel and structure of the District. There were as many as 18 and as few as 11 separate units during the period, including regional studies and offices. The names and numbers of units changed, but the work of the District continued. Personnel in the District were part of the staff of the District Chief, administrative services, computer services, reports section, hydrologic data section, district project offices, field or subdistrict offices, laboratory, regional studies offices, and regional supervisory offices.

Principal program functions in the District Office involved administrative duties; report processing for publication; data acquisition and processing; and research in the areas of streamflow characteristics, surface water, sediment transport, water quality, ground water, ground-water recharge, surface-water/ground-water relations, development of computer applications, and organic chemistry.

District Chief Staff

The period began with the District program under the direction of District Chief Joseph S. Rosenshein and continued into 1988 when he moved to WRD Headquarters in Reston. Thomas L. Huntzinger moved from Associate District Chief to District Chief in 1988 and served there until he moved to a National Water Quality-Assessment project in 1991. Richard A. Herbert became Chief in 1991 until illness forced his retirement. Walter Aucott was Chief in 1994.

E. Robert Hedman was principal assistant to the District Chief in 1980–81 when he retired. Russell K. Livingston became Associate District Chief in 1981 and into 1984 when he transferred. Thomas Huntzinger became Associate District Chief in 1984–85 and

served in that capacity until he became District Chief in 1988. There was no formal Associate District Chief from 1988 until 1992 when Johnette C. Shockley assumed those duties.

During the period the following personnel also were involved on the District Chief staff: Donald G. Jorgensen, Claud H. Baker, Avhdesh K. Tyagi, Jerry E. Carr, Joe B. Gillespie, Elizabeth A. Scribner, Stacey A. Chapman, Cristine M. Foote, and Donita M. Turk.

Administrative Services Section

This is an important group in any District. The Kansas District was fortunate to have the leadership of this Section in the very capable hands of Margaret E. Broeker and Darlene K. Berry during the period: Margaret from 1979 until she retired in 1981 and Darlene who joined the District from the Corps of Engineers in 1982 and led the Section to the end of the period. They were ably assisted by an outstanding support staff including Eleanor L. Gulley, Mildred M. Trefz, Becky S. O'Connor, Mary E. Sims, Carol A. Van Winkle, Renee M. Stewart, Anne R. Whedon, Kathy A. Burt, Desiree A. Kelsch, Marylynn R. Powell, Iona L. Gillaspie, Jennifer A. McChesney, Stacy S. Sanders, Julie M. Finger, Kyla J. Young, and Stephanie L. Mayer.

Computer Services and Applications Section

The period began with minimal computer capacity and employee computer capability in the Kansas District and WRD. The situation changed rapidly. A minicomputer, one of three acquired by WRD, arrived in the District office in late November 1978, and comprehensive training began for each employee in January 1979. Training of personnel and development of programs to facilitate District operations were continuing tasks. A more sophisticated minicomputer was acquired in 1982, and in 1991 workstations arrived. The District successfully made the transition into the computer age. Jesse M. McNellis headed up the Section from 1979 through 1989 when he retired. Claud H. Baker succeeded Jesse into 1993 when he retired. Steven J. Brady was in charge at the end of the period. Other personnel working in the computer area were Charlene E. Merry, Thomas B. Reed, Stephen P. Barsky, John R. Craig, Clement M. Doffing, Kathleen V. Neill, Iola F. Russell, Deneise R. Schneider, Alan G. Wiseman, James G. Baird, Charles W. Haring, Darin D. Wilken, Christopher S. Brady, Ronald B. Zelt, Kyle E. Juracek, George M. Mah, and John O'Neill.

Reports/Publications Section

This is the another of those service sections in a District operation that directly governs the success of the District. Report authors and cooperating agencies will attest to that. The number of people in the Section ranged from three to five from the beginning of the period through 1988, but from 1989 through the end of the period there were from seven to nine employees. This Section has been very well led by three individuals during the period: Harold E. McGovern from 1979 through 1982, Joan F. Kenny in 1983, and Lanna J. Combs from 1984 through the end of the period. During the period, the following personnel also contributed to the success of this group: Patricia M.Turcotte, Pamela J. Nebgen, Judy M. Crissler, Joanne Piezonki, Anne R. Whedon, Kent O. Russell, Ingrid M. Knudsen, Michael D. Kemppainen, Ronald B. Zelt, Kristi A. Powell, Charles F. Jacobs, Ricardo Hernandez, Charlene E. Merry, Amy J. Graham, Jennifer L.Carolan, Roberta Lara, Richard A. Woodbridge, Julia D. Goger, Jeffrey R. Hartley, and Donna J. Roberts.

Hydrologic Data Management Section

This is the unit in the District that takes raw hydrologic data and makes it usable and available to users in and out of government. Melvin L. Thompson was head of the Section in 1979 and 1980 when he retired. He was succeeded by Claude O. Geiger who transferred back to the Kansas District. Claude led the Section through the balance of the period. Very able assistance was provided by Harold J. McIntyre, Jr., Rayvon L. Shelton, Linda R. Quy, Mildred L. Penny, Diana M. Skinner, Deneise R. Schneider, Donna S. Boles, Dennis L. Lacock, Charlene E. Merry, Philip E. Harrold, Alan G. Wiseman, Brandy L. Riche, Lisbeth E. French, Michael L. McCartney, Kyle D. Medina, Seth E. Studley, Patrick P. Rasmussen, James D. Craig, and Michael D. Carlson.

District Project Offices

District project offices often reflect one of the three traditional disciplines of hydrologic studies. The

traditional disciplines are "surface water," "ground water," or "water quality." However, most of the studies are integrated to some extent and include at least two of the disciplines. The Kansas District did not differentiate the different discipline projects from 1979 through 1988 and simply called them "project offices" even when the work involved only one discipline. The project name reflected the discipline view as "ground-water projects," "hydrologic characteristic projects," or "water-quality projects" in the Kansas District from 1989 through 1991. From 1992 to the end of the period the project offices were placed under the name "hydrologic investigations" and labeled "unit 1," "unit 2," or "unit 3." Employees who headed project offices in the period were Arthur M. Diaz, Paul R. Jordan, Kyle D. Medina, Joe B. Gillespie, Waite R. Osterkamp, John K. Stamer, John O. Helgesen, Larry M. Pope, David M. Wolock, and Andrew Ziegler. Others working in the project offices during the period were Calvin D. Albert, Hugh E. Bevans, Bennie L. Day, Timothy B. Spruill, Joan F. Kenny, Scott D. Freeman, William A. Dark, James E. Putnam, Ralph W. Clement, William J. Carswell, Russell E. Curtis, Clarence V. Burns, Philip E. Harrold, Peter G. Jarchow, Ralph J. Stingo, Alan G. Wiseman, Charles O. Peek, Charles O. Perry, Stephen V. Bond, Philip M. Armstrong, Anthony J. Gogel, Robert D. Burnett, Tuvyah N. Gross, Ronald S. Wallace, Mark K. Schroeder, Cynthia L. Miller, Hugh G. Crowther, Thomas B. Reed, James A. Berg, John E. Gray, Elizabeth K. Voss, Kenneth J. Schriner, Camille Hernandez, Michael J. Haley, Kim E. Hazarvartian, Ronald E. Henderson, Linda R. Quy, Elizabeth J. Underwood, Robert J. Hart, Ronald J. Wolf, Joseph M. Spinazola, Cristi V. Hansen, Edward A. Halenar Jr., Daniel W. McCullough, Clydeen M. Logan, Albert T. Rutledge, Phillip R. Bigsby, Nathan C. Myers, Dirk A. Hargadine, Lesley D. Brewer, Gregory D. Godwin, Brian A. Heck, Barbara A. Kollmeyer, James D. Fallon, Thomas J. Trombley, Gloria M. Ferrell, Jennifer A. McChesney, Scott C. Morgan, Ronald B. Zelt, Phil Barnes, Connie M. Broxterman, Kyle E. Juracek, Michael L. Pomes, Joe R. Eagleman, Brandt D. Maxwell, Kurtis A. Shobe, Gregory T. Zamarripa, Patrick P. Rasmussen, and Ivan L. Nordquist.

Field Offices

A Field Office was located in Lawrence throughout the period, and Wichita gained an office in 1993 through the end of the period. Program and personnel assignments in the Field Offices were determined by the ongoing activities in their respective areas. Field Offices participated in the basic data programs of streamflow, ground water, water quality, and sediment transport. Areal investigations in eastern and central Kansas were conducted from Lawrence, and those in western Kansas from Garden City. All Field Offices received coordination and support from the District Office in Lawrence.

Lawrence Field Office

Glenn G. Quy was Lead Tech of the Lawrence Field Office from 1979 through 1983 and James D. Craig became Supervisory Hydrologic Technician from 1984 through 1990. The work load was formally split between the Kansas and Arkansas River Basins in 1991 with Patrick J. Finnegan in charge of the Kansas River Basin and Craig A. Dare in charge of the Arkansas River Basin through the end of the period. Others in the Lawrence Field Office over the years included Larry M. Pope, James P. Marshall, Delbert P. Gariepy, Richard E. Weiser, James G. Gish, Robert J. Hart, James E. Putnam, Diana M. Skinner, Michael Michalowski, Randall K. Porter, Bruce Pedersen, Michael D. Carlson, James D. Fallon, Walter D. Mack III, Jeffrey R. Barnard, Eric S. Wakeman, Michael P., Holt, Duane D. Wilmes, Craig A. Davies, Mark K. Lysaught, and Brenda Seaton.

Garden City Subdistrict

Hayes Grubb was Subdistrict Chief in Garden City in 1979 and 1980 when he transferred. Jack Kume was in charge of the office in 1981–82; Lloyd E. Stullken was Supervisory Hydrologist from 1983 through 1987. When he retired, the Subdistrict was changed to a Field Office. Curtis G. Sauer headed up the office in 1988; James E. Putnam became Supervisory Hydrologic Technician in charge in 1989 through the rest of the period. Other personnel at the Garden City Office during the period included Rene A. Barker, Lloyd E. Dunlap, Kenneth R. Watts, Dennis L. Lacock, Marilyn Pabst, Joseph M. Spinazola, Lynn K. Miller, Glenda E. Julian, Jerry L. Phares, Lisa K. Hort, Karen K. Carlson, Mary A. Bowen, Paul J. Kyle, Richard J. Lindgren, Alan L. Brewsher, Robert A. Swanson, Barbara J. Dague, Arlen Orosco, Linda S. Brown, Michael J. Haley, Teresa L. Purvis, Marvin D.

Stevens, David W. Anderson, Seth Studley, Walter D. Mack III, Michael B. Haddican, Trudy J. Bennett, Dwayne A. Snyder, Eric M. Wetherill, and Charles Weston.

Salina Subdistrict

Joe M. Alexander was Subdistrict Chief in Salina in 1979 and transferred. No replacement as Chief was made, but Joseph T. Religa was in charge of the office in 1980. Stanley A. Druse transferred from Wyoming as Supervisory Hydrologist in 1981 and remained in charge until the office was closed in 1983. Druse transferred to Wyoming at that time. Other personnel at the Salina office during the period included Stanley T. Green, Richard D. Thomas, Roger N. Herrington, Marshall R. Jeffrey, Michael Michalowski, David G. Johnson, Michael J. Green, Steven J. Brady, Deborah J. (Prickett) Cates, Dorothy A. Smock and Arleen F. Browning.

Wichita Field Office

A Field Office was reopened in Wichita in 1993 under the direction of Eric S. Wakeman. The previous Wichita Field Office had closed in 1973. Other personnel in the office through the end of the period included Michael P. Holt, Trudy Bennett, and James Bruce.

Central Midwest RASA

The Central Midwest Regional-Aquifer System Analysis began in 1980 under the direction of Donald G. Jorgensen and was headquartered in the Kansas District until it was finished during 1988. The study encompassed parts of Arkansas, Colorado, Kansas, Missouri, Nebraska, New Mexico, Oklahoma, South Dakota, and Texas. WRD employees working on the project included Donald C. Signor, Robert B. Leonard, John O. Helgesen, Elizabeth J. Underwood, Carol A. VanWinkle, Shelley M. Brodie, Earnest Angino, Kristi A. Powell, Frederick L. Sherman, and Donald Wolfram.

Research Project Office–Organic Research

E. Michael Thurman transferred to the Kansas District in 1988 to develop an organic chemistry laboratory to determine pesticide concentration, longevity, "daughter products," and movement within the environment. Those working in the laboratory during the period were Craig D. Adams, Michael D. Meyer, Michael L. Pomes, Jeri L. Damman, Christopher V. Wilcox, Debra Brown, Margaret S. Mills, Kenneth A. Shamet, Shawn C. Saving, Lisa R. Zimmerman, Linda D. Zacher, Jennifer M. Papineau, James D. Fallon, Diana S. Aga, Aron E. Cromwell, Christian B. Krueger, Elisabeth A. Scribner, Jane Garbisch, Doug Holub, Janice McClelland, and Michelle Yockel.

Research Project Office—Manhattan

This office opened in 1988 in the Agronomy Department at Kansas State University and was active through 1991. Those working in the office during the period included Paul A. Schwab, James M. Steichen, Cathy M. Tate, R. David Jones, Steven M. Siegele, Connie M. Broxterman, Paul Ingle, and Philip L. Barnes.

National Water-Quality Assessment

The National Water-Quality Assessment (NAWQA) project of the Central Nebraska Basin began in 1991 under the direction of Thomas L. Huntzinger. The project was ongoing at the end of the period. Others working on the project included John K. Stamer, John O. Helgesen, Ronald B. Zelt, Jennifer A. McChesney, Joe B. Gillespie, Steven A. Frenzel, Patrick J. Emmons, and Kathy E. Lee

Administrative Information System Development

The project to develop an Administrative Information System for WRD began in 1991 under the direction of Steven J. Brady. The project was ongoing at the end of the period. Others working on the project included Jeffrey L. Miller, James E. Morris, Gerald L. Feese, Jeffrey M. Laube, Michael C. Golledge, Michael B. Flannery, and Brett Close.

Office of the Regional Hydrologist

WRD established an Office of the Regional Hydrologist at the Kansas District in 1991 with James E. Kircher as Area Assistant Regional Hydrologist. Midwest (Kansas, Nebraska, and Iowa) programs of regional interest fell under the purview of the office. Kathleen M. Reed assisted in the work.

Personnel

A number of interesting personnel statistics come to light when information contained in the yearly WRD Directory is examined. Their were 15 employees working in the Kansas District in 1979 who remained in the District during the entire period. Those employees were Becky S. O'Connor, Charlene E. (Merry) Calhoun, Deneise R. Schneider, James D. Craig, Lanna J. Combs, Joan F. Kenny, Larry M. Pope, Joe B. Gillespie, Paul R. Jordan, Ralph W. Clement, Charles O. Perry, Kyle D. Medina, James E. Putnam, Curtis G. Sauer, and Dennis L. Lacock.

The number of people employed in the District ranged from 52 in 1988 to 94 in 1979 and 1981. Full-time employees ranged from 42 in 1982 and 1983 to 71 in 1993, and part-time employees ranged from 2 in 1988 to 49 in 1981. The percentage of full-time employees to total number of employees ranged from 48 percent in 1981 to 96 percent in 1988. The percentage of employees with a grade of 12 or above ranged from 22 percent in 1979 and 1980 to 37 percent in 1988. The grade of the District Chief remained a 15 from 1979 through 1988 and then fell to a 14 for the rest of the period.

FUNDING

Funding for the operation of the Kansas District has three principal sources. There is WRD (Federal) funding for programs of broad national interest, funding from other Federal agencies (OFA) for work the Kansas District does for a specific agency and cooperative program funding with Kansas (State Match) and WRD (Federal Match) providing approximately equal dollars to use on projects of interest to Kansas.

Total Cooperative Program (Coop) funding in the initial 4 years of the period averaged about 64.5 percent of the total funding. That changed substantially during the last 9 years of the period as Coop funding averaged less than 54 percent of total funding. Federal and OFA funding picked up the slack and even increased the total funding available to the program in the latter part of the period.

Hydrologic Data

The hydrologic data-collection programs and the program core of long-term data-collection stations remained relatively stable during the period. Some change in the number and location of data stations did occur to meet the needs of ongoing or planned investigations. The number of data stations operated toward the end of the period, in water year 1993, was representative for the program.

There were 134 streamflow-gaging stations in operation in 1993, 27 high-flow partial-record gaging stations, and 2 low-flow partial-record stations.

Kansas District funds, fiscal years 1979–94

Fiscal year	Federal	OFA	State	Federal matching	Total
1979	551,288	723,314	1,035,157	1,057,082	3,366,841
1980	610,744	620,335	1,133,727	1,089,255	3,454,061
1981	661,893	437,825	1,047,055	1,075,462	3,222,238
1982	687,171	364,136	1,013,580	991,052	3,055,939
1983	475,211	339,110	694,174	600,228	2,108,723
1984	551,028	236,209	581,038	398,399	1,766,674
1985	692,528	273,541	679,416	542,171	2,187,656
1986	831720	513,150	978,366	974,800	3,298,036
1987	1,081,460	510,944	963,595	992,800	3,548,799
1988	1,263,180	664,995	1,015,330	1,012,580	3,956,085
1989	1,239,180	986,029	868,566	860,000	3,953,775
1990	1,002,880	773,142	962,550	853,000	3,491,772
1991	997,345	527,056	1,155,773	1,132,700	3,812,874
1992	1,190,652	701,108	1,102,749	1,092,569	4,087,078
1993	879,960	796,057	1,216,169	1,140,926	4,033,112
1994	837,809	1,264,352	1,178,555	1,159,655	4,440,371

Gaging stations measuring elevation and contents for 24 lakes and reservoirs were operated.

Water-quality data were obtained at seven of the streamflow stations. Water-quality data were collected at 123 measured sites and at 20 sampled sites. Suspended-sediment data were collected at least once at 18 streamflow stations.

There were two National Atmospheric Deposition Program/National Trends Network stations where precipitation-quality data were collected.

Water-level measurements for 1,385 wells were obtained throughout the State in 1993, many of them in the heavily pumped High Plains aquifer of western and central Kansas.

Throughout the period the Kansas District published an annual water-resources data report, did an outstanding, timely job, and is rightfully proud of the collective effort of those working on the report.

People and Projects

Streamflow

Maintenance of streamflow is a major concern for many reasons including, but not limited to, water supply for cities and towns, for irrigation, for bridge and highway construction, for flood control, and for fish and wildlife. A number of activities and conditions affect streamflow: climate (precipitation distribution, too little and too much); reservoir construction and storage of water; water supply for cities and towns; agricultural practices; and flood protection.

William J. Carswell determined storage requirements to sustain gross reservoir outflow from small basins in Kansas. He worked with Robert J. Hart on transit losses and traveltimes along the Neosho River.

Ralph W. Clement developed flood-frequency estimates for small watersheds in eastern Kansas, using a rainfall-runoff model, and on the magnitude and frequency of floods in Kansas on unregulated streams.

Paul Jordan studied rainfall-runoff relations and expected streamflow in western Kansas; developed magnitude and frequency of low flows of unregulated streams in Kansas and estimation of flow-duration curves for ungaged sites; worked on the design of a sediment data-collection program in Kansas as affected by time trends; reported on the magnitude and frequency of high flows of unregulated streams in Kansas. Jordan and Robert Hart reported on transit losses and traveltimes for water-supply releases from Marion Lake during drought conditions. John K. Stamer analyzed available surface-water water-quality data in the lower Kansas River Basin of Kansas and Nebraska.

Kyle D. Medina analyzed the surface-water data network in Kansas for effectiveness in providing regional streamflow information, developed floodflow characteristics, and characterized proposed bridge sites. He and Claude O. Geiger evaluated the cost effectiveness of the stream-gaging network in Kansas.

Waite R. Osterkamp, Russell E. Curtis, Jr., and Hugh G. Crowther performed sediment and channel-geometry investigations for the Kansas River Bank-Stabilization Study, Kansas, Nebraska, and Colorado; E. Robert Hedman and Alan G. Wiseman studied channel geometry, basin characteristics, discharge and particle-size data from gaged stream-channel sites in the Western United States; and Wiseman analyzed particle sizes of bed and bank material from channels of the Missouri River Basin.

Charles A. Perry studied regional precipitation periodicity, developed a method of estimating flood volumes in western Kansas, and determined the effects of reservoirs on flood discharges in the Kansas and Missouri River Basins. Perry and Seth E. Studley determined the effect of flood-control reservoirs on peak discharges along the Kansas River, and Hart estimated flood frequencies for five gaged basins in Wichita.

Other participants in streamflow studies included Larry M. Pope, Hugh E. Bevans, and David G. Johnson.

Organic Research Studies

E. Michael Thurman and the workers in his laboratory were extremely productive in their research from their beginning in 1988 through the rest of the period. More than 50 reports were produced during this time and were authored or coauthored by 20 investigators. Their work has dealt with water from wells and streams that may be affected by pesticide products applied to fields by farmers. Some of the work focused on development of improvements in techniques of analysis.

Other Studies

The office in Garden City completed its part of the High Plains RASA, headquartered in Denver, Colo., during the period. Joseph M. Spinazola developed hydrologic maps of the High Plains and the Ogallala aquifers in Kansas. Lloyd E. Stullken and others reported on the "Geohydrology of the High Plains aquifer, western Kansas." Ed Gutentag and others produced Professional Paper 1400–B, "Geohydrology of the High Plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming."

The Central Midwest RASA, headquartered in Lawrence and headed by Donald G. Jorgensen, was very active during the period. Jorgensen and Donald C. Signor developed the plan of study for the project, which included parts of Arkansas, Colorado, Kansas, Missouri, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. Jorgensen, John O. Helgesen, and J.L. Imes reported on the geohydrologic framework of the regional aquifers in the study area. Helgesen, Robert B. Leonard, and Ronald J. Wolf reported on the hydrology of the Great Plains aquifer system in Nebraska, Colorado, Kansas, and adjacent areas. Signor and Imes reported on the geohydrology of the regional aquifer systems in Cretaceous and older rocks underlying the Central United States. Spinazola, Wolf, and Harold E. McGovern developed maps of the physical framework of the Great Plains aquifer system in Kansas.

Seven landfill projects were undertaken between 1988 and 1990. The name of the county or city with the landfill, the year the work began, names of the investigators and the year of the report are shown in the table below.

Analysis and computer simulation of stream/aquifer hydrology in the Arkansas River Valley in southwest Kansas was done by Rene A. Barker, Lloyd E. Dunlap, Curtis G. Sauer, Jack Kume, Kenneth R. Watts, and Joseph M. Spinazola.

Hugh E. Bevans investigated coal hydrology, updated the hydrology of Sedgwick County, and with C.H. Fromm and S.A. Watkins reported on the occurrence and transport of agricultural pesticides in the Tuttle Creek Lake/stream system in Kansas and Nebraska.

Robert D. Burnett and Thomas B. Reed investigated the availability of water for irrigation in the South Fork Solomon River Valley, Webster Reservoir to Waconda Lake, north-central Kansas and simulated the effects of management alternatives of the stream/aquifer system, South Fork Solomon River Valley between Webster Reservoir and Waconda Lake, north-central Kansas.

Many other investigations could be enumerated as more than 350 reports were developed by numerous investigators during the period.

Computer Applications and Acquisitions

During this period the computational capability within the Kansas District changed from minicomputers to workstations; post-1994, almost every desk had a personal computer of some sort. Prior to the minicomputer contract for WRD there were probably fewer than 300 computer-literate employees in the Division. After the minicomputer installation in WRD offices around the country, the number of capable computer users approached the number of employees in WRD.

The minicomputers were quite successful and the word spread on computer capability across the Division. WRD District Offices continued development of computer capability at the local level. Joseph S. Rosenshein, District Chief in Kansas through 1988, supported and encouraged the efforts of Jesse M.

Landfill projects

County-City name	Begin year	Investigators	Year of report
Geary	1988	Nathan C. Myers, Phillip R. Bigsby	1989
Emporia-Lyon	1988	Myers, Bigsby	1990
Linn	1988	Ronald Falwell, Bigsby, Myers	1990
Reno	1990	Brian A. Heck, Myers, Dirk A. Hargadine	1992
Sumner	1989	Myers, Heck, Hargadine	1993
Harvey	1990	John O. Helgesen, Heck, Hargadine	1993
Olathe	1990	Patrick P. Rasmussen, Johnette C. Shockley, Hargadine	1994

McNellis in that regard. The Kansas office continued to demonstrate leadership in the computer area with Claud Baker, then Steve Brady after McNellis retired in December 1989.

The Worlds Fair in New Orleans in 1984 provided an opportunity for WRD to demonstrate to the public, to WRD, and other government departments the merits of online, current data acquisition. WRD placed a minicomputer and several terminals at the assigned exhibit area. WRD had data platforms at gaging stations in many States and on the Mississippi River near New Orleans. A visitor to the WRD exhibit at the fair could choose one of the stations and see the current information about the chosen location in real time. The software to do the graphics and make the demonstration in New Orleans a success was developed in the library in the Kansas District Office through the efforts of McNellis, Mike Hathaway from Florida, Rich Hollway from Oregon, Steve Brady from Missouri at that time, Skip Eshelman from Wyoming, and Merritt Blalock from Georgia. Doug Posson, Charles Nethaway, and Arlen Harbaugh from Reston, Va., provided backup and leadership at Headquarters. Others contributed, but the above individuals were the major players.

After the successful minicomputer acquisition, installation, and Division-wide usage, the WRD instituted planning for the next computer generation. L. Michael Hathaway from Florida and Jesse M. McNellis in Kansas were designated to lead the effort. Objectives of the project were (1) to determine the Division's computer requirements, (2) to develop technical specifications that met those requirements, and (3) to obtain the computer resources. Five work groups covering hydrologic information, hydrologic applications, geographic information systems, reports and electronic publishing, and administrative information were organized to analyze the Division's major activities and determine the functional requirements for future computer systems. Utilizing the results from the work groups, the Division successfully benchmarked systems, then acquired workstations.

Tidbits

As part of the development of the software for the Worlds Fair, the group doing the work used "brilliant pastels of blue, yellow, green, and red" on the computer terminals and discovered that the reviewers, people from the Kansas District, had trouble distinguishing some of the pastels as they appeared to them as some shade of grey. The nonpolitically correct phrase is "color blind" and as it turned out, line patterns had to be placed on the different colors to make sure all the general population could see what to some was obvious. LIVE and LEARN!

MINNESOTA

By George H. Carlson, *including information provided by* J.R. Stark, M.R. Have, G.N. Delin, *and* G.B. Mitton

ORGANIZATION AND PERSONNEL

During 1979, the Minnesota District consisted of the District Office and Field Office in St. Paul, a Subdistrict Office in Grand Rapids, and a Field Headquarters in Montevideo. The staff of 74 included 43 permanent employees, 18 employed part time, and 13 WAE (while actually employed). Employed staff during this history period reached 79 in 1980, a low of 43 in 1990, and 57 in 1994. Changes in projects, funding, and retirements resulted in changing the Grand Rapids Subdistrict Office to a Field Headquarters in 1985 and closing the Montevideo Field Headquarters in 1991. All employees were permanent full time or term during 1994.

DISTRICT HEADQUARTERS

During 1979, the District Office was on the seventh floor of the main Post Office Building at 180 East Kellogg Boulevard in downtown St. Paul. During July 1992, the office was moved to 2280 Woodale Drive in Mounds View, about 12 miles northwest of the downtown location. This office was in a new warehouse building with the interior constructed to the District's specifications.

OFFICE OF THE DISTRICT CHIEF

In 1979, Donald R. Albin was District Chief, having transferred in from Lawrence, Kans., in 1977. He was transferred to Colorado in 1988 and William J. Herb moved from Fort Worth, Texas, to become the District Chief. He held that office until 1991 when a reorganization to Regional Areas created an Area Assistant Regional Hydrologist position. Herb moved to that position with an office at the Minnesota District

Headquarters. George Garklavs transferred from the Central Region in 1991 to become District Chief.

Shirley A. Evertz was District Secretary until 1983 when she was moved to the Administrative Services Unit. Evertz was succeeded by Rosa W. Chamblee until she retired in 1992. About that time, the Interagency Sedimentation Project at the St. Anthony Falls Hydrologic Laboratory ceased operations, and Ruth C. Julseth from that office came over to succeed Chamblee.

ADMINISTRATIVE SERVICES SECTION

This Section consisted of an Administrative Officer, Marre Jo Sager, and a staff of three to four assistants. Shirley A. Evertz served as Administrative Operations Assistant from 1983 until she retired in 1993. Others serving in the Section were Dorothy A. Sadowski, Deanna C. Carbone, Susan M. Fullerton, Anne M. Weaver, Linda C. Groebner, Gloria A. Morse, Angela M. (Bohland) Hughes, Lisa (Hagen) Syde, Linnae M. Moey, and Sally A. (Tomascak) Simmons.

COMPUTER APPLICATIONS UNIT

During 1979, a computer terminal was installed at the District Headquarters and connected to other U.S. Geological Survey (USGS) offices. The terminal was replaced in 1985 with a minicomputer, and staff were provided with personal computers or computer terminals depending on their needs. The positions of Site Administrator, District Computer Specialist, or Chief of the Computer Applications Unit was occupied by Gerald D. Wilson (1979–80), Robert T. Miller (1980–81), James E. Jacques (1981–88), and Allan D. Arntson (1988–97). Others who served in the Unit were Linda M. Christenson, David L. Lorenz, David J. McNamara, Luanne Nelson, Joe Federer, and Frank Sager.

PUBLICATIONS UNIT

The staff of the Publications Unit numbered from four to five. Donald G. Adolphson was Reports Specialist and Chief of the Publications Unit until 1982. He was replaced by Dennis G. Woodward who served for about one year. Thomas A. Winterstein was named to this position in 1984, and he served until 1990 when he became Chief of a newly formed Geographic Information Systems Unit. He was succeeded by Rebecca A. Miller. John L. Callahan was principal illustrator until he left in 1987 and was succeeded by Rebecca A. Miller. Other illustrators were Jeffrey Trionfante, Paul Hanson, and Robert Borgstede. Others assigned to the Unit were Margaret M. Diedrich, Amy G. Doll, Robert I. Dorenfeld, Margaret D. Hein, Joan M. Helms, JoAnne A. Jannis, Shelly A. Kruse, Kristen Leaf, Shelly A. Morrison, Sandra J. Surrat, Julie A. Tapper, Anne M. Weaver, and Ginger L. Amos.

WATER-QUALITY UNIT

Mark R. Have was Water-Quality Specialist and Chief of the Water-Quality Unit until 1989 when he was placed in charge of the combined Hydraulic and Network Surveillance Sections. Lan H. Tornes became Water-Quality Specialist and served in that capacity until he joined the Red River of the North Basin NAWQA in 1991. At that time, Gregory W. Stratton was assigned the water-quality work. The Water-Quality Unit was discontinued in 1993 when Stratton joined the Studies Technical Support Unit under the Upper Mississippi Basin NAWQA. Others serving in the Water-Quality Unit were Kenneth D. Fossom, Gala D. Goldsmith, and Jeffrey L. Henry.

HYDRAULIC INVESTIGATIONS AND NETWORK SURVEILLANCE (DATA) SECTION

This Section consisted of two parts in 1979: the Hydraulic Investigations Unit, and the Network Surveillance Field Headquarters Unit at St. Paul and at Montevideo. George H. Carlson had become Section Chief in charge of the two Units during 1977. The Hydraulic Investigations and Network Surveillance Sections were separated in 1988. Carlson was named Surface-Water Specialist and Chief of the Hydraulic Investigations Unit with one staff person, Charles J. Smith. Mark R. Have was moved from the Water-Quality Unit to be Chief of the Network Surveillance Section and Data Chief.

Other personnel assigned to the Hydraulic Investigations include Michael K. Anderson, Allan D. Arntson, Richard M. Bejcek, Eric H. Berlin, Kurt T. Gunard, James E. Jacques, David L. Lorenz, Gloria A. Morse, Luanne Nelson, Gregory A. Payne, Nasser E. Wazwaz, Joseph Hess, Dwayne A. Wickland, and Thomas A. Winterstein. Due to funding changes and differing talent needs, staff were shifted between sections. Some people served in several sections over

the years and their names are included wherever they served. Personnel serving in the Field Headquarters are listed with their respective unit.

HYDROLOGIC INVESTIGATIONS (STUDIES) SECTION

Section Chiefs were Perry G. Olcott (1979), Daniel C. Gillies (1980–86), and Jeffrey D. Stoner (1986–90). When Stoner left in 1990 to become Chief of the Red River of the North Basin NAWQA, the Section was divided into two Sections. James R. Stark was Chief of Section I, and Donald S. Hansen transferred in from Huron, S. Dak., to be Chief of Section II. The Upper Mississippi River Basin NAWQA was organized in 1994 with Jim R. Stark as Chief. Don Hansen became Chief of the combined Studies Section with a staff of 11 hydrologists and 1 student trainee. The Hydraulic Investigations Unit was combined with the Hydrologic Investigations Section I in 1993. Four members were stationed at the Grand Rapids Subdistrict in 1979. Section activities decreased at Grand Rapids and were discontinued in 1985. Section staff numbered from 24 in 1980 to 11 in 1985.

Other personnel who served in the Hydrologic Investigations Section were Donald G. Adolphson, James E. Almendinger, Henry W. Anderson Jr., Thomas E. Anderson, David S. Armstrong, Allan D. Arntson, Richard S. Aune (Grand Rapids), Mark A. Ayres, James A. Berkeland, Donald L. Boyce, Mark E. Brigham, Robin G. Brown, Jay P. Busch, John B. Czarnecki, Drew K. Davis (Grand Rapids), Geoffrey N. Delin, Paul E. Felsheim, Catherine A. Forster, Carl E. Graul, George E. Groschen, John H. Guswa, Steven R. Hane, Marilee A. Horn, Marc F. Hult, Gregory B. Justin, Steven C. Komor, Matthew K. Landon, Dana Larson, Kari L. Liljeblad, Richard J. Lindgren, Jerry Linholm, (Grand Rapids), Gail L. Lowry, Patrick J. Lynch, Alan J. Mackenzi, John M. Mason, Steven A. Meger, Michael A. Menheer, Michael J. Metzmaker, Edward J. Miller, Robert T. Miller, Gregory B. Mitton, Abdul Mohammad, Charles F. Myette (St. Paul and Grand Rapids), Kristopher J. Nelson, Paul C. Olson, Gregory A. Payne, Harold O. Reeder, Daniel L. Rosemore, James F. Ruhl, Michael E. Schoenberg, Blaine R. Schoyer, Stephen W. Sether, Donald I. Siegel, Shannon E. Smith, William G. Soukup (Grand Rapids), Gregory W. Stratton, Martha M. Theilmann, Nathan B. Trites, Lee C. Trotta, Terese M. Winkler, Ronald J. Wolf, Dennis G. Woodward, and Beth M. Wrege.

NATIONAL WATER-QUALITY ASSESSMENT (NAWQA) STUDY SECTIONS

Staffing for the Red River of the North Basin NAWQA began in 1990 with Jeffrey D. Stoner as Chief. The staff grew to seven in 1994. Other members of this study unit were Kelly Boesflug, Gary Burkhart (Grand Forks, North Dakota Field Office), Mark E. Brigham, Timothy K. Crowdery, Robert M. Goldstein, David L. Lorenz, and Lan H. Tornes.

Staffing for the Upper Mississippi Basin NAWQA in 1993 included James R. Stark as Chief, James D. Fallon, Wallace W. Larson, Paul E. Hanson, Kathy E. Lee, Sharron E. Kroening, Todd C. Schmidt, and Alison L. Fong. Along with the Upper Mississippi Basin NAWQA, a Studies Technical Support Unit was formed in 1993. Staff of this Unit included Wallace W. Larson as Supervisory Technician, Michael A. Menheer, Abdul Mohammad, and Gregory W. Stratton.

FIELD OFFICES

Responsibility for collection of hydrologic data in Minnesota during 1979 was distributed among the Field Offices at St. Paul and Montevideo, and the Grand Rapids Subdistrict. Service areas were approximately the northern 40 percent of the State near Grand Rapids, the southeastern 40 percent near St. Paul, and the southwestern 20 percent near Montevideo. By agreement between Districts, the Minnesota District was responsible for data collection for the Mississippi River, where it formed the border with Wisconsin. The North Dakota District was responsible for data collection for the Red River of the North where it formed the border with North Dakota.

ST. PAUL/MOUNDS VIEW FIELD HEADQUARTERS

The office was located with the District Headquarters in downtown St. Paul in 1979. Eno G. Giacomini had become Chief with the leadership changes in 1977. Giacomini died suddenly in 1980 and Joseph H. Hess succeeded him as Chief. Hess served in that capacity until 1988 when the Hydraulic Studies Unit was separated from the Network Surveillance Section. At that time, Mark R. Have was moved from the Water-Quality Unit to be Chief of the Network

Surveillance Section, Data Chief, and Hydrologist-in-Charge of the St. Paul Field Headquarters where he served until he retired in 1998. The St. Paul Field Headquarters moved in 1992 with the District Headquarters to Mounds View.

Others who served in the St. Paul/Mounds View Field Headquarters were Henry W. Anderson, Jr., Anthony D. Arhart, David J. Bauer, William D. Bemis, Ruth E. Bergstrom, Alex Brietkrietz, Linda M. Christenson, Florence D'Heilly, Paul E. Felsheim, Steven A. Gustafson, Jeffrey L. Henrey, Jerry K. Hicks, Wallace W. Larson, David L. Lorenz, Gregory B. Mitton, Leslie M. Myles, Leonard L. Reed, George A. Roach, Brett E. Savage, Janis P. Sawicki, Leo G. Schaffer, Todd C. Schmitt, Gregory W. Stratton, and Duane A. Wicklund. Kurt T. Gunard, Alex Brietkrietz, and Leslie C. Myles served in the Hydrologic Data Unit in 1989. Myles resigned, and Kurt T. Gunard and Alex Brietkrietz continued in the Data Unit until 1992 when the St. Paul Field Headquarters was renamed the Network Surveillance Section and the Data Unit was merged into that Section.

MONTEVIDEO FIELD HEADQUARTERS

During 1979, Charles E. Cornelius was Technician-in-Charge of the office located at 301 South First Street. Charles retired in 1991. Roderick Johnson replaced Charles until 1992 when the office closed. Others who served in this office were Patrick J. Finnegan, Marlys Fluto, Richard L. Kittleson, and Rod Johnson.

GRAND RAPIDS SUBDISTRICT/FIELD HEADQUARTERS

The office was located at 415 South Pokegama Avenue. Donald W. Ericson had transferred from Wisconsin to become the Subdistrict Chief in 1965. Ericson continued as Chief until he retired in 1985 and the office was redesignated a Field Headquarters. James L. Zirbel was promoted to Technician-in-Charge of the Field Headquarters, and he continued until he retired in 1993. Zirbel was succeeded by Kevin G. Guttormson. Four staff members of the Hydrologic Investigations Section were stationed at this office. As funding for their activities in the Iron Range area was reduced, fewer of that Section were needed. The last member of the Hydrologic Investigations Section resigned in 1985. Other staff of the Network Surveillance Section that served in this office were Rich Aune, Matthew R. Becker, James A. Berkeland, Howard D. Braden, William A. Gothard, Marlene Hay, Wallace W. Larson, Russell J. Lewins, David Lorenz, Gregory R. Melhus, Gerald J. Metzer, Daniel M. Ritten, Daniel L. Rosemore, Maren E. Smith, and Tillie L. Yocus.

PROJECT OFFICES

Two Project Offices were operated during 1991 and 1992 for research projects. Paul D. Capel and Steven J. Larson were located at the Gray Freshwater Biological Institute, University of Minnesota, at Navarre; a second office was operated in Stattgast Hall, Bemidji State University, and was primarily a contact location for researchers working at the Toxic Substances Hydrology crude-oil spill site near Pinewood.

Two additional offices, not part of the District, were located in Minnesota. The Interagency Sedimentation Project headed by John V. Skinner, was located at the St. Anthony Falls Hydrologic Laboratory, University of Minnesota, and was funded by the USGS and other Federal agencies to supply and improve sediment-sampling equipment. This office was discontinued in 1991 when Skinner retired.

FUNDING AND COOPERATION

Several State and Federal agencies were long-term cooperators for hydrologic data collection: the Minnesota Department of Natural Resources, Division of Waters (DNR), the U.S. Army Corps of Engineers, St. Paul District and Detroit District (USCOE), the Minnesota Department of Transportation (MNDOT), the Metropolitan Waste Control Commission of the Twin Cities (MWCC), the Minnesota Department of Health (DOH), Red River Watershed Management Board, the U.S. Department of State through the International Joint Commission with Canada (IJC), U.S. Department of Housing and Urban Development (HUD), the Iron Range Resources and Rehabilitation Board (IRRB), the Minnesota Pollution Control Agency, (MPCA), the Minnesota State Planning Agency (SPA), the Minnesota Land Management Information Center (LMIC), the Minnesota Waste Management Board (WMB), the Legislative Commission on Minnesota Resources (LCMR), National Park Service (NPS), U.S. Bureau of Mines, U.S. Environmental Protection Agency (USEPA), Federal Emer-

Minnesota District funds, fiscal years 1980–94

[Source: Administrative Officer's records 1980–82, District program documents for 1983–94]

Funding source	Fiscal year (Funds in thousands of dollars)														
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	1,612	1,479	1,208	1,296	1,471	1,205	1,219	1,419	1,684	1,942	2,091	2,131	2,209	2,167	2,107
OFA	627	909	747	824	577	522	466	469	589	639	540	477	417	534	485
Fed	468	436	355	439	503	495	622	612	549	423	636	1,073	1,568	1,910	2,327
Total	2,706	2,823	2,311	2,559	2,551	2,222	2,307	2,500	2,822	3,004	3,267	3,681	4,194	4,611	4,919

gency Management Agency (FEMA), and the Department of Defense (DOD), among others.

The DNR was also a principal cooperator for many of the investigative projects, several with counties contributing funds. Agencies contributing to investigative studies include the Water and Conservation Districts of Hubbard, Beltrami, Pine, East Otter Tail, Wadena, Todd, and Wilkin Counties. Other agencies contributing to investigative studies were the Indian Communities of Grand Portage, Mille Lacs, Red Lake, Lower Sioux, Upper Sioux, Shakopee Mdewakanton, Bois Forte Lake Superior, White Earth, Fond du Lac, Blue Earth, and Nett Lake. During 1980, 15 counties were contributing cooperators through local development commissions or steering committees with the DNR. Because of water needs or uses for activities, 15 private companies had agreements with the DNR or the Federal Energy Regulatory Commission (FERC) to fund streamflow or water-level monitoring by the District. Other cooperators were the University of Minnesota, Snake River Watershed Management Planning Commission, Moorhead Public Service, and the City of Rochester.

SUMMARY OF PROGRAMS

Annual Water-Resources Data Report

Kurt T. Gunard assembled the Annual Water-Resources Data reports for publication until he retired in 1992. Gregory B. Mitton was named his successor. Mark R. Have and Lan H. Tornes verified water-quality samples and retrieved tables of water-quality data for the annual reports. When Have was named Chief of the Network Surveillance Section in 1988, Tornes continued to care for water-quality samples and retrieve the water-quality tables until he joined the Red River of the North Basin NAWQA in 1991. Greg W. Stratton then assumed these responsibilities.

Streamflow Stations

The Field Offices were operating 105 continuous-record discharge stations, 13 continuous stage only stations and, 163 crest-stage stations during 1980. Records published in the Annual Water-Resources Data reports include water levels at seven reservoirs and the daily mean discharges from those reservoirs as furnished by the USCOE. Six of the reservoirs are in the headwaters of the Mississippi River. The number of continuous-record stations was gradually reduced to 85 during 1991. In 1992, two stations were added to tributaries of the Red River of the North in conjunction with the Red River of the North River Basin NAWQA study unit.

In the early 1980's stage records for most continuous-record stations were obtained using the 16-channel digital punch-tape recorders and a few graphic-chart recorders. Records were processed by reading the digital tapes into the computer terminal at St. Paul, and the data were transmitted to the computer in Reston, Va., Headquarters for developing the daily mean discharge table. This method began to experience technical problems. The Wisconsin District was not having such problems. As a result, digital tapes were mailed to Madison, Wis., to be read and transmitted to Reston, and the processed data were sent back to the Minnesota District for part of 1984 and 1985 until the District got its own computer. A minicomputer was installed at the District office in 1985. Once this system was up and running, record processing proceeded; but with the backlog of data tables to edit and digital tapes to process, it was about 3 years before the office caught up and published the Annual Water-Resources Data report by the target date.

During 1983–84, data-collection platforms (DCP's) were installed at five stations funded by the IJC at remote locations on the Canadian border. The

USCOE also began installing DCP's in stations they funded. The National Weather Service began installing data loggers called Limited Automatic Remote Collectors (LARC's) in 1996 at District gaging stations where telephone service was available. This enabled them to obtain data quickly and inexpensively to aid their flood forecasting. The District began accessing the LARC's to obtain daily stage records. By the end of 1994, the primary means for obtaining continuous stage records was by having the computer dial up the data loggers in the early morning hours and download the previous day's stage data to the District computer and from DCP's.

Water-Quality Stations

Principal cooperating agencies in 1980 were the DNR, MNDOT, MWCC, USCOE, NPS, and the cities of Eagan, Apple Valley and, Lakeville. During 1997, the surface-water-quality network consisted of 10 stations in the National Stream Quality Accounting Network (NASQAN) program; two stations in the Hydrologic Benchmark program; and 11 stations on the Minnesota and Mississippi Rivers, and tributaries in and near Minneapolis and St. Paul, operated in cooperation with the MWCC. In 1980, the MWCC cooperatively funded 10 water-quality monitoring stations equipped with 4-parameter monitors located upstream and downstream from the wastewater treatment plants. Periodic samples were obtained at each monitoring site and at three additional sites in cooperation with the USGS. The USGS laboratory performed the analyses. Two of the sampling sites were also NASQAN stations. This monitoring and sampling provided water-quality information on the water being pumped from the Mississippi River for city supply upstream from the wastewater-treatment plants. Over the years, the MWCC developed its own laboratory and by 1993 had phased out the entire program with the USGS.

Much additional water-quality sampling and analyses were completed and compiled. For example, it was the practice to determine streamwater temperature and specific conductance at the gaging stations each time a discharge measurement was made. The work with the NPS and the three cities named as cooperators was to assess water quality of lakes and inflow to the lakes. Several of the interpretive studies include determining chemical quality of water.

Systematic monitoring of ground-water quality was carried on throughout the period. During 1980, analysis was for common ions and nutrients from 84 wells and for radiochemicals from 35 wells. The ground-water-quality monitoring expanded considerably and in 1984 included approximately 230 wells sampled for common ions and nutrients; 22 of these wells were also sampled for pesticides and volatile organics. The program was reduced to 79 wells sampled for common ions and nutrients and 12 for organics during 1988–93. During 1994, 190 wells were sampled for common ions and nutrients, 19 wells for organic chemicals, and 58 wells for radiochemicals.

Fluvial-Sediment Stations

Ten daily, eight periodic, and nine monthly sediment stations were operated during 1980. The number of daily stations during 1982 was reduced to five; three for 12-month operation, and two for 6-month operation. The periodic and monthly sampling stations included nine NASQAN and two Hydrologic Benchmark stations. Over the years one benchmark station was removed from the network and one station was added in the NASQAN program. One of the 12-month daily stations and the two 6-month daily stations were discontinued after 1988. That left two daily sediment stations, eight NASQAN stations, and one benchmark station involved in the sediment program. By 1999, one daily sediment station remained, but the benchmark and NASQAN stations were discontinued. Sediment samples were analyzed at the Iowa City Sediment Laboratory. A summary of the results of sediment sampling in Minnesota is reported by Lan H. Tornes ("Suspended Sediment in Minnesota Streams," WRIR 85–4312)

Precipitation Station

One precipitation station was funded by the USGS as part of the National Atmospheric Deposition Program in 1983. The station was installed in a remote location in the Camp Ripley Military Reservation in Morrison County. The installation includes wetfall and dryfall collectors and a recording rain and snow gage. Chemical analysis was made by the Illinois State Water Survey. Results each year were reported in the Annual Water-Resources Data Report.

Ground-Water Observation Wells

A statewide network of wells, reaching a maximum number of 382 in 1980, was maintained in cooperation with the DNR. Twenty-four of the wells were equipped with water-level recorders. To save money the DNR began assuming responsibility for the observation well network. By 1991, the number of wells funded had been reduced to 124, 16 of which were equipped with recorders. By 1993 the DNR had assumed responsibility for most of the observation well network. The District operated recorders on 14 wells in 1994 and hired observers for reading levels in 2 wells.

Water-Use Data

The program began in 1978 in cooperation with the DNR. The DNR provided the project leader, set up the beginning data base, and coordinated data collection from the MPCA, DNR Well Permits Section, and the DOH, receiving direct services credit. Project leadership was changed in 1981 to Marilee A. Horn of the USGS, and the ground-water data base was redesigned. The SPA and LMIC became cooperators in 1983. The State Water-Use Data System (SWUDS) was developed and was made compatible with the National Water-Use Data Base. Marilee prepared two reports, WRIR 83–4033 and WRIR 85–4306, documenting results and the development of the water-use data system. The 1990 National Water-Use Data compilation was completed for Minnesota. A water-use compilation for the Red River of the North NAWQA study was prepared in 1993. The water-use data are available from the LMIC and the National Water-Use data base.

INTERPRETIVE STUDIES

During the period, approximately 70 investigative studies were underway or were completed. Forty-two Federal, State, or local cooperating agencies, 17 county organizations, and management groups of 5 Indian Reservations were involved. Most of the investigations were from 1 to 3 years' duration.

Cooperative Ground-Water Investigations

Availability, chemical quality or contamination, and effects of pumping are the major concerns of most ground-water investigations. Of the 70 investigative studies during the period, 22 were ground-water assessments. An additional 11 were combined assessments of ground water and surface water. Eight investigations involved the bedrock aquifers underlying the Twin Cities metropolitan area. Early in the reporting period, Donald G. Adolphson, James F. Ruhl, and Ronald J. Wolf identified 14 principal water-supply aquifers in Minnesota (WRIR 81–51).

Ronald J. Wolf studied the Buffalo aquifer (WRIR 81–4). James F. Ruhl investigated characteristics of several aquifers (WRIR 87–4224), and with Donald G. Adolphson (WRIR 84–4111), and with Ronald J. Wolf (WRIR 83–4000 and 84–4150), and with Ronald J. Wolf and Donald G. Adolphson (WRIR 82–4080 and 83–4085). Donald G. Adolphson studied surficial aquifers in southwestern Minnesota (WRIR 83–4030). Robert T. Miller investigated Pelican River sands. Charles F. Myette investigated aquifers in Todd, Cass, and Morrison Counties (WRIR 83–4156); in Hubbard, Otter Tail, Morrison, and Wadena Counties (WRIR 84–4080); and in Carlton, Kanabec, and Pine Counties (WRIR 85–4334). Surficial aquifers in the Pomme de Terre and Chippewa River valleys were appraised by William G. Soukup, Daniel C. Gillies, and Charles F. Myette (WRIR 84–4086), and confined drift aquifers by Geoffrey N. Delin (WRIR 86–4321).

Geoffrey N. Delin investigated glacial drift in the Brooten-Belgrade area (WRIR 88–4124 and 88–4193). A similar study in the Bemidji-Bagley area was conducted by James R. Stark, Jay P. Busch, and Marshall H. Deters (WRIR 89–4136). James F. Ruhl studied quality of ground-water around Vadnais Lake, a water-supply reservoir lake for St. Paul (WRIR 94–4062). Richard J. Lindgren investigated aquifers in four northwestern counties while Michael E. Schoenberg studied aquifers in the southern part of the Red River Valley.

Henry W. Anderson, Jr., evaluated the effects of agriculture on ground-water quality in Douglas, Kandiyohi, Pope, and Stearns Counties (WRIR 87–4040); in the Anoka Sand Plain aquifer (WRIR 93–4074); and in the Rosholt Research Farm that overlies a sand plain aquifer in west-central Minnesota. Anderson studied crystalline-rock aquifers of Archean and Proterozoic age (WRIR 86–4033). Dennis G. Woodward and Anderson described characteristics of the Cretaceous aquifer in southwest Minnesota (WRIR 84–4153).

James F. Ruhl studied the fracture orientation in the Karst Prairie du Chien Group. James F. Ruhl and

Ronald G. Wolf studied the St. Peter aquifer (WRIR 83–4200), and the Upper Carbonate aquifer (WRIR 84–4150); and with Donald G. Adolphson, the Ironton-Galesville aquifer (WRIR 82–4080), and the Prairie du Chien-Jordan aquifer (WRIR 83–4045). Ronald J. Wolf, James F. Ruhl, and Donald G. Adolphson reported on the Mount Simon-Hinkley aquifer (WRIR 83–4031). Geoffrey N. Delin studied the ground-water supply area at Rochester (WRIR 90–4081), and recharge areas with James E. Almendinger (WSP 2397).

Northern Midwest Regional Aquifer Study, Minnesota District

The study involved the Cambrian-Ordovician aquifer system underlying approximately the southeastern one-fifth of the State. The aquifer is bounded on the east by the St. Croix and Mississippi River valleys. In southeastern Minnesota the area of these aquifers is known as the Hollandale embayment. Project activities included collection, compilation, and interpretation of geologic, hydrologic and water-quality data, and preparation of maps and computer data files. Water-level, water-use, specific capacity, and aquifer-test data were compiled for each of the overlying aquifers, the St. Peter, Prairie du Chien-Jordan, Ironton-Galesville, and Mount-Simon-Hinkley. Municipal wells were inventoried throughout the area and commercial and industrial wells in the Twin Cities area. Reports were prepared by Dennis G. Woodward (WRIR 83–4222 and HA 677) and by Woodward and Geoffrey N. Delin (WSP 2219). Woodward and Delin authored several conference papers and journal articles.

Water Resources of Indian Reservations

James F. Ruhl appraised the water resources of the Fond du Lac Reservation (WRIR 88–4114), the White Earth Reservation (WRIR 89–4074), and the Red Lake Reservation (WRIR 90–4263). Lee C. Trotta studied ground water of the Mille Lacs Reservation, and James F. Ruhl investigated hydrogeology of the Grand Portage Reservation.

Studies of Ground-Water Contamination and Fate of Contaminants

The Prairie du Chien aquifer, the municipal water-supply source for St. Louis Park, had become contaminated by coal-tar derivatives prior to 1932. By 1980, eight municipal wells were contaminated, and contaminants were found in the aquifer 2 miles from the source. Coal-tar derivatives had entered the ground water by three routes: infiltration, recharge from ponds, and at least one spill into a 909-ft-deep well. Marc F. Hult and Michael E. Schoenberg prepared a preliminary evaluation (WRIR 81–72 and WSP 2211). A three-dimensional, multilayered ground-water-flow model was developed by James R. Stark and Marc F. Hult (WRIR 85–4087). Flow simulations were reported by David L. Lorenz and James R. Stark (WRIR 90–4150). That large model of the artesian basin underlying the Twin Cities metropolitan area was later modified several times to suit the needs of other studies involving the artesian basin. Other studies of the ground-water system in the Twin Cities Metropolitan area are by John H. Guswa, Donald I. Siegel, and Daniel C. Gillies (WRIR 82–44), by Michael E. Schoenberg (WRIR 83–4237, WRIR 90–4001, and 94–41630), and by Richard J. Lindgren (WRIR 90–4165 and WRIR 94–4204). James R. Stark of the District with J.D. Strudell, P.A. Bloomgren, and Paul Edgar of the State cooperator studied the spread of contaminants from two abandoned pesticide burial sites (WRIR 87–4115).

Crude-Oil Contamination of Ground Water near Bemidji

On August 20, 1979, approximately 10 miles northwest of Bemidji near Pinewood, a crude-oil pipeline burst and spilled approximately 450,000 gallons of crude oil onto a glacial outwash aquifer. After partial cleanup was completed, approximately 106,000 gallons of crude oil remained. The USGS Toxic Substances Hydrology Program funded research in 1983 to study the mobilization, transport, and fate of petroleum derivatives in the shallow subsurface at the site. Research was conducted by a combined effort of researchers from the National Research Program, Districts of the Water Resources Division, and employees in the Geologic Division of the USGS, and several academic institutions. Results are reported in proceedings of conferences that were combined,

edited by Marc F. Hult, and published (WRIR 84–4188, WRIR 88–4220) and by Matthew K. Landon and Hult (WRIR 91–4034). A bibliography of research papers was prepared by Shannon E. Smith and Hult (OFR 93–373) and of hydrologic data collected (OFR 93–496).

Fate and Mobilization of Agricultural Chemicals in Sand-Plain Aquifers

Research is in collaboration with the University of Minnesota, Soil Science Department, and the U.S. Department of Agriculture, Agricultural Research Service. A site referred to as a Management System Evaluation Area (MSEA) for the research was selected near Princeton. A variety of farming practices and methods of application of agricultural chemicals and fertilizers were tested. Results are presented in compilations of Toxic Program conference proceedings (WRIR 93–4014 and WRIR 95–4104), numerous journal articles, and USGS reports primarily authored by Geoffrey N. Delin and Matthew K. Landon (WRIR 91–4034, OFR 92–107, OFR 93–42, OFR 93–43, OFR 93–79, OFR 93–80, OFR 93–337, OFR 93–454, WRIR 94–4015, WRIR 94–4149).

Thermal-Energy Storage in the Ironton-Galesville Aquifer, St. Paul

The University of Minnesota funded investigations of injection and withdrawal of heated water into and from the Ironton-Galesville Formation at the St. Paul Campus. Results are presented by Robert T. Miller in "Selected Papers in Hydrologic Sciences" (WSP 2270), in U.S. Geological Survey Circular 974, and by Robert T. Miller and Geoffrey N. Delin in U.S. Geological Survey Professional Paper 1530–A.

Combined Investigations of Ground Water and Surface Water

Charles F. Myette investigated the hydrology, water quality, and simulated ground-water flow at a taconite tailings basin near Keewatin (WRIR 88–4230).

The effects of ground-water withdrawals for irrigation from shallow drift aquifers and use of agricultural chemicals in fields near the Straight River, a designated trout stream in north-central Minnesota, were investigated by James R. Stark and David S. Armstrong of the USGS and Daniel R. Zwilling of the DNR. Of concern were the effects on temperature, water quality, and flow variability in the trout stream. Results are reported in WRIR 94–4009 and in papers presented at several conferences.

Quality of ground water around Vadnais Lake and Lambert Creek watershed and the interaction of ground water with Vadnais Lake, a reservoir for St. Paul municipal water supply were studied by James F. Ruhl (WRIR 94–4062).

Flood Investigations

The District performed flood-frequency analyses and delineated flood-plain areas for the DNR Land-Use Management Program in the same manner as for detailed flood-insurance studies and was performing flood-insurance studies for HUD as well. If a community was studied and later included in the flood-insurance program, the flood-insurance report could be prepared very quickly. Flood-plain areas along a reach of the Mississippi River delineated by George H. Carlson and Lowell C. Guetzkow were presented in WRIR 80–972. The last six of about 40 flood-insurance studies by the District were completed in 1980. Cities involved were Milaca, Princeton, Oronoco, Jordan, Brooklyn Center, and Brooklyn Park.

When the delineation of flood-plain boundaries was started, a requirement of the DNR was that the USCOE, USGS, and the U.S. Department of Agriculture, Soil Conservation Service (SCS) form a hydrology review committee and that the committee agree on a coordinated 100-year discharge estimate for all of the continuous-record gaging stations in stream reaches involved in projects subject to State or Federal regulation. George H. Carlson served as the District's representative on the Hydrology Review Committee throughout the period.

The operation of crest-stage gages began as an investigation of flooding on small streams in 1958 in cooperation with the State Highway Department (now the MNDOT). Emphasis was on streams draining 10 mi^2 or less. Over the years, the DNR and USCOE added continuous-record stations, which were eventually discontinued and the emphasis shifted away from the small basins. When gages had been operated in one location for 25 years, gages on the smallest basins were discontinued and fewer were added on streams draining larger areas. By 1991, the number of crest-

stage stations operated was reduced to 81. The number was increased again to 84 by 1994. Cooperators continued to fund the program as it filled in the lack of flood data for basins less than 200 mi^2 and continued the collection of flood data at discontinued daily record stations.

In 1987, James E. Jacques and David L. Lorenz combined the flood records from the crest-stage program with flood data from continuous-record stations and prepared an updated statewide report detailing techniques for estimating magnitude and frequency of floods in Minnesota (WRIR 87–4170). The method used regression equations incorporating drainage area and several basin characteristics. Drainage areas and needed basin characteristics had been determined only for stations in the small streams program. Drainage areas and basin characteristics for daily-record stations were only approximate, having been determined many years ago from maps then available. The 7.5-minute series of topographic maps was not available for the entire State until 1983. That led to development of the project to determine and record drainage areas and basin characteristics statewide in a computerized data base described later.

During 1980–94 a considerable number of indirect measurements of peak discharge were made to document unusual peak flows from locally intense rainstorms. Noteworthy are determinations of peak discharges on Nine Mile Creek and Minnehaha Creek in southwest Minneapolis and Bloomington during July 1987 (after the second 9-inch rainfall in the same area 2 days apart), of the flash flood on Stockton Valley Creek at Stockton in 1991 (about 5 inches of rain in one-half hour on steep terrain), and of floods in southern Minnesota in summer of 1993.

Drainage-Basin Characteristics of Minnesota Streams

A project to delineate drainage-basin boundaries on topographic maps and record the boundaries in a computerized geographic information system was started in 1983, funded by the USCOE. Later, the MNDOT cooperatively funded the project, and with assistance from the University of Minnesota the information system was perfected so that anyone with a computer and the proper software could call up the map, mark the location of interest, and the program would list the drainage area above that point, main channel length, main channel slope, area of the basin in lakes, area of the basin in ponds and marshes, and the mean annual rainfall for the area. By the end of the period, most of the Minnesota River Basin had been entered into the geographic information system. The method of integrating and aggregating these data using a geographic information system is described by David L. Lorenz in U.S. Geological Survey Bulletin 2016.

Surface-Water Hydrologic and Water-Quality Investigations

Hydrologic effects of mining of peatlands near the Upper and Lower Red Lake was investigated by Donald I. Siegel (WRIR 81–24). Water-quality of Schmidt, Hornbeam, and Horseshoe Lakes was studied by Gregory A. Payne (WRIR 80–3). Mark R. Have studied Rogers Lake in Dakota County (WRIR 88–4053) and Alimagnet, Farquar, and Long Lakes in Apple Valley (WRIR 81–40). Tornes and Have sampled four lakes in Lakeville (WRIR 80–66). Mark A. Ayres, Gregory A. Payne, and Have studied effects of urbanization on lakes in Eagan (WRIR 80–71) and later a similar study was done by Tornes (WRIR 86–4331).

George E. Groschen, with James W. LaBaugh and Thomas C. Winter of National Research Program, studied the limnology and geochemistry of Williams Lake (WRIR 81–41). Allan D. Arntson and Lan H. Tornes studied the Coon Creek watershed (WRIR 84–4013). Mark A. Ayres and Robert G. Brown of the District and Gary L.Oberts from the Metropolitan Council investigated quality of runoff from small watersheds in the Twin Cities metropolitan area (WRIR 85-4122). Gregory A. Payne sampled water quality of lakes and streams in Voyageurs National Park (WRIR 88-4016). Charles J. Smith, Payne, and Tornes reported on hydrologic effects of impoundments on water quality of streams in the Coteau des Prairies (WRIR 90–4033). Robert G. Brown studied the hydrology of Big Marine Lake (WRIR 85–4176) and hydrologic effects of impoundments in Sherburne Wildlife Refuge (WRIR 84–4175). Brown also studied the effect wetlands have on quality of runoff entering lakes in the Twin Cities metropolitan area (WRIR 85–4170). A comprehensive study of sources of sediment, nutrients, and oxygen-demanding substances in the Minnesota River was reported by Payne (WRIR 93–4232).

In 1989 the MWCC had difficulty meeting criteria of the Clean Water Act in the Mississippi River downstream from the wastewater-treatment plants because the flow from upstream contained so much suspended sediment and oxygen-demanding substances. The apparent source was the Minnesota River inflow. The MPCA funded a comprehensive study conducted by Gregory A. Payne to determine the sources within the approximately 16,300-mi^2 Minnesota River Basin of the sediment and other substances (WRIR 93–4232).

Regional and National Water-Quality Assessments

The National Water-Quality Assessment Program of the U.S. Geological Survey has collected a large amount of data pertaining to quality of water in the rivers and streams of the Red River of the North Basin (REDN) in Minnesota and North Dakota. These data, which were accumulated from 1993 through 1995, constitute a valuable data base for developing a better understanding of the quality of the water resources in the REDN. Jeffrey D. Stoner described the plan for the NAWQA study in the Red River of the North Basin (OFR 91–151). Lan H. Tornes and Mark E. Brigham investigated nutrients, suspended sediments, and pesticides in the REDN (WRIR 93–4231). Stoner and others described the physical, chemical, and aquatic-biological characteristics that could affect the REDN; these characteristics define the overall environmental setting of the REDN (Water Resources Bulletin, v. 4).

Miscellaneous Studies

Dennis G. Woodward investigated the use of seismic-refraction methods to locate drift-filled bedrock valleys in Ramsey County (WRIR 85–4107). Lee C. Trotta studied water use for aquaculture in Minnesota (WRIR 88–4159). Robert G. Brown sampled for chemistry of atmospheric deposition in the Twin Cities metropolitan area (WRIR 83–4195). Paul D. Capel studied wet atmospheric deposition of herbicides, reported in proceedings of technical meetings (WRIR 91–4034). Paul D. Capel, with Daniel S. Barbeau, described a method for evaluating organic chemical retention by solid-phase extraction columns in proceedings of the USGS Toxic Substances Hydrology Program meeting (WRIR 91–4034). Donald I. Siegel studied effects of acid precipitation on Filson Creek and Omady Lake (WRIR 81–66).

MONTANA

By Joe A. Moreland

ORGANIZATION AND PERSONNEL

At the beginning of the period, the Montana District consisted of a Headquarters Office in Helena, a large Subdistrict Office in Billings, and Field Headquarters Offices in Helena, Kalispell, and Fort Peck. The four offices were staffed with about 58 permanent and 12 part-time employees in 1979, but reductions in funding for energy-related investigations and the termination of regional aquifer studies resulted in steadily declining staff levels. In 1987, most investigative work (primarily related to coal hydrology) in the Billings office was concluded and the Subdistrict was converted to a Field Headquarters Office. In 1987, staff levels reached a low of 48 permanent and 4 part-time employees. In 1991, the District received funding to initiate the Rocky Mountain Intermontane Basins Regional Aquifer-System Analysis (RASA) program, and personnel levels began to increase substantially. By the end of the period, the District employed about 60 permanent and 3 part-time staff.

District Headquarters, Helena

Office of the District Chief.—The District Office was located in the Federal Building at 301 South Park Avenue and remained at that location through the period.

In 1969, George M. Pike became the second Montana District Chief. He served in that position until he retired in 1984. In 1985, Joe A. Moreland was selected to serve as District Chief and continued through the end of the period.

R. Gale McMurtrey served as Assistant District Chief until he retired in 1982. He was followed by Moreland, who served until 1985 when he was promoted to District Chief. Robert E. Davis served as Assistant District Chief from 1986 through the end of the period.

District Secretaries included Patricia B. (Harris) Ladd (1979–92) and Dorothy A. Barnett (1993–94).

Mark S. Gerl was Administrative Officer and Chief of the Administrative Services Unit for the District throughout the period. He was assisted by Luanne P. Romasko who served as Administrative Clerk and Accounting Technician. Also serving in the

Administrative Services Unit during the period were Carol Henry (1980–85), Lillian R. Gribbons (1986–87), Laura J. Koval-Sloughter (1988–92), Billie L. Large (1993), and Rose I. Ramsey (1994).

James E. Elliott served as District Equipment Specialist under the Office of the District Chief from 1988 through 1991 when he retired. Timothy J. Morgan held the position from 1991 through 1994. The position was responsible for testing, calibration, and maintenance of data recorders, data-collection platforms (DCP's), and other specialized scientific equipment.

Gary W. Rogers joined the District in 1980 to serve as the District Computer Specialist. Evonne S. (Molyneaux) Mitton served as his assistant from 1988 through the remainder of the period. During the period, the District acquired a minicomputer and provided workstations for virtually every employee in the District. Although many of the computer operations were performed by individuals assigned to the Hydrologic Surveillance Unit, Rogers was responsible for site administration, staff training, and system maintenance. In addition to his District responsibilities, Rogers also contributed substantially to the Division by serving on numerous computer committees and work groups tasked with preparation of computer software. His participation in the development of GWSI and ADAPS was particularly noteworthy.

At the beginning of the period, the Publications Unit was under the oversight of the Chief of Hydrologic Investigations but was placed under the District Chief in 1982. Robert S. Roberts served as the District Reports Specialist and Chief of the Publications Unit until he retired in 1993. Cynthia J. Harksen headed the Unit after Roberts retired. Harksen joined the District in 1980 as the District Librarian charged with the responsibility of organizing the District's impressive collection of U.S. Geological Survey publications and other documents. She was reassigned as Technical Publications Editor in 1987. Kurt C. Jenewein served as Cartographic Technician in the Publications Unit throughout the period. Michelle F. Johnston served as an Editorial Assistant (1979–86). Karen S. (Crowley) Midtlyng served as Editorial Clerk and Editorial Assistant from 1980 through the remainder of the period. Melinda I. Martin served as an Editorial Clerk in 1980. Montana held the distinction of being the first District in the Nation to earn Fast Track report-processing privileges in 1989, which allowed Montana District reports to bypass normal review procedures and be submitted directly to Headquarters for Director approval.

The International Waters Section, responsible for monitoring and apportioning transboundary streams, was under the direction of Claude O. Geiger at the beginning of the period. After Geiger transferred to Lawrence, Kans., in 1980, David B. Hanson transferred from North Dakota to lead the Section through the remainder of the period. Others who worked in the Section included Francis M. O'Neill (1979–86), Dave R. Johnson (1979–85), Ronald R. Thompson (1985–86), Norman A. Midtlyng (1987–94), and Donald A. Bischoff (1987–94).

Hydrologic Surveillance (Data) and Analysis Section.—At the beginning of the period, the position of Chief was vacant. Ronald R. Shields was selected to serve as Chief in 1980 and continued through the remainder of the period. J. Roger Knapton served as the District Water-Quality Specialist throughout the period. Gary W. Levings served as District Ground-Water Data Specialist from 1981 to 1986 when he transferred to Albuquerque, N. Mex. John H. Lambing served as the District Sediment Specialist from 1988 through 1994. Until 1988, the Section operated as a single entity. In 1988, the Section was divided into the Data Management Unit and the Environmental Sciences Unit.

During the period of 1979–88, when the Section was undivided, employees included Tordis Brosten (1979–88), Richard L. Clements (1979–84), Jay H. Diamond (1979–88), James E. Elliott (1982–88), Rodger F. Ferreira (1979–85), John F. Guipre (1979), Marjory A. Jacobsen (1979–85), Marion L. Kasman (1979–86), Mildred L. Lennie (1981–82), Michael H. Mahman (1979), Karen S. (Crowley) Midtlyng (1980), Evonne S. (Molyneaux) Mitton (1979–87), Donna K. (Vincent) Running (1979–85), Ronald E. Thompson (1981–83), Stanley C. Wells (1984), Melvin K. White (1979–88), Joseph F. Williamson (1979), and Wayne A. Wood (1986–87).

Jay Diamond was selected to serve as Chief of the Data Management Unit in 1988. When Diamond retired in 1991, Melvin White was selected to lead the Unit. White served as Chief through the remainder of the period. Others assigned to the Unit included Tordis Brosten (1988–94) and Patricia Ladd (1993–94).

Roger Knapton was selected to serve as Chief of the Environmental Sciences Unit in 1988 and served in that position through the remainder of the period. Others assigned to the Unit included Lambing

(1988–94), Kent A. Dodge (1989–94), Michael S. James (1991–94), and Terry L. Heinert (1993–94).

Hydrologic Investigations Section.—Moreland served as Chief of the Section from 1979 to 1985. Davis served as Chief from 1986 through the remainder of the period. The Chief supervised employees of the Section and provided technical oversight on all research and investigations conducted in the District, including project activities in the Hydrologic and Surveillance Section and the Billings Subdistrict. At the beginning of the period, the Section was divided into a Publications Unit, the Northern Great Plains Regional RASA Unit, and a general hydrologic investigations unit. The Northern Great Plains RASA program was terminated in 1981, and the Publications Unit was placed under the Office of the District Chief in 1982. From 1982 until 1988 when the District reorganized, the Section operated as a single entity. In 1988, the Section was divided into the Hydraulics and Hydrology Unit and the Geohydrology Unit. The Rocky Mountain Intermontane Basins RASA Unit was established in 1993.

Prior to the 1988 reorganization, staff assigned to the Section included Arnold J. Boettcher (1979–80), Thomas D. Brooks (1986–88), Michael R. Cannon (1980–88), Robert E. Davis (1981–86), Kent A. Dodge (1982–88), Rodger F. Ferreira (1986–87, James A. Hull (1979–88), Robert B. Leonard (1979–80), Richard O. Clausen (1980–81), Dave R. Johnson (1985–88), John H. Lambing (1982–88), Julianne Levings (1982–86), Neal E. McClymonds (1979–86), Robert J. Omang (1979–88), Charles Parrett (1979–88), Thomas E. Reed (1979–88), Andrew A. Skerda (1979–81), Steven E. Slagle (1979–88), Ronald E. Thompson (1982–84), Kathleen R. Wilke (1979–81), Wayne A. Wood (1979–84), and Paul F. Woods (1980–86).

William R. Hotchkiss served as Chief of the Northern Great Plains RASA Unit from 1979 through 1981 when the Unit was abolished and he transferred to Lakewood, Colo. Also assigned to the Unit were Gary W. Levings (1979–81), Julianne (Fleigner) Levings (1979–82), Kent A. Dodge (1979–82), and Ronald P. Rioux (1980–81). Several hydrologists assigned to the Billings Subdistrict Office also contributed to the RASA program.

In 1988, the Section was divided into the Hydraulics and Hydrology Unit and the Geohydrology Unit. The Hydraulics and Hydrology Unit included Lawrence E. Cary (assigned to the Billings office from 1988 to 1994), Stephen R. Holnbeck (1992–94), James A. Hull (1988–94), Dave R. Johnson (1988–94), Robert J. Omang (1988–94), and Charles Parrett (1988–94). The Geohydrology Unit included Fred A. Bailey (1991–94), David W. Briar (1988–92), Thomas D. Brooks (1988–89), Michael R. Cannon (1988–94), Clarence L. Chambers (1990–94), David W. Clark (1989–92), Kent A. Dodge (1988–92), James P. Madison (1990–92), Steven W. Nichols (1989), David A. Nimick (1989–94), Daryll A. Pope (1993), Thomas E. Reed (1988–91), Steven E. Slagle (1988–94), Joanna N. Thamke (1989–94), Lori K. Tuck (1989–92), and Steven D. Craigg (1992–94).

In 1993, the Rocky Mountain Intermontane Basins RASA Unit was added to the Section. David W. Clark was selected as Project Chief (1993–94) and was assisted by David W. Briar (1993–94), DeAnn M. Dutton (1993–94), Eloise Kendy (1993–94), Sean M. Lawlor (1993–94), and Lori K. Tuck (1993–94).

Subdistrict and Field Headquarters Offices

Billings Subdistrict and Field Headquarters.—At the beginning of the period, the office was located at 3 North Seventh Street West, Billings. In 1982, the office was relocated to 2525 Fourth Avenue North. Reductions in staffing levels prompted relocation to the campus of Eastern Montana College where office space was shared with a field office of the Montana Bureau of Mines and Geology. During the period 1979–86 when the Billings office was classified as a Subdistrict, Rickard D. Hutchinson (1979–82) and Richard D. Feltis (1983–86) served as Chiefs. Lawrence A. Merritt served as Head of the Billings Field Headquarters from 1987 through 1994. Others assigned to the office included Sheldon D. Ayers (1979–80), Bruce M. Bochy (1979–94), Lawrence E. Cary (1979–94; initially a BLM employee participating in the Scientist Exchange Program but subsequently reassigned to the USGS in 1982 and assigned to the Hydraulics and Hydrology Unit in Helena in 1988), Betty G. Cowger (1979–85), Richard D. Feltis (1979–83), James L. Fisher (1979–94), Thomas I. Follinglo (1979–94), David M. Flynn (1980–82), Douglas E. Gibbs (1979–80), Joel D. Johnson (1980–84), Roger W. Lee (1979), David W. Litke (1979–84), Lawrence A. Merritt (1979–87), William R. Miller (1979–80), Willard J. Page (1979–82), Joseph D. Paige (1982), Marian D. Piatte (1979–94), Ronald P. Rioux (1979), B. Paul Schmitt (1979),

Jeffrey D. Stoner (1979), Steven A. Strausz (1979), and D. June Thomsen (1979–82).

Fort Peck Field Headquarters.—The Fort Peck office was located at the U.S. Army Corps of Engineers Administration Building at Fort Peck Dam. Norwood B. Melcher served as Office Chief in 1979 before he transferred to Louisville, Kentucky. Scott D. Waltemeyer served as Chief in 1981 and 1982 before transferring to Sante Fe, N. Mex. Kenneth L. Tangen served as Office Chief from 1983 through 1990. John J. French was Chief from 1991 through 1994. Others assigned to the office during the period included Robert J. Brandle (1992), John J. French (1979–91), Michael R. Johnson (1980–94), Kenneth G. Nieskens (1979–85), Kenneth L. Tangen (1979–82), and Virginia Redstone (1979–94).

Helena Field Headquarters.—The Helena Field Headquarters was collocated with the District Office in Helena during the period. The Chief was Ronald R. Shields in 1979 before he was promoted to Chief of the Hydrologic Surveillance and Analysis Section. Millard M. Hiner was Chief of the office from 1980 through 1990. Stephen V. Lynn was Chief from 1991 through 1994. Others assigned to the office included Robert J. Brandle (1991), Clarence L. Chambers (1979–89), Richard O. Clausen (1979), Ranald G. Cramer (1991–94), Roy S. Darnell (1983–90), James E. Elliott (1979–83), James R. Finley (1980–85), Philip L. Karper (1981–94), Stephen V. Lynn (1979–91), Norman A. Midtlyng (1979–86), Timothy J. Morgan (1991–94), Leslie R. Murray (1979), Steven W. Nichols (1990–94), Scott K. Quimby (1987), Kevin L. Sattler (1991–94), William F. Schoch (1986), Andrew A. Skerda (1982–94), and Sally A. Staley (1981–83).

Kalispell Field Headquarters.—The Kalispell office was located in the Western Woodwork Building at 1015 E. Idaho St., Kalispell. Edward J. Blank served as the Office Chief from 1979 to 1984 when he retired. Raymond J. Weinberg served as Office Chief through the remainder of the period. Others assigned to the office included Richard L. Clements (1984–90), James R. Finley (1986–94), Douglas E. Gibbs (1981–82), Thomas Hall (1980), Shirley K. Nicholson (1979–83), Laverne G. Sultz (1991–94), Raymond J. Weinberg (1979–84), Joseph F. Williamson (1980–81), and Wayne A. Wood (1984–86).

FUNDING AND COOPERATION

The Federal-State Cooperative (Coop) program grew steadily throughout the period with minor exceptions. The Coop program increased from $0.74 million in 1979 to more than $2.27 million in 1994. Funding from other Federal agencies (OFA) experienced relatively small fluctuations from year to year and remained essentially constant through the period. The OFA program reached a peak of $1.62 million in 1993 and was lowest in 1987 at $1.12 million. The Federal (Fed) program conversely had large changes through the period. The Fed program was more than $1.64 million at the beginning of the period but declined steadily until it reached a low of $0.38 million in 1988. In 1991, the Fed program increased substantially to more than $1.06 million but the increase was brief. In 1993, the program again declined and remained below $0.85 million through the end of the period.

Federal-State Cooperative Program

The Coop program grew in funding, diversity, and number of cooperators during the period. In 1979, nine cooperators funded primarily data-collection programs, but by the end of the period, 14 State and local entities were supporting collection of basic hydrologic data, local and regional hydrologic assessments, and basic and applied research on various topics. The growth in program is a clear reflection of the diligence and entrepreneurial efforts of the Montana staff. It is important to note that the growth occurred during a period when State and local agencies were struggling under severe financial constraints.

Several State agencies maintained cooperative programs throughout the period. The Montana Department of Natural Resources and Conservation supported streamflow and reservoir monitoring programs to manage State water projects and adjudicate water rights. They also participated in the water-use inventory program and, on occasion, supported investigative projects related to water management. The Montana Bureau of Mines and Geology supported ground-water monitoring activities and local and regional ground-water investigations. The Montana Department of Fish, Wildlife, and Parks supported streamflow and water-temperature monitoring programs and investigations related to fishery habitat concerns. The Montana Department of Health and Environmental Sciences supported water-quality

monitoring programs related to waste-discharge permitting activities and also supported an investigation of ground-water quality in the Clarks Fork of the Yellowstone River valley. The Montana Department of Transportation supported a statewide crest-stage gage monitoring program related to bridge and highway design. They also supported an investigation of peak runoff from small watersheds and bridge-scour studies. The Wyoming State Engineer's Office provided funding each year for streamflow monitoring required by the Yellowstone River Compact Commission.

Other State agencies that participated in the Coop program during the period included the Montana Department of State Lands, the Montana Department of Agriculture, the Governor's Office, and the Montana Reserved Water Rights Commission. The Department of State Lands programs were primarily related to coal-mining permit activities. The Department of Agriculture contributed funding for an investigation of ground-water quality in the Clarks Fork of the Yellowstone River valley.

The Governor's Office supported water-quality and sediment data-collection programs related to Superfund activities in the Clark Fork Basin. The Montana Reserved Water Rights Commission provided funds to collect streamflow records needed in the adjudication of water rights.

Local agencies that participated in the Coop program during the period included Lewis and Clark City/County Health Department (ground-water investigations in the Helena Valley), Missoula and Powell Counties (ground-water investigations in the Swan-Avon area), Daniels County Conservation Board (investigation of brine contamination in the Poplar River Basin), Musselshell County (water use), the cities of Helena and Bozeman (streamflow monitoring), Montana State University and the University of Montana (streamflow monitoring), Blue Ribbons Area Planning Organization (streamflow monitoring), and Beaverhead County (ground-water investigations in Dillon area).

In 1983, the Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation and the Salish and Kootenai Tribes of the Flathead Indian Reservation entered into cooperative agreements with the District to collect hydrologic information needed for negotiations with the Montana Federal Reserved Water Rights Commission. In 1989, a cooperative agreement with the Fort Belknap Indian Reservation was developed to conduct ground-water studies on tribal lands. A cooperative program with the Blackfeet Nation was initiated in 1990 to investigate ground-water resources. In 1993, a cooperative program to investigate the effects of irrigation on ground-water resources was initiated with the Northern Cheyenne Indian Reservation.

Other Federal Agencies

Several Federal agencies relied upon information from District hydrologic monitoring programs to fulfill their objectives and missions. For example, the Omaha District of the U.S. Army Corps of Engineers needed streamflow and sediment information in the Missouri and Yellowstone River Basins to manage reservoirs in the Missouri River system. The Seattle District of the Corps of Engineers funded streamflow, water-quality, and limnological data-collection programs in the Kootenai River Basin to manage Koocanusa Reservoir. The Bureau of Reclamation in Regions 1 and 6 funded streamflow and reservoir-stage monitoring sites in order to manage reservoirs in the Missouri and Flathead River Basins. Federal Energy Regulatory Commission and Bonneville Power Administration funded streamflow-monitoring programs related to hydroelectric facilities. The U.S. Forest Service funded streamflow-monitoring sites on National Forest lands. The Department of State, through the International Joint Commission, funded collection of streamflow and water-quality data needed to apportion water in transboundary streams in accordance with treaties with Canada. All of these agencies maintained relatively constant programs throughout the period.

Department of the Interior agencies were major cooperators during the period. From 1979 through 1988, the Bureau of Land Management (BLM) provided substantial funding through the Energy Minerals Resources Investigations and Analysis (EMRIA) program to investigate potential effects of coal extraction on hydrologic systems. The BLM Montana State office also provided funds to investigate ground-water supplies, water conservation facilities, and waste-disposal sites. The Bureau of Indian Affairs provided substantial funding during the 1980's to monitor streamflow and investigate ground-water resources on Indian reservations to aid in negotiations with the Montana Federal Reserved Water Rights Commission. A consortium of Interior agencies including the Bureau of Reclamation, Fish and Wild-

life Service, Bureau of Indian Affairs, and the U.S. Geological Survey provided funds to investigate water-quality problems associated with irrigation drainage. The National Park Service funded water-supply studies and investigations of geothermal features in Yellowstone National Park.

Other Federal agencies that provided funding during the period included the Environmental Protection Agency (water-quality and sediment-transport monitoring in support of Superfund activities in the Clark Fork Basin) and the Federal Emergency Management Agency (flood-insurance studies).

Federal Program

U.S. Geological Survey funding (Fed program) fluctuated substantially during the period. In 1979, funds were provided for geothermal investigations, coal-hydrology studies, and regional groundwater investigations—the Madison Limestone study and the Northern Great Plains RASA. The geothermal program and the Madison Limestone studies ended in 1980 and the Northern Great Plains RASA program ended in 1981. In 1985, the coal-hydrology program ended. From 1986 to 1990, Fed program funding was limited to data-collection programs. In 1991, the Rocky Mountain Intermontane Basins RASA program was initiated. That program ended prematurely in 1994. The same year, the Northern Rockies National Water-Quality Assessment (NAWQA) Program began.

SUMMARY OF PROGRAMS

Hydrologic-Data Programs

The District routinely was among the first in the Nation to complete the Annual Data Report and met every WRD target for date of transmitting camera-ready copy of the report to the printer. Primary responsibility for quality assurance of streamflow records was delegated to White. Knapton was responsible for water-quality records. Lambing reviewed and approved sediment records. Levings, Reed, and Chambers were responsible for quality assurance of groundwater information.

Streamflow stations.—At the beginning of the period, the District operated 226 continuous streamflow-monitoring sites. The number of sites grew to 260 in 1983 and then declined to a low of 202 sites in 1988. The number of sites again increased after 1988 and ended the period with a total of 224. The number of seasonal sites varied from 0 in 1979 to 55 in 1985. From 1979 to 1983, the District operated about 170 crest-stage gages. In 1984 and 1985, the District operated 192 crest-stage gages, but the number decreased to about 160 in 1986. In 1992, following a statewide review of the network, the number of crest-stage gages was reduced to about 105 sites. The District took advantage of every opportunity to install DCP's in gaging stations and had a total of 75 in operation by 1994.

State agencies that supported streamflow monitoring included the Department of Natural Resources and Conservation; Department of Fish, Wildlife and Parks; and the Department of Transportation. Local agencies that supported either long-term or substantial short-term streamflow monitoring included Lewis and Clark County, Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation, Salish and Kootenai Tribes of the Flathead Indian Reservation, and the City of Helena. Federal agencies supporting streamflow-monitoring activities included the U.S. Army Corps of Engineers, Bureau of Reclamation, Bonneville Power Administration, Federal Energy Regulatory Commission, Bureau of Indian Affairs, Department of State, and Fish and Wildlife Service.

Water-quality stations.—The District operated 18 National Stream-Quality Accounting Network (NASQAN) stations from 1979 through 1981, 19 stations in 1982 and 1983, 18 stations from 1984 through 1986, 16 stations from 1987 through 1992, 15 stations in 1993, and 11 stations in 1994. The District also operated numerous miscellaneous water-quality stations in cooperation with State and Federal agencies. In 1979, the number of miscellaneous sites monitored was 80; but the number grew to 125 in 1983, largely as a result of monitoring activities related to coal-hydrology studies. When the coal-hydrology program ended, the number of sites declined significantly and fluctuated between 55 and 75 sites through the remainder of the period.

The major State agency that supported water-quality monitoring activities was the Department of Health and Environmental Sciences. The Department of State Lands and the Department of Fish, Wildlife, and Parks also supported water-quality monitoring. Federal agencies that supported water-quality monitoring activities included the Corps of Engineers, Department of State, U.S. Environmental Protection Agency, Bureau of Reclamation, National Park

Service, Bureau of Indian Affairs, and Fish and Wildlife Service.

Sediment stations.—The District operated 5 daily sediment stations in 1979, but the number of monitoring sites grew steadily to a high of 13 stations in 1990. At the end of the period, the District operated 12 stations. Sediment-monitoring activities were funded by the Fed program (long-term fluvial-sediment research in the Powder River Basin), the Corps of Engineers (reservoir operations in the Yellowstone and Missouri River Basins), and the U.S. Environmental Protection Agency (transport of heavy metals in the Clark Fork Basin).

Because of the large number of daily sediment stations operated by the District and the logistics of transporting sediment samples during winter months, the District operated a sediment laboratory in Helena during most of the period. Laboratory activities were limited to measurement of total suspended-sediment concentrations of samples collected at District sediment stations.

Ground-water levels.—The number of observation wells equipped with continuous recorders ranged from a low of 5 in 1994 to a high of 31 in 1992. During most of the period, about 20 observation wells were equipped with recorders. In addition, the District operated a large number of miscellaneous water-level monitoring sites in conjunction with project activities. The number of wells being measured varied from year to year but averaged about 150. In 1992, the number of wells measured was 276.

The Montana Bureau of Mines and Geology maintained a statewide observation well program during the period. To avoid duplication of effort, the District limited ground-water monitoring activities to national networks, Federal programs, and data collection in support of projects.

International Activities

The District Chief (George Pike from 1979 to 1984 and Joe Moreland from 1985 to 1994) served as the Field Representative for the St. Mary–Milk River Apportionment Committee for the International Joint Commission. The Committee operated a network of stream, canal, and reservoir monitoring stations to determine natural flow in the St. Mary–Milk River Basins and apportioned water between Canada and Montana in accordance with terms of the Boundary Waters Treaty. Many of the stations were operated on a seasonal basis, but apportionment was based on yearly water yields of the basins. Annual meetings were held with Water Survey of Canada and Provincial water agencies in Alberta and Saskatchewan to approve records, apportion flow, and compile annual reports to governments.

In 1981, Moreland served as the U.S. representative on an international committee formed to investigate the potential effects of the proposed Cabin Creek Coal Mine in British Columbia on the North Fork Flathead River Basin. Seepage measurements in the North Fork and its tributaries, a geology reconnaissance, and a water-quality inventory were done. A report summarizing findings of the study was prepared for the International Joint Commission.

In 1985, during a period of prolonged drought conditions, below-normal flow in several streams that flow north out of Montana into the Milk River caused concern among Canadian water users. At their request, the International Joint Commission formed the Southern Tributaries Task Force to investigate water use in the basin and seek solutions to problems. Moreland served as the U.S. Co-Chair of the Task Force. Personnel in the International Section and their counterparts from Canada conducted several synoptic flow studies in the tributaries to document runoff, diversions, and return flows and to quantify gains and losses from ground water. Tuck conducted an investigation of ground-water resources in the Sweetgrass Hills area to determine ground-water withdrawal rates, areas of ground-water discharge, and underflow to Canada. The Task Force conducted several inspection tours, held two public hearings, and prepared a final report to the International Joint Commission that summarized findings and outlined alternatives.

Pike (1979–84) and Knapton (1984–94) served as the U.S. Co-Chairs of the Poplar River Bilateral Monitoring Committee of the International Joint Commission. The Committee was responsible for monitoring the impacts of the Coronach coal-fired powerplant just north of the international boundary. The District monitored streamflow and water quality in the East Poplar River at the international border, and the Montana Bureau of Mines and Geology monitored ground-water conditions. Annual meetings were held with Canadian officials to exchange information and prepare an annual report to the International Joint Commission.

Hydrologic Investigations

Regional ground-water studies.—At the beginning of the period, the District was involved in two multi-District regional ground-water investigations: the Madison Limestone study and the Northern Great Plains RASA program. William Miller led the Montana District efforts on the Madison Limestone study, and Hotchkiss was Chief of the Northern Great Plains RASA program.

The federally funded Madison Limestone study ended in 1981, but the Montana Bureau of Mines and Geology continued to support mapping studies by Richard Feltis under the Coop program through 1983. Monitoring of potentiometric pressure in two deep test wells installed during the Madison Limestone study continued through the remainder of the period. Miller produced a series of potentiometric maps for several regional aquifers as part of the Madison Limestone study, and Feltis completed a series of structural contour maps for aquifers and confining layers.

The Northern Great Plains RASA project also ended in 1981. During the course of the project, the District contributed to Professional Papers authored by regional project staff and completed numerous reports summarizing the results of data-collection efforts in the State. Levings and Feltis produced several hydrogeologic maps of the Montana portion of the study area. Fleigner and Hotchkiss constructed several subregional ground-water flow models.

In 1990, the District initiated the Rocky Mountain Intermontane Basins RASA program. Clark was selected to serve as Project Chief. Although the project was terminated prematurely in 1994, project personnel worked diligently to complete several reports that were well underway when funding was terminated. Kendy conducted ground-water/surface-water investigations in stream reaches connecting intermontane basins. Briar conducted geophysical studies in several basins and developed Geographic Information System (GIS) products. A series of map reports was produced that described the geologic history and hydrogeologic units, water levels, and water quality for the intermontane basins. Reports summarizing well inventories, water-quality sampling efforts, and general hydrologic characteristics were compiled.

Coal-hydrology investigations.—Studies to assess effects of potential coal mining on hydrologic systems was a major part of District activities throughout the period, but the level of effort declined substantially in 1985 when Fed program funding ended. The BLM EMRIA program provided substantial support to coal-hydrology efforts, but the level of support decreased significantly after 1988. The Montana Department of State Lands provided support through the Coop program from 1982 through 1990.

Coal-hydrology investigations included regional assessments of ground-water resources by Hotchkiss, Lee, Lewis, Stoner, and Slagle; water-quality investigations by Knapton, McKinley, and Litke; surface-water investigations by Ferreira; ground-water modeling by Hotchkiss; salinity modeling by Woods; geochemical investigations by Davis; runoff modeling by Cary; and site-specific ground-water studies of potential mine areas by Cannon and McClymonds. Wilke provided oversight of contractors hired to inventory wells and conduct seepage studies and produced compilations of data from contractors.

To integrate all of the various hydrologic studies conducted in support of the coal-hydrology program, the District produced several Coal Area reports. These reports provided a synopsis of surface-water, ground-water, and water-quality conditions in specific areas and provided a summary of available hydrologic information for use by agencies responsible for managing State and Federal coal resources.

Ground-water appraisals.—Numerous ground-water appraisal studies were done during the period. Many were part of a long-term cooperative program with the Montana Bureau of Mines and Geology. Several studies were done on Indian reservations either in support of Bureau of Indian Affairs water-rights issues or in cooperation with individual tribal governments. Other studies were done in cooperation with local agencies.

Areas where ground-water appraisals were done include Flathead Indian Reservation (Boettcher, Slagle), Fort Belknap Indian Reservation (Feltis, Briar), Swan-Avon area (Wilke), Helena Valley (Moreland, Leonard, Briar), Cascade County (Wilke), Lake Creek area (Wilke), Stillwater area (Feltis), Big Hole Basin (J. Levings), Clark Fork alluvium (Brooks, Nimick), Sweetgrass Hills (Tuck), Fort Peck Indian Reservation (Levings, Thamke), Pryor Creek (Briar), Blackfeet Reservation (Cannon), Clarks Fork Yellowstone River (Slagle), and Gallatin Valley (Slagle).

Hydraulics and surface-water hydrology studies.—Omang and Parrett conducted flood studies for Housing and Urban Development (HUD) in Lewis and Clark County and Cascade County. They also

mapped flood areas along the Poplar River on the Fort Peck Indian Reservation and along streams in the Northern Cheyenne Indian Reservation.

Omang, Parrett, and Holnbeck conducted investigations of bridge sites after extreme runoff events and initiated research on the effects of peak flows on scour at bridge sites throughout Montana. Holnbeck and Parrett conducted research on extending short-term records from precipitation stations to estimate the frequency of extreme precipitation events for use in determining streamflow characteristics in small, ungaged watersheds.

Omang and Parrett studied streamflow characteristics in the Upper Missouri River Basin, Yellowstone River Basin, and other major streams in Montana. Natural flow studies were conducted in the Milk River Basin. Irrigation return flows were documented in the Musselshell River Basin.

Parrett used channel-geometry techniques to estimate streamflow characteristics at numerous sites. Streamflow characteristics obtained from these measurements were used in a variety of programs including water-rights negotiations, highway and bridge design, and water-management studies.

Water-quality investigations.—Knapton compiled baseline information on water-quality conditions in streams in the Powder and Tongue River Basins as part of coal-hydrology programs. Ferreira and Woods studied salinity in the Redwater River, Tongue River, Powder River, Rosebud Creek, and Armells Creek. Woods developed a salinity model of the Tongue River for use in evaluating the cumulative effects of potential coal development in Wyoming and Montana.

Ferreira conducted limnological studies in several reservoirs in Phillips and Valley Counties for the BLM to determine effects of land use on reservoir water quality. Throughout the period, the Kalispell Field Headquarters collected limnological information in Koocanusa Reservoir for the Corps of Engineers. Reservoir managers were concerned that mining and industry in the Kootenai River Basin in Canada might result in eutrophication. Ferreira and others used limnological data collected from the date of initial filling of Koocanusa to simulate water-quality conditions.

Knapton and Nimick monitored naturally occurring arsenic discharging from geothermal areas near Yellowstone National Park. Synoptic sampling exercises were conducted in the Gallatin and upper Missouri Rivers to determine arsenic loads and document the effects of biological activity on arsenic concentrations. Nimick collected samples from wells near irrigated areas to determine if irrigation return flows contributed to arsenic concentration in the Missouri River.

Geochemistry and ground-water contamination studies.—Davis investigated geochemistry in coal-mine spoils at Decker and Big Sky mines. He also conducted laboratory experiments to predict post-mining ground-water-quality evolution.

Clark investigated movement of pesticides in shallow ground-water systems in the Yellowstone River Valley. He also conducted research on the use of environmental tracers to document rates and patterns of ground-water flow in the Dillon area. Ground-water flow rates determined by measurement of environmental tracers were compared with results of a digital ground-water flow model.

Briar investigated the effects of septic tanks in the Bitterroot River Valley. Land-use planners used the results of the study to develop zoning regulations in proposed subdivisions.

Levings and Thamke investigated ground-water salinity in oil fields in the Poplar River Basin. Levings mapped contaminated areas and related increases in chloride in the Poplar River to ground-water discharge. Thamke used geophysical techniques to define the vertical and lateral extent of saline plumes in the vicinity of oil fields.

Moreland and Lawlor investigated solid-waste disposal sites on BLM lands to determine potential effects on ground-water quality. No significant effects were noted.

Irrigation-Drainage Studies.—Knapton and Nimick conducted irrigation-drainage studies in the Sun River and Milk River drainages in cooperation with the Bureau of Reclamation, Fish and Wildlife Service, and Bureau of Indian Affairs. Initial screening investigations led to more detailed studies in the Greenfields Bench area of the Sun River drainage and the Benton Lake area. In addition to collecting water samples and describing hydrologic conditions, Knapton and Nimick served as principal authors of final reports for the program.

Superfund Activities.—The U.S. Environmental Protection Agency requested assistance from the District to monitor transport of heavy metals in the Silver Bow Creek–Clark Fork system. Lambing designed and operated a network of daily sediment stations and conducted several synoptic sampling exer-

cises in 1993 and 1994. Kendy and Nimick provided technical assistance to the U.S. Environmental Protection Agency on ground-water modeling and ground-water geochemistry. Primary assistance was in the form of technical reviews of study plans and contractor reports.

District personnel also provided technical assistance to the U.S. Environmental Protection Agency on several National Priority List sites during the period. Sites included wood-treatment facilities at Somers, Bozeman, and Butte and mining- and smelting-related sites at East Helena, Butte, Anaconda, and along the Clark Fork downstream as far as Missoula. Assistance was primarily in the form of technical review of contractor reports and design of data-collection programs. Briar, Davis, Kendy, Lambing, Moreland, and Nimick provided most of the technical assistance for these sites.

NEBRASKA

By William M. Kastner
Reviews *by* Glenn B. Engel *and* A. Douglas Druliner

INTRODUCTION

Nebraska, like most of the Plains States, is dependent on irrigation to support its major industry, which is agriculture. Throughout the 1979–94 period, approximately 95 percent of Nebraska's surface-water and ground-water usage was devoted to irrigation. Irrigation, especially ground-water irrigation, increased during that period. Water tables declined in some areas where there was ground-water irrigation and rose in other areas where surface water was used for irrigation. The courts and the State Legislature formally recognized that surface and ground water could not be treated separately. This realization resulted in a change in the demand for data collection and for project work in the Nebraska District. Another factor that affected the data-collection and project work was the growing deterioration of water quality of surface water and ground water and heightened awareness of this deterioration.

ORGANIZATION

Throughout the period the Nebraska District Office and the Lincoln Subdistrict/Field Headquarters were located in Lincoln in the Robert V. Denney Federal Building, 100 Centennial Mall North. The Lincoln Field Headquarters was responsible for data collection in eastern Nebraska. Field Offices also were located in Ord and Cambridge. The Ord office collected data in the north-central part of the State and the Cambridge office in the south-central and southwestern areas. The USGS presence in Cambridge ended in 1986. A new Field Office was created in North Platte in 1992. The responsibilities of this office were primarily connected to the Central Nebraska Basins National Water-Quality Assessment (NAWQA) project.

The Nebraska Department of Water Resources (NDWR) and the USGS shared office space in Ord and Cambridge. Some NDWR personnel were present in all Field Offices and were under USGS supervision.

PERSONNEL

The District Office and Field Headquarters were staffed by 38 employees in 1979. The number of employees declined over the next few years to totals in the mid-30's. In 1987 and 1988 the number of personnel reached a low of 26 employees when the consolidation of the Kansas and Nebraska Districts was under consideration and the filling of vacancies was put on hold. After 1988, with the filling of vacancies and an increase in funding, the numbers of employees increased and reached a high of 41 by 1993. At the end of the period there were 35 employees in the District.

Office of the District Chief

William M. (Bill) Kastner transferred from the Texas District in 1979 to become the District Chief in Nebraska. He moved to the Central Region Office in mid-1988 and Glenn B. Engel acted as District Chief after Kastner's departure until December 1988. After transferring from the California District, Michael V. Shulters served as District Chief from December 1988 until he returned to the California District in 1993. The next District Chief was Linda S. Weiss. She transferred to the District from Maryland and served in the position from 1993 through the end of the period.

The District secretaries during the 1979–94 period were Arlene P. Summers, from 1979 until she retired in 1981, and Mary Jo Griffin from 1990 through 1994.

Agnes M. Watson was the District Administrative Officer from 1979 until her retirement in 1983. Rebecca O. Colberg, who had served in the Section under Watson, became the next Administrative Officer until she resigned in mid-1984. Mary Jo Shlotfeld was hired in December 1984 and served as Administrative Officer through the end of the period. Others who served in the Section were Jane M. Green (1979–81), Lou Ann Quinn (1991–94), Judi A. Liebig (1989–92), Mary A. Siske (1989), and Mary A. Long (1993).

The Technical Services (Computer Services) Section was headed by Donald E. Schild until he transferred to the Colorado District in 1992. John W. Eno, who had been working in the Section since 1990, became Section Chief in 1992 and served through the remainder of the period. Others who were attached to the Section were Jean E. McKinney (1979–81), Leona G. (Bunny) Loerch (1979–86), Janice C. Sybrandts (1979–92), David J. Burchell (1992–94), and Muhammad H. Azadmanesh (1993).

Hydrologic Surveillance (Data Management) Section

The Hydrologic Surveillance Section included personnel in the District Office as well as all the employees in the Field Headquarters. At the beginning of the period, in 1979, Lester R. Petri supervised the Section. He retired in 1981 and returned in While Actually Employed (WAE) status. In 1982 Glenn B. Engel was promoted from within to be Section Supervisor. He served in the position through 1994. Others who served in the Hydrologic Surveillance Section were Richard A. (Dick) Engberg (1979–82), Jack A. Anderson (1979–85), Martin S. Johnson (1979–84), Eugene K. Steele, Jr. (1979–86), Neal R. (Dick) Harmon (1979–94), Carol G. Hoy (1979–94), Robert B. (Bob) Swanson (1979–81), Jean E. McKinney (1981–91), Judith A. Boohar (1981–94), Lloyd C. Blackburn (1984–85), Paul A. Bartz (1991–94), Francis J. Jelinek (1991–94), and Janice C. Sybrandts (1993–94). The publication of data reports was handled by members of the Section.

Hydrologic Investigations (Studies) Section

Throughout the period all personnel in this Section were attached to the District Office in Lincoln. The position of Section Chief was vacant during 1980 and 1981. Engberg was Section Chief from 1982 until he transferred to the Iowa District in 1986. The position was again vacant until 1990 when Daniel J. Fitzpatrick transferred to the District. He was Section Chief through 1994.

Others who worked in the Section were Robert A. (Bob) Pettijohn (1979–82), William F. (Bill) Lichtler (1979–82), Michael J. Ellis (1979–94), Hsui-Hsiung (Abraham) Chen (1979–94), Jon M. Peckenpaugh (1979–94), David I. Stannard (1979), Charles W. Conklin (1979), Jack T. Dugan (1979–94), Paul A. Bartz (1979–91), David M. Schwartz (1979–83), Jean E. McKinney (1991–92), Roger E. Adams (1983–94), A. Douglas Druliner (1984–94), Norman W. Higley (1985), Ryne D. Hobbs (1985), Edward E. Fischer (1986–88), Ronald B. Zelt (1988), Gregory V. Steele (1988–94), Dwight Q. Tanner (1989–91), Sandra S. Luebbe (1989), Mary W. Siske (1990–91), Kimberly M. Studnicka (1990), David R. Halsinger (1990–92), Jill D. Frankforter (1990–94), Jodi R. Norris (1991–92), Ingrid M. Verstraeten (1991–94), Tim S. McGrath (1992–94), Denise L. Johannes (1992), Virginia A. McGuire (1992–94), Donald E. Robinson (1993), Michael E. Wieczorek (1993), and Anna M. Sojka (1993–94).

Various personnel within the Hydrologic Investigation Section handled the publication duties for the unit.

Lincoln Subdistrict/Field Headquarters

The Chief of the Lincoln Field Headquarters was Maynard Kubicek throughout the period from 1979 through 1994. Other personnel during the period were Lloyd C. Blackburn (1979–84), Judith A. Boohar (1979–81), Stephen H. Hull (1979–94), Robert B. (Bob) Swanson (1981–83), David M. Schwartz (1984–94), Gregory V. Steele (1984–88), Vincent C. Walezyk (1986–94), Michael T. Thompson (1989), Thomas G. Shudak (1989–92), Joel A. Petersen (1989–90), and Steven M. Johnson (1992–93).

Ord Subdistrict/Field Headquarters

The supervisors in the Ord Field Headquarters were Howard D. (Dean) Stephens (1979–82), Richard C. (Dick) Beard (1983–87), Frances J. Jelinek (1988–91), Robert B. (Bob) Swanson (1992), and Ronnie A. Drudik (1993–94). Nonsupervisory personnel in the office were Kenneth H. Calver (1979–84), Drudik (1979–93), Lou Ann Quinn

(1979–81), Lorraine M. Sidak (1981–87), Swanson (1985–92), Virginia A. John (1987–94), and Kevin L. Sheldon (1993).

Cambridge Subdistrict/Field Headquarters

In the Cambridge Field Headquarters, the head of the office was Clarence R. (Bob) Liggett (1979 until the office closure in 1982). Others who served in the office were Marjorie M. Gilbert (1979–82), Loyd K. Thompson (1979–83), and Robert B. (Bob) Swanson (1983–85).

North Platte Field Headquarters

The North Platte office was opened in 1992. Daniel E. Hitch arrived in the office in 1993 and served as Office Chief. Others in the office were Swanson (1992–94), Dwain L. Curtis (1992–94), and Kimbra A. Miller (1994).

FUNDING AND COOPERATION

The Nebraska District funding from 1980 through 1994 is given in the funding table. The figures are listed by Federal funding (Fed), funds from other Federal agencies (OFA), and the State and local agency contributions to the Federal-State Cooperative (Coop) program.

The total funding remained relatively constant from 1979 through 1987, varying only about 6 percent. In 1988 the total funding increased by 23 percent in response primarily to added project work in the Coop and OFA categories. From 1989 through 1994 the total funding increased an additional 71 percent. The Coop and OFA funds increased moderately and then declined. The primary reason for the increase in the 6-year period was due to large increases in Fed funding and the inception of the Lower Kansas River Pilot National Water-Quality Assessment (NAWQA) and the Central Nebraska Basins NAWQA projects, which began in 1989 and by 1994 made up approximately 40 percent of the total District budget.

The District received the Federal funding through the USGS budget process which consisted of funds for maintaining a national data network and also project funding to support projects of national interest. The Federal funding also included the Federal share of the Federal-State Coop program.

The other Federal agency (OFA) funds received by the District during the period were from the Omaha and Kansas City Districts of the U.S. Army Corps of Engineers; Bureau of Reclamation (BOR), either directly or through the Federal Missouri River Basin program; Department of Energy; Federal Emergency Management Agency (FEMA); National Weather Service; Bureau of Indian Affairs (BIA); and the U.S. Environmental Protection Agency (USEPA). Most of the OFA funding was used by the District to collect and supply data to the other agencies; however; interpretive studies were funded by BIA, FEMA, and USEPA.

The cooperators' contribution to the Federal-State Coop program came in the form of matching financial support or repay and in the form of in-kind direct services. The Nebraska Department of Water Resources (NDWR) was the major cooperator in the surface-water data program. Most of the NDWR contribution was in direct services. The University of Nebraska Conservation and Survey Division (CSD) was the major cooperator in the ground-water data program. The CSD also cooperated in interpretive project activities. Much of their cooperation was in direct services. The cooperation with the Nebraska Natural Resources Commission (NNRC) was largely in interpretive studies. The cooperation was a varying mix of repay and direct services. Other State and local agencies who cooperated with the District during the 1979–94 period were the Nebraska Department of

Nebraska District funds, fiscal years 1980–94

[Source: Nebraska District funding status reports; funds in thousands of dollars]

Funding source	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fed	1,289	1,259	1,237	1,124	1,173	1,173	1,126	1,217	1,302	1,208	1,263	1,363	1,824	2,842	2,979
OFA	157	195	115	145	219	235	336	189	386	499	460	403	282	279	341
Coop	535	539	597	609	656	564	604	594	703	703	731	864	814	767	768
TOTAL	1,981	2,000	1,949	1,879	2,047	1,972	2,066	2,000	2,391	2,410	2,454	2,631	2,920	3,888	4,088

Environmental Control, Nebraska Department of Roads, Nebraska Department of Health, Kansas-Nebraska Big Blue River Compact Administration, and the cities of Lincoln, Grand Island, and Omaha.

The entire geographic area of Nebraska was divided into 24 Natural Resource Districts (NRD) until 1989 when 2 were joined to reduce the total to 23 NRD's. These districts had taxing authority and were responsible for the natural resources in their areas. Nearly all the NRD's cooperated with the District in varying degrees between 1979 and 1994. Their cooperation was in interpretive studies as well as in the collection of data. With the exception of the Water Use Program, their contributions were in repay.

SUMMARY OF PROGRAMS

HYDROLOGIC DATA COLLECTION

Surface-Water Stations

In 1979, 158 streamflow-gaging stations were operated by the USGS in Nebraska. The number of stations remained relatively stable through 1991 then decreased to 121 stations by 1994. Because of a declining interest in the development of new surface-irrigation systems, funding from some sources such as the BOR Missouri River Basin Program was curtailed. Some of the stations that lost funding were long-term record stations. In general, other agencies were found to furnish funding so the stations could be continued. Throughout the period, however, a growing number of stream gages were funded for only short periods of time.

Interest in partial-record and miscellaneous stations declined early in the period, and the number of stations dropped rapidly from 53 in 1979 to 15 in 1984 and then declined more slowly; by 1994 there were only 5 remaining.

Gages to provide the stage and contents of reservoirs and lakes remained stable throughout the period, changing in numbers from 10 in 1979 to 11 by 1994.

Ground-Water Records

During the 1979–94 period there were approximately 70,000 irrigation wells in Nebraska plus municipal, domestic, and industrial wells. Water-level measurements were collected by the USGS and State and local agencies from approximately 3,000 of the wells in 1979, with the number increasing to approximately 3,900 wells by 1994. The number of wells with continuous water-level recorders varied in the period, depending on areas of special interest. In 1979 there were 80 wells with continuous water-level recorders. The number decreased to 65 in 1982, then steadily increased to 119 by 1994.

The water-level data collected were used to compile an annual water-level change map in cooperation with the CSD. Lead personnel in creating these maps and supervising the ground-water data collection were M.J. Ellis, M.S. Johnson, and G.V. Steele.

Observation-well data published in the "Annual Water Resources Data of Nebraska" report represented a very small fraction of the total data collected and ranged from only 55 to 65 wells.

Water-Quality Data Collection

The water-quality data published by the District varied greatly from year to year, depending on changes in local interest and project work. These water-quality data were from stream-gaging stations, ungaged stream sites, and wells. The sampling from stream-gaging stations varied from a high of 58 in 1979 to a low of 17 in 1992, and ended with 20 in 1994. At ungaged stream sites, the number of collection points was 44 sites in 1979. A low of 3 was in 1992; the high for the period was in 1994, with 46 sites sampled.

There was a large variation from year to year in water-quality sampling from wells published by the District. The overall trend, however, was an increase in the wells sampled as interest in ground-water quality increased. One hundred ninety-two wells were sampled in 1979, and 255 were sampled in 1994. The most sampling sites with collected data published by the District were 336 in both 1991 and 1993, and the fewest were 57 in 1982.

The water-quality information published in the "Annual Water Resources Data of Nebraska" report does not represent a complete picture of the amount of water-quality data collected, for much data collected in multi-District Federal projects were published outside the District.

Sediment Data

The number of regular sediment-data-collection sites was seven to eight sites throughout the period. Shorter term sediment data also were collected for certain projects. The funding for sediment data collec-

tion was from BOR and various USGS Federal programs. Engel and Hoy were responsible for the program.

Water-Use Data

The Water-Use Program was in operation from 1979 through 1994. Data were supplied to the USGS National Water-Use Data System, and District reports were prepared at 5-year intervals. Main cooperators on the project were the NNRC and NDWR. Many State and local agencies provided data used in the Water-Use Program. Lead authors were E.K. Steele, P.A. Bartz, and J.D. Frankforter.

Atmospheric Precipitation Record

There was one atmospheric-precipitation collection site located in North Platte, which was operated from 1979 through 1994 as part of the National Trends Network. The data were published by the National Atmospheric Deposition Program. This site was operated in conjunction with the CSD.

The "Annual Water Resources Data of Nebraska" reports covered most aspects of the hydrologic data collected by the USGS in the State. Lead personnel responsible for the reports were Engel and Boohar.

INTERPRETIVE HYDROLOGIC STUDIES

Projects with Areal Interest

Projects covering a specific area of the State where interest existed in the general hydrology of the area or in a particular phase of the hydrologic cycle in the area were carried out throughout the 1979–94 period. Many of the studies used hydrologic modeling techniques to define the hydrology and to provide a predictive tool.

General hydrology studies were conducted in Box Butte County (Pettijohn), south-central Nebraska (Peckenpaugh), the southern Sand Hills (M.S. Johnson), the Republican River Basin (Ellis), and the Central Platte and Lower Loup NRD's and Tri-Basin NRD (Peckenpaugh).

Specific phases of the hydrologic cycle in a specific area were investigated in the Big and Little Blue River Basins where stream/aquifer interrelationships were studied (Ellis), in the Niobrara River where streamflow characteristics and trends were investigated (Fischer), and in the Upper Republican NRD where the effects of ground-water withdrawals were studied (Peckenpaugh).

Interest in water quality increased during the period, and areal investigations included an atrazine and herbicide study in the Big Blue Basin (Frankforter), urban surface-water quality in Lincoln (Pettijohn and Blackburn), and ground-water quality in the Nemaha NRD (Tanner and G.V. Steele). At the end of the period there were several studies in progress to define surface- and ground-water quality in NRD's, Indian reservations, and the city of Omaha.

Studies of Statewide Interest

There were statewide studies and studies that covered local sites but had results that were applicable to the entire State or a large portion of the State. Examples of these studies are an appraisal of ground-water quality in Nebraska (Engberg, WSP 2245), an investigation of artificial recharge to aquifers (Lichtler), a definition of floods and droughts (Engel), a surface-water network evaluation (Engel), an examination of the occurrence of atrazine and nitrate beneath a corn field at Sheldon, Nebr. (Druliner), a study of nonpoint-source agricultural chemical contamination of ground water in six areas of the High Plains (Chen and Druliner), an investigation in using surface geophysical methods for collection and verification of hydrologic data in the Sand Hills (Ellis), and several reports and studies on the water-level changes in the High Plains aquifer since predevelopment (Dugan and McGrath).

Multi-State Studies

Multi-State studies were in progress throughout the 1979–94 period. The projects were conducted either in the Central Region Office or in other Districts. Most of the interpretation and publication of reports took place outside the Nebraska District. The Nebraska District played an important role in the projects, however. The District collected and provided data. District personnel provided the local expertise, wrote ancillary reports, and were secondary authors on major publications. Some of these projects were as follows: High Plains Regional Aquifer-System Analysis (RASA) (Ellis and Pettijohn, Nebraska participants); Central Midwest RASA (Ellis, Nebraska participant); Lower Kansas River National Water-

Quality Assessment (NAWQA) (Tanner, Nebraska participant); Central Nebraska Basins NAWQA (Ellis, Nebraska participant); Toxic Substances Hydrology Program (Druliner, Nebraska participant); and Water-Level Changes in the High Plains Aquifer Project (Dugan, Nebraska participant).

A series of projects resulted in publications that encompassed all the above-mentioned project categories. Dugan's knowledge of the hydrologic characteristics of soils contributed to many of Nebraska's areal studies wherein Dugan was able to relate soil characteristics to consumptive water use and to ground-water recharge. It also made possible the mapping and description of the hydrologic characteristics of soils in Nebraska (WSP 2222), in Arkansas, Colorado, Kansas, Missouri, Nebraska, New Mexico, Oklahoma, South Dakota, and Texas (HA 678), and in the areas covered by the High Plains, Northern Great Plains, and Central Texas Carbonates regional aquifer systems (HA 714).

NEW MEXICO

By Robert L. Knutilla, *and* John P. Borland, *including articles provided by* Gary W. Levings, Douglas P. McAda, *and* Scott D. Waltemeyer, *and reviewed by* Russell Livingston and James Blakey.

ORGANIZATION AND PERSONNEL

As the 1979–94 period began, the New Mexico District consisted of the Headquarters Office in Albuquerque, Subdistrict Offices in Albuquerque and Santa Fe, and Field Headquarters in Carlsbad, Las Cruces, Roswell, San Antonio, and Silver City. An Office of the Chief Hydrologist was also in Albuquerque. These offices were staffed by approximately 85 employees. By 1994 the offices in Roswell, San Antonio, and Silver City were discontinued, the Albuquerque Subdistrict Office was converted to a Field Headquarters, and Las Cruces was upgraded to a Subdistrict Office.

District Headquarters, Albuquerque

Office of the District Chief. — In 1979, the District Office was in the Western Bank Building at 505 Marquette NW. In 1987, the office was relocated to the Pinetree Park at 4501 Indian School Road NE where it remained through 1994. William E. Hale entered the period as District Chief and continued in that capacity until he retired and was succeeded by James F. Daniel in 1980. Daniel was transferred to the Reston Headquarters in 1985 and was replaced by Robert L. Knutilla, who transferred from Tampa, Fla. Knutilla retired in 1989 and was succeeded by Russell K. Livingston, who continued as District Chief through 1994. Associate District Chiefs were Pat L. Soule until 1988 when he retired, Livingston (1988–89) until his reassignment as District Chief, and Rodger F. Ferreira (1989–94).

Secretaries in the District Chief's office were Bobbie Cloud until 1983, Jacqueline E. Savage (1983–85), Pamela K. Overson (1986–87), Darla E. Straka (1987–90), Barbara C. Henderson (1991–92), and Dorothy L. Fuch (1994).

Elsie F. Sanchez was the Administrative Officer at the beginning of this period. She continued as Administrative Office until 1988 when she retired. The position was vacant until it was filled in 1990 by Clifford E. Peterson (1990–92) and by Rita Childress (1993–94). Others who served in the Administrative Section were Sulema A. Atencio, Arabella L. Mora, Ruth E. Adams, Nora R. Graeme, Denise Dennett, Nancy E. Vigil, Laverna K. Patterson, Martha Sueur, David P. Wasson, Valerie V. Yanez, Leslie S. Duran, and Renee Garcia.

During this reporting period, one major change was computer use for data storage and computer applications for investigative projects. Eventually most employees had a computer terminal on his or her desk. Because of this change, the District formed a Computer Unit to handle hardware and software problems. In 1983 the Unit consisted of three employees: Edward V. Thomas, Jeffrey James, and Benjamin Garcia. Subsequent employees in the Unit were Daniel O. Winkless, Dirk R. Martinez, Linda V. Beal, Darcy Person, Patrick M. Rael, and Cynthia J. Shattuck. Although the Unit increased in size, initially it consisted of three or four employees as computer users became more proficient in computer applications.

The Publications Section in 1979 was headed by David W. Wilkins and staffed by nine employees, seven of whom worked part-time. Wilkins was succeeded by Robert R. White in 1980, John V. Flager (1981–87), and Henry R. Hejl, Jr. (1988–90). In 1990, the Section was reorganized entirely along functional lines with Harriet R. Allen heading the Editorial Unit and Herbert M. Grossman the Drafting Unit.

Employees in the Section were Ann F. Wright, Deidre J. Jeys, Olga M. Sandoval, Barbara J. Henson, Shareen G. Duncan, Pamela K. Overson, Juan A. Medina, Arcilia M. Alvarez, Mary Montaño, Cynthia J. Shattuck, Darla E. Straka, Anthony F. Castillo, Mary C. Simmons, Victoria I. Mikolajczak, Petra L. Dickey, Janelle N. Gonzales, and Emma V. Bencoma. There were generally about eight or nine employees in the Section.

Office of Chief Hydrologist, Albuquerque.—In 1979 this office was located with the District Office in Albuquerque. Charles V. Theis, a Research Hydrologist, was assigned to the office. He was assisted by Marc W. Bodine, Jr., a consultant. The office was discontinued in 1987.

The Field Offices.—In 1979, responsibility for collection of hydrologic data was distributed among eight offices. Four of the offices were discontinued during the 1979–94 reporting period.

Albuquerque Subdistrict.—In 1979 the office was located at 3540–B Pan American Freeway, NE. John P. Borland was the Hydrologist-in-Charge. The office was relocated in 1987 to 5821–D Midway Park Boulevard. Borland continued in charge until 1988 when he transferred to the District Office. Richard P. Raione (1988) and subsequently Robert L. Gold (1988–94) followed Borland as Hydrologist-in-Charge.

In the initial part of the reporting period, the office staff consisted of six to nine individuals. In 1987, the District Water Quality and Sediment Laboratory responsibilities were reassigned from the District Office to the Subdistrict. Thereafter, the office staff ranged from 12 to 15 in size. Other staff during the period were Jim C. Schafer, David Ortiz, Luis C. Madrid, Tino J. Quintana, Anita M. Garcia, Phillip C. Teeters, Edward E. Fischer, John J. Rote, David H. Marshall, Gerald L. Young, Veronica L. Alarcon, Richard P. Thomas, Georgianna E. Kues, Kevin D. Metzger, Richard L. Lepp, Robert M. McBreen, Harriet R. Allen, Dale R. Rankin, Harry W. Yoder, Steven Lewandowski, Cecilia D. Foghorn, Frankie Franco, Mark A. Salvatore, Kathy M. Lange, John W. Heaton, George H. Sieber, Gary R. Roybal, David E. Funderburg, Scott A. Kimball, Brian Gutierrez, Greg Mendez, Jamie Warren, Drew Milewski, Mark L. Shewmake, and Jeremy G. Larson.

Santa Fe Subdistrict.— In 1979 the office was located in Room 115 of the Federal Building on Cathedral Place. William K. Dein was the Hydrologist-in-Charge. The office was relocated to 1939 Warner Circle in 1991. Dein remained in charge until 1984 when Herbert S. Garn, who transferred from the Bureau of Land Management, was assigned to that position. He was subsequently succeeded by D. Michael Roark in 1992. Other staff members located in Santa Fe were Louis J. Reiland, J.L. Kunkler, Robert R. White, Terry J. Perkins, Bobby R. Tribble, Pedro Gonzales, Massie F. Ortiz, Richard P. Thomas, Scott D. Waltemeyer, Clinton E. Nagel, Carolyn W. Raney, David A. Shaull, Robert M. Moquino, Lynn A. Garrabrant, Phillip C. Teeters, Roy J. Martinez, Victoria Cordova, Fred Gebhardt, Dennis Vander Meer, and Mary K. Young.

Field Headquarters, Roswell.—In 1979, the office was located in Room 127 of the Federal Building and U.S. Courthouse. The office was staffed by Ronald L. Rogers, a Hydrologic Technician. The office was closed in 1986 and Rogers retired.

Field Headquarters, San Antonio.—In 1979 Emilio Pargas was the Hydrologic Technician in charge. The one-person office was charged with data-collection responsibilities in the Middle Rio Grande area. The office was discontinued in 1987 when Pargas retired.

Field Headquarters, Carlsbad.—In 1979 the office was located in Room 101 of the Federal Building. Loyd A. Waite was the Hydrologist-in-Charge. Waite transferred to Missouri in 1981 and was replaced by Richard A. Hunrichs in 1982. Hunrichs transferred to California in 1986. Ronny L. McCracken was assigned as Hydrologic Technician-in-Charge from 1986 to 1992, and Glenn A. Todd for the remainder of the period. Other staff members were R.K. DeWees, Jr., Martha J. Moore, John S. Simitz, Penelope S. Birckett, Shareen G. Duncan, Barbara S. Bronwynn, Ronald L. Rogers, Lois A. Watson, Benjamin S. Carr, Kathy Hamilton, and Bennett G. Phillips.

Field Headquarters, Las Cruces.—In 1979 the office was located with the Water Resources Research Institute on the campus of New Mexico State University. The sole employee at the time was Clyde A. Wilson. In 1982 Brennon R. Orr was assigned to the office as Supervisory Hydrologist. In 1990 Robert G. Meyers was placed in charge; Meyers was succeeded by Michael E. Slifer in 1994. Other staff employees were Edward L. Nickerson, Clinton D. Nagel, Paul E. Reed, and George T. Basabilvazo. The office was

upgraded to Subdistrict status in 1988 to reflect the expanded project activities undertaken.

Field Headquarters, Silver City.—In 1979 the office was located at 109 West Broadway Street. Ronny L. McCracken was the sole employee at that time. The office was discontinued in 1981, and McCracken transferred to the Carlsbad office.

Field Headquarters, Farmington.—The Farmington office was established in 1981 and continued operating until 1984. It was located at 2014–A San Juan Boulevard. The office consisted of two hydrologic technicians: David A. Shaull (Technician-in-Charge) and Phillip A. Teeters. When the office closed, Shaull and Teeters transferred to the Santa Fe office.

Hydrologic Data Collection/Management.— The Section was responsible for collection and publication of streamflow, water-quality, sediment, and ground-water level data. These programs were primarily overseen by a District Office staff with support from each Subdistrict Office and Field Headquarters. Section Chiefs during the period were Louis P. Denis (1979–87) and John P. Borland (1988–94). Others, besides those in the Field Offices, who were assigned to the data program were Eileen F. Roybal, Henry T. Mottl, Jim D. Hudson, Bruce M. Delaney, Howard E. Lobley, Roy R. Cruz, Linda V. Beal, Carolyn W. Raney, Harry W. Yoder, Dale R. Rankin, Gerald L. Young, Cecilia D. Foghorn, Robert L. Gold, Kim Ong, R.K. DeWees, Jr., Harriet R. Allen, David Marshall, Darcy Person, Patrick M. Rael, Henry K. Gabaldon, Benjamin M. Garcia, James A. Basler, Shareen G. Shelton, Deanne D. Kimball, David E. Funderburg, Richard Lepp, Robert M. McBreen, Steven Lewandowski, Jim C. Schafer, and Ronny L. McCracken.

During the period 1979–94 the data-collection workload and staffing fluctuated due to the loss of energy-related investigations in northwestern New Mexico, reductions in funding for water-quality sampling by the Office of New Mexico State Engineer/ Interstate Stream Commission, and continued expansion of the Albuquerque Urban Project.

Hydrologic Investigations Section.— Approximately 70 people (mostly hydrologists) were assigned to this Section during this reporting period. During the period the Section was given various other titles, but the main purpose was investigations. Section Chiefs were John S. McLean, Harvey L. Case, Kathy D. Peter, and Rodger F. Ferreira. Others who were assigned to the Section were Donald L. Hart, Glenn A. Hearne, Walter A. Mourant, George E. Welder, Douglas R. Posson, Peter F. Frenzel, Douglas P. McAda, Raymond G. Roybal, Brennon R. Orr, James A. Basler, Judith Lee, Helen E. Hagan, Victor R. Lira, Carmen M. Goke, Benjamin M. Garcia, Jerry W. Mercer, William B. Scott, Paul A. Davis, Henry R. Hejl, Kim Ong, Jack D. Dewey, Forest P. Lyford, John J. Rote, Edward D. Villanueva, Larry V. Boyd, Thomas M. Crouch, Amjad M. Umari, Joe A. Baldwin, Carole L. Goetz, Robert W. Hull, Robert L. Klausing, Kenneth E. Stevens, Dennis W. Risser, Bruce M. Delaney, Randall Hanson, Eileen F. Roybal, Gary R. Roybal, Cynthia M. Abeyta, Georgianna E. Kues, Elizabeth Padgett, Pamela Overson, David W. Wilkins, John M. Kernodle, Oscar Tibbets, Daniel O. Winkless, Scott K. Anderholm, Charles Kaehler, Kevin F. Dennehy, Jane G. Wells, Peter B. Davies, Robert R. White, James A. Basler, Shareen G. Duncan, Steven F. Richey, Darla E. Straka, Leslie S. Duran, John V. Flager, Paul J. Blanchard, Ralph W. Wilcox, Charles E. Heywood, Don J. Irwin, Dale R. Rankin, Dirk R. Martinez, Felix Torres, William L. Dam, Conde R. Thorn, Stephen H. Lewandowski, Roger A. Durall, Allen C. Gellis, Fred Gebhardt, Paul A. Reed, Carole L. Thomas, Elizabeth A. Benavidez, Robert J. Rogers, Jack E. Veenhuis, Jerry D. Larson, Joseph J. Szalona, Orlando Romero, Patricia A. Kincaid, Henry K. Gabaldon, and Carol A. Remington.

FUNDING AND COOPERATION

During the period 1979–94, the amount of funding available for the Cooperative (Coop) programs doubled. Even though the program kept up with inflation, the amount of funding failed to match the amounts that cooperators had to produce to match funds for additional work. At times during the period the cooperative program with the Office of the New Mexico State Engineer/Interstate Stream Commission resulted in a 53/47 percent match due to the lack of additional Coop funds. This type of split was also used for other long-term Coop programs (such as the Pecos River Commission) during the period.

Following the end of coal hydrology studies in northwest New Mexico, Federal funding to the District declined until the start of the Regional Aquifer-System Analysis (RASA) for the San Juan Basin in northwestern New Mexico. Federal funds increased and then decreased during the study period (1984 to 1990).

New Mexico District funds, fiscal years 1979–94

[Funds in thousands of dollars; Source: District program documents 1979–92; Administrative Information System records for 1993–94]

Fund source	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	1,718	1,863	1,884	N/A	N/A	N/A	1,527	1,747	2,386	2,775	3,081	3,039	3,209	3,281	3,590	3,648
OFA	1,062	1,187	1,081	N/A	N/A	N/A	639	689	874	1,416	1,520	2,438	2,607	3,582	4,135	3,495
Fed	840	1,474	1,353	N/A	N/A	N/A	730	896	996	925	774	657	617	997	1,481	2,105
Total	3,621	4,524	4,319	n/A	N/A	N/A	2,896	3,332	4,256	5,116	5,375	6,134	6,433	7,860	9,206	9,248

The amount of Federal funding received in 1991 was the smallest amount received during the period. Federal funds increased again in 1992 with the start of the Rio Grande Valley National Water-Quality Assessment (NAWQA) study. Funding increased in each of the remaining years through 1994 as the new NAWQA study became fully operational.

As the coal hydrology studies ended, so did interest in the area by other Federal agencies (OFA). This resulted in a reduction in the amount of funding from OFA through 1985. An increase in OFA funds started in 1986 when the Bureau of Land Management (BLM) requested the District to study an area near Farmington to determine if ground water in the area was being contaminated by discharge from a refinery bordering BLM land. In 1987 the District was asked by Kirtland Air Force Base (KAFB) to continue a study begun by private contractors in 1981 to determine whether there was any contamination of ground water at the base. This Installation Restoration Program (IRP) was the start of extensive work with the Department of Defense for IRP work at other military sites in the State and at KAFB.

As indicated by the table, Coop funds in general increased throughout the period. Whereas in 1979 Coop funds represented 47 percent of the total District budget, they represented only 39 percent in 1994. In contrast, OFA funds represented 29 percent in 1979, but that percentage had increased to 38 percent by 1994. With the exception of the years when the coal hydrology studies were being conducted, the Federal portion of the District budget remained at approximately 23 percent.

SUMMARY OF PROGRAMS

Surface Water.—The Field Offices operated approximately 240 continuous-record stations on streams, reservoirs and lakes and 138 crest-stage gages in 1979. These numbers were reduced with discontinuance of approximately 20 continuous-record sites between 1982 and 1984 that were related to coal hydrology studies financed by Federal funding. It was also during this period that the WRD experiment to use private contractors to operating gaging stations in northwestern New Mexico, southwestern Colorado, and southeastern Utah ended. The crest-stage gage network, operated in cooperation with the New Mexico State Highway and Transportation Department, consisted of approximately 138 crest-stage gages through 1986. This number was reduced to 108 in 1987 and remained somewhat constant through 1994. What originally began in 1976 as a project consisting of two streamflow-gaging stations with rainfall recorders to study rainfall-runoff relationships in the Albuquerque metropolitan area developed into a large data-collection program. In 1994, the network consisted of approximately 25 seasonal streamflow- gaging stations with rain recorders and an additional 37 rainfall gages located at various fire stations, golf courses, schools, and residences throughout the city.

In 1979 there were no gaging stations that were equipped with data-collection platforms in the New Mexico District. Eight gaging stations were equipped with telephones operated by the National Weather Service, and these telephones were used as a flood warning system. In 1987, midway through the period, six telephones continued to be operated by the National Weather Service; however, 11 data-collection platforms (DCP's) had been installed, mostly by the U.S. Army Corps of Engineers (Corps). By 1994 there were 46 DCP's collecting streamflow data at gaging stations in the New Mexico District. Most of the new equipment was purchased by either the Corps or the Bureau of Reclamation but was installed and operated

by Water Resources Division staff. Only 2 of the 46 DCP's collecting data in the New Mexico District were owned by the District, but data received from all platforms operated by District staff was used in the computation of streamflow records and for storage. The National Weather Service continued to provide all maintenance of their DCP's but were convinced to change their reporting interval so streamflow records could be computed for the data received from their DCP's.

Of special interest during this reporting period was the recognition of 100 years of streamflow data collection on the Rio Grande at Embudo Station, N. Mex. The Embudo Station is the site where in 1889 a group of scientists assembled to develop and define methods for monitoring streamflow in the United States. In September 1989 a monument was erected at the site holding a plaque acknowledging it as the birthplace of stream gaging in America. The dedication ceremony was highlighted with the attendance of Manuel Lujan, the Secretary of the Interior, Stephen E. Reynolds, New Mexico State Engineer, and Dallas L. Peck, Director of the U.S. Geological Survey, as well as numerous interested individuals.

Ground Water.—In 1979, in cooperation with the Office of the New Mexico State Engineer, water levels were being measured in 97 observation wells across New Mexico. Of these, 16 wells were equipped with continuous water-level recorders in various parts of the State. These numbers had increased to 132 observation wells, and 21 were equipped with continuous recorders by 1994.

In the first week of January each year, from 1979 through 1994, staff from the Water Resources Division measured approximately 250 ground-water wells in the eastern High Plains. These water-level measurements were used by Water Resources Division personnel to draw maps that show the amount of ground-water depletion in the Ogallala Formation. These maps were then used by farmers, ranchers, and the Internal Revenue Service to determine the allowable ground-water depletion for income tax purposes.

Water Quality.—The surface-water-quality sampling network constituted about 91 stations in 1979. The primary cooperating agencies for baseline water-quality data were the New Mexico State Engineer, Interstate Stream Commission, and the Pecos River Commission. At times during the period (from 1979 to 1994) additional water-quality data were collected for the Bureau of Land Management, U.S. Army Corps of Engineers, Bureau of Indian Affairs, Bureau of Reclamation, National Park Service, and the Cities of Albuquerque and Gallup. Not included in the 91 stations are the water-quality data collected at ground-water sites for miscellaneous projects, which amounted to 340 additional samples being collected in 1979.

By 1988 the number of stations where baseline water-quality data were being collected was reduced to 59. This reduction was the primary result of the end of coal hydrology studies in northwestern New Mexico and reduced funding by the Bureau of Land Management and National Park Service resulting in discontinuance of sampling and gaging stations.

By 1994 the number of sites where baseline water-quality data were being collected was 51. The continued reduction in sampling sites was the result of two factors. First, the New Mexico State Engineer and the Interstate Stream Commission felt that they should not be financing the water-quality-sampling program. They felt that this program should be funded by the New Mexico Environmental Department. Therefore, with reduced funding to the water-quality- sampling program, several sampling sites were discontinued. The second reason was the reduction across the board of Federal Coop funds.

During the period, additional water-quality sampling took place in support of the following projects: High Plains RASA study, Evaluation of Water Resources at White Sands Missile Range, Hydrology of the San Andre-Glorieta Aquifer System, Geohydrology of the Estancia Basin, Availability of Ground Water in the Hueco Bolson Basin, and Movement of Radionuclides and other Trace Elements in the Puerco and Little Colorado River Basins of Arizona and New Mexico. Water-quality sampling also took place in support of two acid rain studies, six county studies, and Albuquerque Urban Stormwater Runoff.

Fluvial-Sediment Stations.—In 1979 sediment data were being collected at 95 sampling sites throughout New Mexico. At 15 of these sites a continuous record of sediment load was being computed from samples collected by a local observer and automatic samplers that collect at least one daily sample. Samples were collected more frequently during high-water runoff periods, particularly on sediment-rich streams such as the Rio Puerco and at gaging stations downstream from these sediment-rich tributaries.

Overall, the program continued to decline during the period. The number of sites where sediment data were collected fell from 95 in 1979 to 51 in 1988 to 38 sites in 1994. The number of stations where daily sediment samples were collected fell from 15 to 10 to 7 in 1994. Most daily sampling continued to be on the Rio Grande from Otowi Bridge to San Marcial and one site on the Rio Puerco. The New Mexico District continued to process most of their own samples but started to send some work to the Iowa District for size analysis. The major cooperator for the daily sediment program throughout the period was the office of the New Mexico State Engineer (SEO).

In addition to the previously mentioned water-level measuring program, a new program was begun in 1979 that was continued through 1994. The program was designed to develop a long-term data base in areas of ground-water development or potential development. The areas of ground-water development or potential development were scheduled for intensive water-level measurements at 5-year intervals. In the first year an area was measured intensively, the work consisted of an inventory of wells and collection of data such as depth to water in each well, well drilling and completion records, and well yields and water-quality analyses that could be obtained. Based on the data collected, wells were selected to use as observation wells that were representative of the primary ground-water aquifer. In addition, from each area a well was selected as a key well, and water levels were measured on an annual basis. At the start of the program between 1,500 and 2,000 wells were measured in the period January to March or before the start of irrigation season. In 1994, only about 1,200 wells were measured by the Water Resources Division and the SEO. Through this program, a data base of approximately 6,000 wells was developed.

During the entire period the District continued to monitor ground-water levels at White Sands Missile Range. The program began in 1960 and consisted of measuring ground-water levels in 100 supply wells, test wells, and boreholes throughout the missile range. Ground-water samples also were collected from selected test wells and supply wells, especially in the Post Headquarters area. The data collected provided staff at the missile range with information regarding the depletion of ground water, effects on the aquifer from pumpage, and possible saline-water encroachment from extended pumpage. As a result of the study, a flow model was developed to evaluate quantitatively future water-level declines and water-quality changes in the Post Headquarters well field.

Water Use.—During the entire period, a program to collect, store, and retrieve water-use data was financed in cooperation with the SEO. The purpose of the project was to take water-use data collected by the SEO and recompile the data into the Survey's categories of use, hydrologic units, and aquifers. In addition, the Survey had to collect or estimate data not collected by the SEO and then enter all of the collected and provided data into the Survey's Aggregated Water-Use Data System. These water-use data are now available for reports on the use of water in New Mexico and in the United States.

INTERPRETIVE STUDIES

Flood Investigations.—Flood investigations (highway program), in cooperation with the New Mexico State Highway and Transportation Department, have been a part of the District program since 1948. The project has provided information on flood-flow frequency characteristics at streamflow-gaging stations and techniques to provide estimates at ungaged sites, and indirect measurement of peak discharges at gaged and miscellaneous sites throughout the State. Project Chief since 1982 has been Scott D. Waltemeyer.

Rio Grande Valley NAWQA Program.—In 1991, the New Mexico District was one of the States chosen to implement a National Water-Quality Assessment (NAWQA) Program study. The long-term goal of the NAWQA Program was to describe the status of and trends in the quality of a large representative part of the Nation's surface- and ground-water resources and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources.

The study area chosen for New Mexico's NAWQA was the Rio Grande Valley, which included 45,900 square miles in Colorado, New Mexico, and Texas upstream from the streamflow-monitoring station on the Rio Grande at El Paso, Texas. One of the main reasons for the selection of the study area was that a large amount of surface-water-quality data had been collected for many years at streamflow-gaging stations and miscellaneous sites along the Rio Grande and its major tributaries.

Starting in 1992, a work plan was developed for the program, and the staff that had been assembled

took several training courses including water-quality sampling, biological activities in NAWQA, retrospective report writing, and Quality Assurance/Quality Control (QA/QC). Compilation of previously collected data continued in 1993, and data collection began at the sites selected for use in the study. In 1994 the first report was finished and described the spatial and temporal availability of nutrients, suspended sediment, and pesticides in the Rio Grande study area. Sherman Ellis was NAWQA Chief on this project.

Kirtland Air Force Base Installation Restoration Program (IRP).—The District was asked by staff at Kirtland Air Force Base (KAFB) in 1988 to conduct a series of studies at various sites to determine the extent and types of contamination that possibly existed on base property. Two successive studies had been done, starting in 1981, by private contractors that provided staff members with some data and sites requiring further study.

The District's agreement with KAFB was to assess conditions at 10 sites to evaluate potential contamination. Thirteen monitoring wells were installed and sampled on a quarterly basis that provided numerous samples for analysis of any changes taking place at each well. A report on the data collected was provided to KAFB.

This work led KAFB to request that the District begin a 3-year study in 1991 at additional sites. This effort included augering at over 80 sites for soil samples, installing 25 monitoring wells, and collecting ground-water samples at the monitoring wells. The quality and quantity of the work provided by the District staff at KAFB led to the Air Force and Department of Defense to request that the District do additional IRP work at Canon Air Force Base; Fort Bliss, Texas; Holloman Air Force Base; and White Sands Missile Range.

Regional Aquifer Study.—During 1985–91, the U.S. Geological Survey conducted the San Juan Basin RASA study in northwestern New Mexico. The assessment of the San Juan structural basin involved review and analysis of previous studies, acquisition of new data in selected areas, geochemical analysis of three sandstone aquifers, and development of a computer model to simulate ground-water flow. The focus of the study was on ground-water resources in sedimentary rocks of Triassic through Tertiary age as they are the only source of water in most of the basin. Industrial use increased substantially during the late 1970's and early 1980's because of increased exploration for and development of uranium and coal resources.

Early in the project, the decision was made to use Geographic Information System (GIS) technology to develop the general automated data compilation, data analysis, and map-production capabilities needed for regional geologic and hydrologic resource studies. The development of new GIS program interfaces led to high-quality cartographic products such as Hydrologic Investigations Atlases (HA) for 10 aquifers. This was one of the first studies in the USGS to combine GIS technology with a steady-state, three-dimensional ground-water flow model to simulate modern predevelopment flow in the post-Jurassic rocks. A Professional Paper on the geologic framework, a report on the geochemistry of the Morrison, Dakota, and Gallup aquifers, and a summary report also were produced. The RASA Chief for this project was Gary W. Levings.

Ground-Water-Flow Model Studies.—District hydrologists conducted several ground-water-flow model studies during 1979–94. Peter F. Frenzel and Forest P. Lyford constructed a steady-state model of aquifers in the San Juan Basin of northwestern New Mexico in cooperation with the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) and the New Mexico State Engineer Office (SEO). In cooperation with the Bureau of Land Management (BLM), Frenzel converted that model to transient state for evaluating the effects of proposed development of Federal coal leases in northwestern New Mexico. Douglas P. McAda constructed a model of the Ogallala aquifer in the southernmost part of the High Plains in Eastern New Mexico in cooperation with the SEO.

As part of the Southwest Alluvial Basins Regional Aquifer-System Analysis, Frenzel and Charles A. Kaehler constructed a model of the Mesilla Basin above El Paso, Texas; and John M. Kernodle, Roger S. Miller, and William B. Scott constructed a model of the Albuquerque-Belen Basin in central New Mexico. In cooperation with the International Boundary and Water Commission, Frenzel subsequently revised the Mesilla Basin model to reflect changes in the geologic interpretations of the basin and extend the simulation period. McAda constructed a model of the Española Basin in northern New Mexico in cooperation with the Santa Fe Metropolitan Water Board (SFMWB) and the SEO. In cooperation with the SFMWB, McAda subsequently modified the model and applied it to estimate potential future

effects of pumping on the Rio Grande. In cooperation with Los Alamos National Laboratory, Frenzel revised the Española Basin model to reflect changes in geohydrologic interpretations in the Los Alamos area and used it to estimate the effects of ground-water-withdrawal alternatives.

Brennon R. Orr and Dennis W. Risser constructed a model of the northern part of the Hueco Bolson Basin, located between Las Cruces and El Paso, in cooperation with the U.S. Department of the Army (Fort Bliss), the SEO, and the City of El Paso. Donald L.Hart constructed a model of the Tularosa Basin in the vicinity of Holloman Air Force Base in cooperation with the U.S. Air Force. Paul A. Davies constructed a variable-density ground-water-flow model in the vicinity of the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico in cooperation with the U.S. Department of Energy. Peter F. Frenzel constructed a model of the San Andres-Glorieta aquifer in west-central New Mexico in the Acoma Embayment and eastern Zuni Uplift in cooperation with the SEO, Pueblo of Acoma, Pueblo of Laguna, and the Bureau of Indian Affairs (BIA). Ronald H. Hanson, John S. McLean, and Roger S. Miller constructed a model of the Mimbres Basin, located in southwestern New Mexico, in cooperation with the SEO. Kernodle constructed a steady-state model of the San Juan Basin as part of the Regional Aquifer-System Analysis of the San Juan structural basin.

In 1993 the District began extensive study of the Albuquerque Basin in cooperation with the City of Albuquerque. The Project Chief was John M. Kernodle, and other team members were Douglas P. McAda and Conde R. Thorn. The study included development of a highly detailed and complex GIS-based model of the Albuquerque Basin based on a more recent interpretation of the hydrogeologic framework of the basin by the NMBMMR. This study resulted in conclusions about the future water supply for Albuquerque and other municipalities that had far-reaching effects nationally as well as locally. The study subsequently became the foundation for a very comprehensive USGS investigation of the basin, which was a collaborative effort by scientists from WRD, GD, NMD, NMBMMR, and SEO.

Hydrologic Investigations and Data-Collection in Coal Areas.—Expansion of coal mining to help in the Nation's needs in becoming energy self-sufficient resulted in the need for hydrologic information for coal development and environmental protection. As a result, several studies and data collection related to the effects of surface mining for coal were initiated in the late 1970's and continued into this reporting period.

The network of hydrologic data-collection sites in the strippable coal areas of the Fruitland Formation in northwestern New Mexico was designed to meet the need of detailed investigations and to provide hydrologic data to support expanding mining activity. In 1970 the data-collection network consisted of 9 streamflow stations and 21 annual maximum discharge stations in the coal area. This data-collection network increased to 34 streamflow stations, 20 stream-water-quality stations, 12 maximum discharge stations, 27 observation wells in coal seams, and 24 wells in channel alluvium downstream from coal areas. Resultant studies and reports based on data collected include geohydrology of the area, a hydrologic surveillance of coal-lease areas, precipitation-runoff modeling of watershed systems, hydrologic effects of proposed and actual coal mining activities, effects on water quality of downstream rivers, and results of water-resources monitoring activities.

Other Investigations.— In northeastern New Mexico, a study of the Ogallala aquifer, "High Plains Regional Aquifer-System Analysis," was conducted by Donald L. Hart. The purpose of the study was to determine the quantity and quality of water resources and operation of the system by collecting and analyzing data, hydrologic properties, recharge, quantity of pumpage, and distribution of pumpage.

Extensive work was done by Jerry W. Mercer and others in southeastern New Mexico in evaluating salt beds for use as a potential repository for defense-associated radioactive waste. Primary purpose was to determine the direction and rate of movement of ground water in the Rustler Formation in the vicinity of the selected site. The data collected provided the ground work for the establishment of the Waste Isolation Pilot Project (WIPP) that is now operational near Carlsbad, N. Mex.

Numerous studies were done during the period in the Rio Grande Valley of New Mexico. Early in the period, David W. Wilkins was Project Chief for a study on the entire Rio Grande from Alamosa, Colo., to Presidio, Texas. Later in the period, Edward L. Nickerson, Robert G. Myers, and Peter F. Frenzel also completed reports on the Rio Grande. Their area of study was primarily downstream from Elephant Butte Dam to El Paso, Texas. One other study of potential

interest was done by John M. Kernodle on land-surface subsidence in the area around El Paso. The International Boundary and Water Commission (IBWC) requested that the District study the potential for subsidence from lining and extending the American Canal near El Paso. The American Canal was unlined and transported irrigation water from the American Dam to the El Paso Valley. This unlined channel provided recharge to the aquifer that is extensively pumped for both municipal and industrial supplies. There were concerns that the lined channel would prevent recharge to the underlying aquifer and eventually cause land-surface subsidence.

NORTH DAKOTA

By Douglas G. Emerson *and* LaRue Baker-Odenbach, *including information provided by* Russell E. Harkness, Carolyn S. Helgesen, *and* Cathy R. Martin

ORGANIZATION AND PERSONNEL

As the period began, the North Dakota District consisted of a District Office in Bismarck and small Field Headquarters in Dickinson and Grand Forks. These offices were staffed by 52 permanent employees and two WAE (when actually employed) teachers who worked only during the summer. Students also were hired each summer to help with fieldwork. Annually decreasing personnel ceilings and the end of energy studies, regional aquifer studies, and the countywide ground-water studies resulted in a steady decline in the number of employees. In December 1991, the Field Office in Dickinson was closed and the stream-gaging related functions were transferred to the District Office in Bismarck. At the close of the period, the District had 40 employees.

District Headquarters, Bismarck

Office of the District Chief.—Leo Grady Moore, the fourth District Chief, served until January 1989 when he transferred to Albany, New York. In May 1989, William F. Horak, Jr., who had been a hydrologist in the District and had transferred to Oklahoma City, Okla., to become the Chief of their Hydrologic Studies Section, returned as the fifth District Chief.

Quentin F. Paulson continued as the Assistant District Chief until he retired in December 1983. After his retirement, the Assistant position was eliminated.

District secretaries, in chronological order, were Debbie S. Kolegraf and Lenora A. Hall.

Administrative Services Section.—Mildred M. Schneider was the Administrative Officer at the beginning of the period, but she retired in February 1982. She was succeeded by LaRue A. Baker-Odenbach in July 1982. Others who served in the Section were Helen M. Bullinger, Laurel A. Cottengaim, Michelle F. Gunderson, Sylvia L. Kempf, Ione K. Leet, Susan M. Morman, Deloris I. Roth, and Kathy J. Van Ningen.

Computer Services Section.—John Atwood and Carolyn Sue Helgesen provided computer services throughout the period and were first under the direct supervision of the District Chief. Then in 1990, a Computer Services Section was established with Atwood as the Section Chief. The District started the period using a terminal to send jobs to WRD Headquarters in Reston, Va., to be processed on the mainframe computer. By late 1983, the District started using a minicomputer. By the end of the period, a workstation was being used.

The national Water Data Storage and Retrieval (WATSTORE) system was stored on the mainframe computer in Reston, Va. WATSTORE was used for data processing, storage, and retrieval and basically remained unchanged for about 10 years. A new system called the National Water Information System (NWIS) required downloading water data from the central computer in Reston to the District computer. NWIS streamlined data processing, allowed direct entry of data relayed by satellite, and permitted processing of variable-interval data in addition to fixed-interval data.

All the surface-water streamflow and stage data were downloaded to the North Dakota District computer during 1984. In May 1985, all ground-water site information and water levels were downloaded from Reston. Water-quality data were downloaded to the District computer during 1986. A new Automatic Data Processing System (ADAPS) was installed on the North Dakota District computer in August 1987.

Publications Section.—At the beginning of the period, employees who had publication duties were part of the Hydrologic Studies Section with Orlo A. Crosby as Section Chief and Reports Specialist. Others who subsequently served as Reports Specialist were Robert L. Houghton, George Garklavs, and

Douglas G. Emerson. In June 1989, a Publications Section was established with Emerson as Reports Specialist and Section Chief. In 1992, Marjorie C. Pokladnik succeeded Emerson when he became Chief of the Hydrologic Studies Section. After Pokladnik's retirement in April 1994, the Reports Specialist duties and supervision of the Section again reverted to Emerson. Others who served in the Section were Luverne L. Albright, Valerie M. Dressler, Lenora A. Hall, Cathy R. Martin, and Geraldine B. Wald.

In 1980, manuscripts were prepared on a "memory" typewriter, which stored information on a magnetic card. The cards then could be read into memory, and corrections and updates could be made without retyping the entire page. In 1983, the District purchased word processors, which stored information on 8-inch floppy disks. Workstations were purchased in 1991, and desktop-publishing software was used to prepare and update manuscripts.

From 1980 until 1990, illustrations were produced by tracing images onto scribe material, which was a plastic material covered with an opaque film. An engraver, which cut through the film, was used to trace the images. In 1990, the District purchased a personal computer, which was used to import maps and produce lettering. Information was stored on 3.5-inch diskettes.

Hydrologic Records and Information Section.—The Section was composed of the unit in the District Office in Bismarck and the Field Headquarters in Dickinson and Grand Forks. Russell E. Harkness served as Section Chief for the entire period. Others assigned to the Section were Gilbert L. Berg, Mary E. Berger, Beryl A. Binde, Morris S. Brostrom, Laurel A. Cottengaim, Katherine M. Cox, Randall J. Ehlis, Robert W. Gauger, G. Eldon Ghering, Thomas A. Gleich, Norman D. Haffield, David B. Hanson, James D. Heidt, John B. Kelly, Steven W. Norbeck, Robert J. Renner, Dennis R. Rosenkranz, Larry L. Rutschke, Troy D. Rutter, Joseph A. Smath, Michael J. Voigt, Jeannette E. Wagner, and Edwin A. Wesolowski.

Hydrologic Studies Section.—Orlo A. Crosby served as Section Chief until his retirement in March 1985. He was succeeded by Robert L. Houghton who transferred to the Director's Office in Reston in 1987. Kenneth L. Lindskov transferred from Salt Lake City, Utah, in May 1988 and served as Section Chief until November 1991 when he transferred to the South Dakota District. In April 1992, Douglas G. Emerson became the Section Chief. Others who served in the Section were Clarence A. Armstrong, Wayne R. Berkas, Lawrence I. Briel, Kenneth F. Brinster, Jeffrey W. Brown, Raymond D. Butler, Steven W. Cates, Mack G. Croft, Douglas G. Emerson, Raymond E. Frandsen, R. Scott Guenthner, Anne H. Harrington, G. Eldon Ghering, William F. Horak, Jr., Robert L. Houghton, Robert E. King, Robert L. Klausing, Stephen C. Komor, Ronald L. Kuzniar, Robert M. Lent, Doris A. Larson, Jeffrey E. Miller, Steven W. Norbeck, Philip G. Randich, Kathleen M. Rowland, Thomas B. Reed, Bradley A. Sether, Kevin C. Vining, Tara J. Williams-Sether, David M. Sumner, James D. Wald, Edwin A. Wesolowski, Gregg J. Wiche, and Scott D. Zainhofsky.

Field Offices

As the period began, responsibility for collection of hydrologic data in North Dakota was distributed between the District Office and the two Field Headquarters that were organizationally part of the Hydrologic Records and Information Section. After closure of the Dickinson Field Headquarters in 1991, data collection in the eastern one-third of the State was assigned to the Grand Forks office, and data collection in the western two-thirds of the State was assigned to the Bismarck office.

Dickinson Field Headquarters.—In 1979, the office was located at 669 12th Street West. Roger A. Pewe was the Supervisory Hydrologist-in-Charge. The office was closed December 31, 1991, after George J. Klug retired and only one other employee was still assigned to the office. Other individuals who worked in the Dickinson Field Headquarters were Kelvin L. Boespflug, Douglas L. Ellenbecker, and Sharon L. Schwartz.

Grand Forks Field Headquarters.—During the entire period, the office was located in the Federal Building at 102 North 4th Street. Oren O. Holmen was the Supervisory Hydrologist-in-Charge until his accidental death in 1980. Gerald L. Ryan transferred from the Illinois District and served as Office Chief until 1989 when he transferred to Jackson, Miss. Ryan was succeeded by Norman D. Haffield, who in May 1990 transferred from the District Office in Bismarck to Grand Forks. Haffield served as the Office Chief through the rest of the period. Others who served in the Section were Gary J. Burkhart, Michael J. Burr, Rickey A. Creek, Glenn A. Fladmark, Yvonne R.

Haugland-Morrison, John B. Kelly, Rodney G. Kyar, Sandra I. Nordby, Roger A. Pewe, Randolph L. Prososki, and Wayne R. Westensee.

Funding and Cooperation

In the early 1980's District funding rose each year to keep pace with inflation. The Federal-State Cooperative (Coop) program more than doubled from $529,385 in 1981 to $1,490,826 in 1992. The District had a very fluctuating OFA (other Federal agency) program during this period. The Federal program for collection of hydrologic data decreased. Federal funding for projects increased, resulting in a rise in Federal funds.

Total annual funds rose during the period, ranging from $2,138,299 in fiscal year 1981 to $3,297,430 in fiscal year 1994. Programs were carried out in cooperation with approximately 23 Federal, State, and local agencies.

The District's data program was still mainly funded by the North Dakota State Water Commission, St. Paul and Omaha Districts of the U.S. Army Corps of Engineers, Bureau of Reclamation, U.S. Fish and Wildlife Service, as well as the International Joint Commission funding sites along the U.S.– Canada border. As the years went by, Coop funds could not keep up with inflation, and the District sought the cooperation of the local cities, water-resources districts, and watershed-management boards.

All the county studies that had been funded by the counties, North Dakota State Water Commission, North Dakota Geological Survey, as well as Federal-State matching funds, were completed during the period.

At the beginning of the period a significant part of the District budget came from funding for coal hydrology. Coal hydrology programs were funded by the North Dakota Geological Survey, North Dakota Public Service Commission, and the Bureau of Land Management. After the last coal hydrology project, the District no longer had funded programs with these cooperators.

In 1982, when the funding for coal hydrology programs started to decrease, programs in the James River Basin that were related to the Garrison Diversion Unit (GDU) started. The GDU work was funded by the Bureau of Reclamation, North Dakota State Water Commission, and the Federal program.

Devils Lake began to play an important part in the North Dakota District as the lake levels rose. Programs related to Devils Lake were funded by the St. Paul District of the Corps of Engineers, North Dakota State Water Commission, North Dakota Department of Health, and North Dakota Game and Fish Department.

The District started to perform work on the North Dakota Indian Reservations. In 1985, the District undertook the investigation of the Warwick aquifer on the Fort Totten Reservation in cooperation with the Bureau of Indian Affairs. The District began data programs and investigations with the Three Affiliated Tribes, Spirit Lake Sioux Tribe, and the Turtle Mountain Tribe. Funding and billing for these projects was frustrating because Tribal Council members and tribal water-resources staff changed frequently, and lines of authority were not in place.

SUMMARY OF PROGRAMS

Hydrologic-Data Collection

Since 1987, the annual data report, which is the Data Section's primary product, has been completed by April 1 each year. This accomplishment is due to the teamwork of all the staff in the Data, Computer, and Publications Sections.

North Dakota District funds, fiscal years 1980–94

[Coop, cooperative program; OFA, other Federal agency; Fed, Federal program; in thousands of dollars]

Fund source	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	1,047	1,133	1,110	1,304	1,3350	1,363	1,378	1,219	1,476	1,365	1,388	1,333	1,491	1,459	1,449
OFA	858	1,055	603	591	549,	902	1,169	1,153	1,050	934	660	669	894	840	1,081
Fed	848	790	555	539	539	438	388	447	385	530	744	723	597	8340	767
Total	2,749	2,975	2,319	2,433	2,423	2,703	2,935	2,819	2,911	2,828	2,791	2,725	2,982	3,133	3,297

The District started to phase out the 90 manometers that were being used in the District. The conversion away from mercury manometers was slow. The delay was primarily due to the expense of pressure transducers. In 1994, 75 stations were still equipped with mercury manometers. In the early 1990's, satellite data-collection platforms were being used to transmit data. By 1994, satellite data-collection platforms were being operated at 34 stations.

Streamflow stations.—The District was operating 144 continuous-record stations, 22 river stage stations, and 13 lake or reservoir stations in 1980. Then when the Coal-Lease Monitoring Program ended in 1981, the number of streamflow gages declined by 25 percent. At the same time, activities of the Garrison Diversion Unit increased, resulting in installation of several continuous-record stations in the James River Basin. From 1982 through 1994, the gaging network had minor fluctuations. Continuous-record stations varied in number from 103 to 112, river stage stations varied from 17 to 22, and lake or reservoir stations varied from 10 to 15. Eight crest-stage gages were installed in 1985. Crest-stage gages varied in number from 5 to 17 from 1985 through 1994.

Ground-water observation wells.—In 1979–80, the ground-water program consisted of a 950-well monitoring network operated in cooperation with the North Dakota State Water Commission. However, it became evident that well maintenance required significant amounts of time and effort. A ground-water network evaluation was done in the early 1980's and about 200 wells were discontinued. Observers were hired to read about 250 of the remaining 750 wells. USGS personnel were responsible for about 40 recorder wells, about 400 annual wells, and about 60 monthly or quarterly wells. The ground-water program continued a gradual reduction each year until it reached a total of about 575 wells in 1994. The number of observer wells had risen to about 300 wells by that time.

Water-quality stations.—In 1980, the water-quality network consisted of collecting water samples at 87 continuous-record stations, 33 river stage stations, 39 lake or reservoir stations, and 80 wells. From 1980 through 1994, the water-quality network had constant fluctuations. Collection of water-quality samples at continuous-record stations varied from 68 to 114, river stage stations varied from 0 to 4, lake or reservoir stations varied from 4 to 39, crest-stage gages varied from 0 to 13, and wells varied from 3 to 80.

Various programs affected the fluctuations. The discontinuation of the Coal-Lease Monitoring Program in 1981 significantly affected the water-quality data collection in western North Dakota at that time. In 1981–82, the increased data needs by the Garrison Diversion Unit resulted in the increase of water-quality studies in the James River Basin. A very intensive water-quality monitoring program grew and included monitors installed on rafts at the Arrowwood National Wildlife Refuge and three continuous water-quality monitors on the lower James River. Following the Garrison Reformulation Act of 1987, the needs by the Garrison Diversion Unit declined.

In the mid-1980's, the U.S. Fish and Wildlife Service started a Refuge Monitoring Program in the Souris River Basin. Extensive water-quality sampling was conducted at most streamflow stations in the basin. In 1989, the Souris River Bilateral Water Quality Monitoring Group was established in accordance with the Canada–United States Agreement for Water Supply and Flood Control in the Souris River Basin. Construction was started on two multipurpose dams, Rafferty and Alameda, in Saskatchewan. The Bilateral Group established water-quality objectives for the border crossings of the Souris River near Sherwood and Westhope, and multiparameter water-quality monitors were installed at both locations in 1992. The Bilateral Group recommended monitoring of the primary reservoirs in the basin; however, to keep the program costs down, the streamflow sites being monitored in North Dakota were reduced to the two border crossing sites and the sites upstream and downstream from Minot.

Water-use data.—A water-use program was conducted primarily for national reports on use of water in the United States. In 1980 and 1985, the program was in cooperation with the North Dakota State Water Commission, which received direct-services credit for data from their water permit system. Overhead funds were used to complete the 1990 water-use summary. State reports were produced on estimated use of water in 1980 and 1985.

Interpretive Studies

Cooperative ground-water investigations.—Since the early 1960's, the Geological Survey had continuing programs in cooperation with the State and

other Federal agencies to investigate the ground-water resources of the counties in North Dakota. The studies were conducted under county or multicounty boundaries, and every county had a report completed or in progress at the beginning of this period. Logan County by Robert L. Klausing; Bottineau and Rolette Counties by Philip G. Randich; McKenzie County by Mack G. Croft; and Towner County by Randich were all completed in the early 1980's. The era of county ground-water studies came to an end.

Other ground-water studies that were conducted included "Evaluation of Hydrologic Effects of Withdrawal on the West Fargo Aquifer" by Clarence A. Armstrong; "Evaluation of the Effects on Ground-Water Levels Due to the Rise in Water Level in Lake Audubon, McLean County, North Dakota" by Clarence A. Armstrong; "Evaluation of the Theory and Methodology for Quantifying Recharge and Evapotranspiration for Shallow Glacial Aquifers in North Dakota" by William F. Horak; "Public-Orientated Report on Ground Water in North Dakota in the Stop Format" by Quentin F. Paulson; "Ground-Water Resources of the National Grasslands of McKenzie County, North Dakota" by Mack G. Croft; and "Hydrology of the Fort Totten" by Thomas B. Reed.

A few studies had a significant surface-water or water-quality component to the study. Those studies included "Hydrology of Fort Berthold Reservation" by Steven C. Cates and Kathleen R. Rowland; "Mechanisms that Control Seepage of Saline Ground Water through Glacial Confining Units Beneath the Red River of the North and Its Tributaries" by Michael L. Strobel; and "Sheyenne Delta Aquifer" by Strobel.

Energy resources investigations.—The USGS conducted energy-related investigations through the mid-1980's. "Evaluation of Probable Hydrologic Effects of Future Lignite Mining and Subsequent Reclamation Activities in the M&M Deposit, Williams County, North Dakota" by William F. Horak; "Evaluation of the Hydrologic System in the New Leipzig Coal Area, Grant and Hettinger Counties, North Dakota" by Clarence A. Armstrong; "Evaluation of the Hydrologic System in the Sand Creek–Hanks Coal Area, Williams County, North Dakota" by Clarence A. Armstrong; and "Evaluation of the Hydrologic System in the Dickinson Coal Area, Stark County, North Dakota" by Clarence A. Armstrong were to assess the ground-water flow system and its chemical characteristics, determine the flow frequencies and magnitude, chemical quality, and sediment concentration and load of larger streams.

"Hydrology of Area 47, Northern Great Plains Coal Province, North Dakota" by Orlo A. Crosby and "Hydrology of Area 46 Northern Great Plains Coal Province, North Dakota" by Mack G. Croft and Orlo A. Crosby described the area in a hydrologic framework, a quantitative assessment of the occurrence and availability of water, an assessment of the present quality of available water, and identification of current and planned utilization of water.

Garrison Diversion Unit investigations.—The Garrison Diversion Unit in North Dakota was authorized by Congressional Act of August 5, 1965, Public Law 89–108. The Garrison Diversion Unit was to provide for (1) irrigation, (2) municipal and industrial water, (3) fish and wildlife, (4) recreation, and (5) flood control. The Garrison Diversion Unit Reformulation Act of 1986, Public Law 99–294, specified several modifications and amendments to the 1965 Act. Operation of the Garrison Diversion Unit in North Dakota may have various effects on the quantity and quality of streamflow in various streams in North Dakota. Several investigations and data programs were conducted to support Garrison Diversion Unit.

"Data Development and Analysis for Use in the Bureau of Reclamation Model on the James River" by Gregg J. Wiche, Douglas G. Emerson, and Rick D. Benson was the first Garrison Diversion Unit investigation. The study compiled and analyzed monthly discharge data needed as input to a planning flow model. "Generation of a Data Base for the James River Salinity Model, North Dakota and South Dakota" by Lawrence I. Briel generated input data required by the river salinity model of the Bureau of Reclamation to evaluate a variety of different management options and to index the effect of each option on water quality in the James River. "The Effects of Irrigation and Ground-Water Recharge Practices on the Quantity and Quality of Shallow Ground Water and on Soil Productivity Along the James River, North Dakota" by David M. Sumner provided sufficient data on the hydraulic and hydrochemical properties of the Oakes aquifer and overlying unsaturated zone to evaluate the effects of an irrigation/ground-water recharge management plan for the James River and Oakes aquifer on ground-water quantity and quality. "Evaluation of the Potential for Toxic-Element Consequences due to the Garrison Diversion Unit" by D.A. Goolsby, Wayne R. Berkas, G.F. Huff, and James D. Wald evaluated the potential

effects of expanded irrigation within the Garrison Diversion Unit on the mobility and availability of potentially toxic trace elements. "Data Development and Analysis for Use in Garrison Diversion Unit Monthly Operation Model on the James River" by Douglas G. Emerson compiled and analyzed monthly discharge data needed as input to a planning flow model for 1983–91.

Devils Lake Basin investigations.—The Devils Lake Basin is a 3,810-square-mile closed drainage basin. Changing lake levels are part of the natural condition. Studies and data-monitoring programs were conducted to better understand the hydrology of Devils Lake. Some of the investigations that were conducted were "An Investigation of the Hydrologic and Climatologic Mechanisms Controlling the Water-Surface Elevation of Devils Lake" by Gregg J. Wiche and "Evaporation and Ground-Water Interaction of Devils Lake, North Dakota" by Gregg J. Wiche; "Dissolved-Solids and Nutrient Budgets of Devils Lake, North Dakota" by Robert M. Lent; "Bottom-Sediment/Water-Column Interactions at Devils Lake, North Dakota" by Stephen C. Komor; "Effects of Bottom Sediments on Nutrient Cycles in Devils Lake" by Robert M. Lent; "Chronology of Mercury Loading to Devils Lake, North Dakota, Inferred from Sediment Core Data" by Robert M. Lent; and "Evaluation of Water-Quality Data for the Chain of Lakes and its Tributaries, North Dakota" by Robert M. Lent; "Frequency Analysis for Devils Lake, North Dakota" by Gregg J. Wiche; and "Variation in Surface-Water Quantity and Quality as a Result of the 1993 Summer Flood in the Devils Lake Basin, North Dakota" by Tara J. Williams-Sether, Robert M. Lent, and Gregg J. Wiche.

National Water-Quality Assessment Project.—The U.S. Geological Survey began implementing a full-scale National Water-Quality Assessment (NAWQA) Program in 1991 to address the need for national water-quality information. The Red River of the North Basin was selected as one of the study units. The first 2 years, 1991–92, focused on planning and analysis of available data. Starting in 1993, data collection and analysis were done. The project was managed by Jeffrey D. Stoner of the Minnesota District. The Grand Forks Field Headquarters conducted most of the data collection. Several North Dakota hydrologists assisted the NAWQA staff in completing data analyses.

Other investigations.—The District conducted a variety of other studies. Some of the studies were "Sampling Landscape-Stratified Snow Covers by Ground and Airborne Snow Survey Techniques" by Douglas G. Emerson; "Changes in Hydrologic Responses of the Red River of the North Basin, North Dakota-Minnesota" by Jeffery E. Miller; "Kinematic Wave Approximation of One-Dimensional Dynamic Waves" by Jeffery E. Miller; "Water Quality Assessment of the Souris River within North Dakota" by Edwin A. Wesolowski; "Hydrology of the Lower James River Basin in North Dakota" by Jeffery E. Miller; "Inventory of Information for Flood Plain Management in North Dakota" by Douglas G. Emerson; "Heat and Moisture Transport Model for Seasonally Frozen Soils in North Dakota" by Douglas G. Emerson; "Suspended-Sediment Transport in the Missouri River between Garrison Dam and the Headwaters of Lake Oahe" by Wayne R. Berkas; "Peak-Flow Frequency for Unregulated Streams in North Dakota" by Tara J. Williams-Sether; "Water-Quality Assessment of the Red River of the North near Fargo, North Dakota" by Edwin A. Wesolowski; "Predicting Scour at Bridge Crossing on Streams in North Dakota" by Tara J. Williams-Sether; "Effects of Evapotranspiration on Pesticide Distributions and Transport in the Unsaturated Zones of Northern Cornbelt Sand Plains" by Stephen C. Komor and Douglas G. Emerson; "Hydrologic and Human Aspects of the 1988–91 Drought in North Dakota" by Tara J. Williams-Sether, Kathleen M. Roland, and Douglas G. Emerson; "Nonpoint-Source Assessment of the Fort Berthold Indian Reservation, North Dakota" by Robert M. Lent and Kathleen M. Rowland; "Interactions between Hydrology, Water Quality, and Wetland Functions in the Prairie Pothole Region" by Kevin C. Vining; and "North Dakota Streamflow-Gaging Network Analysis" by Tara J. Williams-Sether.

An incident of data falsification.—A former employee of the USGS, Robert L. Houghton, was known to have falsified data related to his work as a hydrologist with the North Dakota District office. A USGS review of Professional Paper 1340 for which Houghton was the principal author revealed that the report had serious technical errors and that it contained fraudulent data. Houghton was the principal author of numerous other publications that related to the work he did in North Dakota. After reviewing these publications, senior USGS officials concluded that some of the information contained in several of the publica-

tions could not be validated positively. The position of the USGS, therefore, was to disclaim all of the publications, rather than to risk the propagation of possibly falsified data and technical findings. The USGS disclaimed 29 publications associated with Houghton.

OKLAHOMA

By James F. Blakey

ORGANIZATIONS AND PERSONNEL

As the period began, the Oklahoma District consisted of the District Office in Oklahoma City and Field Headquarters in Pryor and Woodward. Forty-seven of the 50 employees were located in the District Office; there was one technician in Pryor and two technicians in Woodward.

In 1983 the Pryor office was closed and the Tulsa Field Headquarters was established. Derryl White transferred from Pryor to Tulsa as Chief of the office. By 1988, the Tulsa staff had grown to five and was responsible for data collection in the eastern part of the State. In the early 1980's the District staff declined to about 40 with the loss of energy-related funds. New funding in Federal, Cooperative (Coop), and other Federal agencies (OFA) programs in the late 1980's resulted in the staff growing to more than 50 by 1989.

District Headquarters—Oklahoma City

Office of the District Chief: In 1979 the District Office was in the old Federal Post Office and Courts Building at 201 Northwest Third in downtown Oklahoma City. James H. Irwin was District Chief, and he had the best office in the Central Region and probably in the Nation. The former judges' chambers had a large reception room, very large office, and a full bath. Irwin retired in 1985 and was replaced by Charles R. (Bob) Burchett, who transferred from the Subdistrict Chief position in San Antonio, Tex. In 1989 Burchett transferred back to Texas as District Chief. Kathy Peter transferred from Albuquerque, N. Mex., to be the first woman District Chief in the history of WRD. Peter remained in the Oklahoma District throughout the period.

Ronald Hanson served as the Assistant District Chief for the 1979–94 period. Patricia Rogers was the District Secretary from 1979 to 1981, and Jeanne Sanchez was Secretary from 1982 to 1991.

Mary Barker was Chief of the Administrative Services Section throughout the period, from 1979 to 1981, and Debra Newsom was an Administrative Clerk; she was replaced in 1982 by Carolyn Norton (Administrative Technician) who remained through the period. Others who served in the Section were Julieanne Farrington, Martha McIntyre, Cheryl Bowden, Cheryle Pruitt, and Mara Tassey.

The Scientific Publications Section was established in 1980 and was staffed by Alan Rogstad (Cartographic Technician) and Gertrude MacDonnell (Editorial Assistant). In 1983 the staff changed to Larry Slack (Hydrologist), Nora Leal (Editorial Assistant), and Margaret Freeman (Cartographic Aide). Others serving in the Section were Charlene Ward (1983), Linda Prock (1985), Nancy Newell (1986–89), Lyn Carpenter (1990–94). John Havens (Reports Specialist) became Chief of the Section in 1988 and remained through the period.

In 1980 the Computer Services Section was established and was staffed by Betty Wills, Mary Berry, and Jo Ellen Easley. In 1983 Jonathon Scott became Chief of the Section and served to 1990. In 1988 Karen Steele transferred to the Section from Austin, Texas, and in 1990 she became Chief of the Section. Jonathon Scott was assigned to a staff position under the District Chief.

The Hydrologic Surveillance (Data) Section was composed of most of the Oklahoma District staff because Oklahoma was primarily a data program. Section Chiefs during the period were Willard Mills (1979–80), Leland Hauth (1981–89), and Robert Blazs (1990–). Others serving in the Section were Thomas Huntzinger, Dale Mitchell, DeRoy Bergman, Robert Tortorelli, Robert Corley, Dale Ferrel, Robert Gurmaat, Alan Smart, Lionel Mize, Derryl White, Robert Chadd, Michael Johnston, Lee Alf, Alphonse Patneaide, Juanita Wells, Kenneth Morris, Ronald Gist, Robert Kohler, Clarence Shay, Tim Lacefield, Danette Baker, Monte Bamford, Mary Ann Wright, Tony Coffey, Robert Carley, Sonya Petty, Joanne Kurklin, Steve Blumer, David Heimann, Gerald Young, Charles Bullock, John Kerestes, and Jess Griffin.

The Field Headquarters reported to the Data Section and in 1979 was staffed by Richard Cossell in Pryor and by Tony Coffey and David Boyle in Woodward. In 1981, Derryl White and Leonard Grubowski

were the staff in Pryor; in 1983, Pryor was closed and White moved to the new office in Tulsa where he was joined by Royce Johnson. By 1988 Toby Parvin, Gry Huff, and Phillip Carpenter had joined the Tulsa staff and in 1989 Martin Schneider and Marty Phillips joined Dale Boyle in Woodward.

Melvin Marcher was Chief of the Hydrologic Studies Section until he retired in 1984. William Horak Served as Chief from 1985 to 1989 when he transferred to North Dakota as District Chief. Ronald Harmon served as Studies Chief and Assistant District Chief for the rest of the period. Other personnel who served in the Section were Joe Reed, Jerry Stoner, Thomas Huntzinger, Robert Morton, Robert Davis, Roy Fairchild, John Havens, Jeanine Kurklin, Scott Christenson, Stephen Blumer, Robert Tortorelli, Robert Goemaat, Clarence Shay, Alphonsse Patneande, Renee Barta, DeRoy Bergman, Cass Willard, David Parkhurst, Gregory Adams, David Pruitt, Donna Runkle, Myles Overton, Dale Ferree, Alice Snow, Jamie Schlottmann, Jayne May, Michael Slifer, Alan Rea, James Greer, Ernest Smith, Margin Abbott, Mark Savoca, Mark Becker, Ben Mesander, and Ronald Funkhouser.

FUNDING AND COOPERATION

As shown in the funding table, the Federal-State Coop Program more than doubled during the period, with large increases in 1988 that were maintained through the period. Funding from other Federal agencies (OFA) also increased after suffering large losses in the early 1980's. The Federal program peaked in the late 1980's with funding increases for the National Water-Quality Assessment (NAWQA) Program.

State and local cooperators during the period included the Oklahoma Water Resources Board; Oklahoma Department of Transportation; Oklahoma Water Department; Oklahoma Geological Survey; Oklahoma State Department of Health; Oklahoma Pollution Central Coordinating Board; Oklahoma City Water Department; Grand River Dam Authority; Central Oklahoma Water Conservancy District; Fort Cobb Reservoir Master Conservancy District; Lugert-Altus Irrigation District; Foss Reservoir Master Conservancy District; Mountain Park Master Conservancy District; Oklahoma Gas and Electric Company; and the cities of Ada, Lawton, Okahoma City, and Tulsa.

Other Federal agencies funding programs in Oklahoma were the Bureau of Land Management, U.S. Army Corps of Engineers, Federal Emergency Management Agency, U.S. Department of Agriculture, Water Power Resources Service, and the Bureau of Reclamation.

Oklahoma District funding, fiscal years 1979–94

[Funds in thousands of dollars]

Fiscal year	Federal	OFA	State	Federal matching	Total
1979	432	1,099	499	471	2,500
1980	601	728	588	547	2,464
1981	563	711	561	579	2,414
1982	546	392	602	598	2,138
1983	325	321	498	447	1,590
1984	339	227	483	394	1,442
1985	283	279	501	442	1,505
1986	596	733	640	674	2,643
1987	789	753	735	754	3,030
1988	931	1,041	1,085	1,085	4,141
1989	873	1,772	1,080	1,080	4,805
1990	871	988	1,089	1,061	4,009
1991	643	1,034	1,123	1,110	3,909
1992	561	1,012	1,236	1,080	3,888
1993	418	1,518	1,244	1,071	4,251
1994	592	1,208	1,066	1,057	3,923

SUMMARY OF PROGRAMS

Hydrologic Data Collection.—In 1979, the District operated 140 streamflow stations; stage and contents for 26 lakes and reservoirs; 42 crest-stage partial-record stations; water quality for 135 gaging stations, 3 lakes, and 76 wells; and water levels for 48 observation wells. By 1984, data collection declined to 122 streamflow stations; 3 partial-record streamflow stations; 39 crest-stage partial-record stations; stage and content for 28 lakes and reservoirs; and water-quality records for 36 streamflow stations, 3 lakes, and 4 ungaged stream sites. The data program remained fairly constant through the end of the period.

In 1994 data collection included 118 streamflow stations; 21 partial-record stations; stage and content for 8 lakes and reservoirs; and water-quality records for 47 streamflow stations and 28 wells.

Major floods occurred during water year 1984 with rainfall reports of 14 to 17 inches, exceeding 100-year storm frequencies. Resulting flood magnitudes exceeded 100-year recurrence intervals at many streamflow-gaging stations.

INTERPRETIVE STUDIES

Throughout the period, the Oklahoma District Program was predominantly a data program. However, the District did publish more than 80 reports. Forty of these were Open-File Reports and 30 were Water-Resources Investigations Reports. In addition to the data reports, there were significant interpretive reports. David Parkhurst, Scott Christenson, Robert Davis, John Havens, and Melvin Marcher investigated the geohydrology and water quality for much of the State, including the Central Oklahoma aquifer, the Roubidoux aquifer, and alluvium and terrace aquifers throughout the State. Steve Blumer, Thomas Huntzinger, Robert Tortorelli, and Jerry Stoner were principal investigators in surface water and surface-water quality. Jonathon Scott contributed to WRD's computer software for analyzing simulations using a ground-water flow model and computerized data-base systems for land-use and land-cover data and for sampling networks.

SOUTH DAKOTA

By Ken Lindskov, *including information and review by* Janet Carter, Dan Driscoll, *and* Michael Burr

ORGANIZATION AND PERSONNEL

In 1979, the South Dakota District Office was in Huron. Other offices were the Subdistrict Office in Rapid City and a Field Headquarters in Pierre. The county ground-water studies in the eastern part of the State mostly were completed by 1994, and State Cooperative (Coop) programs shifted to more emphasis on the hydrology of the Black Hills area in western South Dakota. The national energy crisis in the late 1970's resulted in proposals to move coal from Wyoming and Montana to other parts of the Nation by slurry pipelines using water from the Madison aquifer. The State was considering selling water available from the Madison aquifer in the Black Hills area. Another issue was adequate water supply for the rapidly growing population of the Black Hills area. By 1992, the funding for west-river State Coop program studies was larger than for east-river studies. Thus, the District Office was moved to Rapid City in 1992. Most of the existing Huron employees were given the option of staying in the new Huron Subdistrict Office.

The number of FTE's increased from about 38 in 1979 to a high of 45 in 1989, then decreased to 39 in 1994. The number of support staff (administrative, computer, and reports) increased from 6 in 1979 to 10 in 1994. The ratio of hydrologists/engineers to hydrologic technicians was fairly constant at about 1:1.

Huron, District Headquarters to Subdistrict.—In 1979, the District Office was in the Huron Federal Building at 200 4th Street Southwest, and Richard Fidler was District Chief until he retired in January 1992. Edmund LeRoux was Assistant District Chief until he retired in 1986. Jack Little became Assistant District Chief in 1988 and continued in this position as well as Data Section Chief through 1991. In 1992, Rick Benson was selected for the new position of Subdistrict Chief.

Owen Larimer was Data Section Chief and retired in 1979. Jack Little transferred from Colorado to replace Larimer and remained as Data Chief until he retired in 1992, after the District Headquarters was moved to Rapid City.

Neil Koch was Studies Section Chief from 1979 until he retired in 1989. Patrick Emmons was Studies

Chief from 1989 until 1992, when the District Headquarters was moved to Rapid City.

Margaret Bloomberg continued as Administrative Officer with a staff of two or three until she retired in 1985. Perry Hall transferred from Montana to replace Bloomberg. Hall was Administrative Officer until 1989, when he was replaced by Doris Adair, who transferred from the Colorado District. Adair transferred to the Wyoming District in 1991. Joyl Friese was Acting Administrative Officer until 1993, when Jane Edwards transferred from California to the new Administrative Officer position in Rapid City. The District Accounting Technician, Teresa Harvey, remained in Huron, reporting to Edwards in Rapid City. Deb Matthews also remained in Huron as the District Computer Program Analyst.

The Publications Unit staff was allowed to remain in Huron. The Illustrator, Connie Ross, and the Editorial Assistant, Ella Decker, continued to work under the direct supervision of Rick Benson, who continued as District Reports Specialist after becoming the new Subdistrict Chief.

Rapid City, Subdistrict to District Headquarters.—In 1979, the Rapid City office was in the Federal Building at 515 Ninth Street. Harvey Lee Case was Subdistrict Chief until 1982 when he transferred to New Mexico District. Kim Goddard was Subdistrict Chief from 1982 to 1987 when Mark Anderson replaced him as Subdistrict Chief and Goddard became Project Chief. In 1990, the Rapid City staff had grown to 18 FTE's, and the office was moved to cooperator-rented space in a new building at 1608 Mountain View Road. This space was built and nicely arranged to house the USGS staff. Direct credit was extended to the City of Rapid City/USGS State Cooperative program for studies of Rapid Creek and major ground-water aquifers in the area with emphasis on the Madison/Minnelusa aquifers. Anderson transferred to Arizona in 1991 and was replaced by Ken Lindskov, who transferred from North Dakota.

Terry Lockner was in charge of the Rapid City data program from 1979 until transferring to the Utah District in 1990. Dan Driscoll took charge of the data program in 1991.

In 1992, Ken Lindskov was selected as District Chief when the District Office was moved from Huron to Rapid City and he continued in the position in 1994. In 1992, Dan Driscoll was selected as Chief of Hydrologic Studies, Ralph Teller was selected as Chief of Hydrologic Data, and Joyce Williamson was selected to head the new Information Management Section. Driscoll, Teller, and Williamson served in their respective positions through 1994. In 1993, Jane Edwards transferred from California to become the new District Administrative Officer. Also in 1993, John Zogorski was selected to head the National Water-Quality Assessment (NAWQA) Volatile Organic Compounds National Synthesis project. This Headquarters project provided much needed growth to the District program.

Pierre, Field Headquarters.—The Field Headquarters remained in the Federal Building in downtown Pierre until 1989 when the office was moved to share Bureau of Reclamation rented space in northwest Pierre on the bluff overlooking the Missouri River. Darwin Heyd was Chief of the Field Headquarters from 1979 until he retired in 1988. Marvin Stevens transferred from the Kansas District in 1988 to replace Heyd. Stevens continued as District Chief until his retirement in 1993. Craig Solberg was Chief during 1993–94. The Pierre staff generally consisted of three FTE's except for 1992, when there were four.

Funding and Cooperation

The Federal-State Cooperative (Coop) program increased by a factor of about three during 1979–94, about double the rate of inflation. There were some wide swings in the Federal program between 1979 and

South Dakota District funds, fiscal years 1979–94

[Funds in thousands of dollars]

Fiscal year	Federal	Other Federal agencies	State	Federal matching	Total
1979	652,471	218,659	350,461	350,461	1,572,052
1980	654,389	255,310	509,309	519,678	1,938,686
1981	514,292	336,053	533,365	551,406	1,935,126
1982	224,512	345,600	592,970	592,970	1,756,052
1983	183,110	239,235	510,652	505,180	1,438,177
1984	106,045	275,095	544,522	445,704	1,371,366
1985	250,611	286,597	399,735	417,269	1,354,212
1986	590,700	525,850	646,500	646,500	2,409,550
1987	539,900	412,200	828,235	863,800	2,644,135
1988	484,400	860,800	939,000	939,000	3,223,200
1989	390,800	610,600	988,700	944,000	2,934,100
1990	279,400	434,740	1,225,800	1,125,800	3,065,740
1991	325,000	381,100	1,282,100	1,182,100	3,170,300
1992	380,310	462,500	1,215,058	1,115,058	3,172,926
1993	652,119	348,778	1,205,874	1,105874	3,312,645
1994	874,870	617,040	1,345,878	1,093,878	3,931,666

1984. Federal funds decreased from about $650,000 in 1979 to about $106,000 in 1984, primarily because of completion of Department of the Interior work associated with the Development of the Missouri River Basin program. Federal funds increased significantly during 1985–87, primarily because of Department of the Interior irrigation drainage work. Federal funds decreased to another low (about $279,000) in 1990 as the irrigation drainage work was completed. The increase in Federal funds during 1993–94 resulted from initiation of the NAWQA National Synthesis study of volatile organic compounds and hiring of some staff, and planning had begun.

Other Federal agency (OFA) funding for South Dakota was about $219,000 in 1979, increased to about $340,000 in 1981–82, decreased to about $240,000 in 1983, and then generally increased to a high of about $860,000 in 1988. After 1988, OFA funding generally decreased to about $349,000 in 1993, then increased to about $617,000 in 1994.

Most of the OFA funding came from the U.S. Army Corps of Engineers, Bureau of Indian Affairs, Bureau of Reclamation, U.S. Air Force, and the National Park Service. During years of lower OFA funding, the sources primarily included Corps of Engineers funding for stream gaging. The peak funding of about $860,000 in 1987 resulted from the Bureau of Reclamation's funding work on the hydrology of the James River and refuge monitoring associated with proposed irrigation as part of the Garrison Diversion Unit. Most of the Bureau of Reclamation work associated with the Garrison Diversion was completed by 1991. Some of the decrease in Bureau of Reclamation OFA funding during 1989–91 was offset by Bureau of Indian Affairs funding for 12 gaging stations on several of the nine Indian reservations in the State. Air Force funding was about $200,000 for 1993–94, which was for environmental monitoring associated with dismantling the 150 missile sites in western South Dakota.

In 1979, the Federal-State Coop program funding generally consisted of work on east-river county studies in cooperation with the South Dakota State Geological Survey. The State Survey funding was minimal by 1990, and Coop funding shifted to work in cooperation with cities, Indian reservations, and the West Dakota Water Development District. In 1994, West Dakota and the State Department of Environment and Natural Resources (DENR) funding for the Black Hills Hydrology Study provided about one-quarter (about $300,000) of the cooperator funding for the Coop studies. In 1994, the State Engineer's Office under DENR provided about $200,000 for stream gaging, Rapid City provided about $150,000, five Indian Reservations provided about $100,000, and the State Department of Transportation provided about $50,000. In addition, about 30 other customers consisting of other State agencies, Indian tribes, counties, and other cities provided smaller amounts of Coop funding in 1994.

SUMMARY OF PROGRAMS

Interpretive Studies

County studies.—Water-resource investigations were conducted in cooperation with the South Dakota Geological Survey in a series of county studies that focused primarily on glacial aquifers in eastern South Dakota. These investigations, which were the backbone of the District's ground-water program for many years, began in 1959 and extended beyond 1994. During 1979–94, reports on the water resources of 30 counties were published. In addition to the water-resource investigations, digital ground-water models, water-level records, and water-quality data for selected glacial aquifers, especially the Big Sioux aquifer, were published for many of the counties. These county studies have provided reliable and useful hydrologic and geologic information for almost every county in eastern South Dakota.

Investigations of the geology and water resources of two Indian reservations continued as part of the U.S. Department of the Interior program for the development of the Missouri River Basin; the Project Chief was Howells. Hydrologic Investigations Atlases (HA's) were published for the Cheyenne Indian Reservation (HA–585, 1979) and the Standing Rock Indian Reservation (HA–644, 1982). Along with previously published HA's for the Rosebud, Pine Ridge, Crow Creek, and Lower Brule Indian Reservations, these HA's have been a valuable tool for managing the water resources of South Dakota's Indian reservations. In addition, a water-resources appraisal was published in 1989 for the Lake Traverse Indian Reservation (WRIR 88–4031), and a 3-year water-resources appraisal for the Lower Brule Indian Reservation began in 1992.

Surface-water studies.—Studies of the James River and Sand Lake National Wildlife Refuge in cooperation with the U.S. Bureau of Reclamation for

the proposed Garrison Diversion Unit were conducted by Benson (WRIR 87–4208, 1988), G.J. Wiche (North Dakota District) and others (WRIR 89–4039, 1989), and Sando and others (OFR 90–101, 1990). The proposed diversion would supply water from the Missouri River in North Dakota to the upstream part of the James River Basin for municipal, industrial, irrigation, recreational, and fish and wildlife purposes.

Drainage area studies were completed for the Big Sioux (OFR 85–348, 1985), James (OFR 87–572, 1987), and Vermillion (OFR 88–720, 1988) Rivers. These studies were conducted in cooperation with various State and local agencies and were necessary because of large, noncontributing drainage areas within these basins.

Flood-frequency studies, which began in 1967, continued in cooperation with the South Dakota Department of Transportation. Flood-frequency studies were completed by Becker (WRIR 80–80, 1980; WRIR 82–31, 1982), Little (OFR 94–432), and Hoffman and others (OFR 86–496, 1986). These studies have been used extensively in the design of highway culverts and bridges throughout the State. They also have been useful for land-use planning, mapping flood-prone areas, and establishing rates for flood insurance.

Water-quality studies.—Water-quality issues in eastern South Dakota have been addressed in many county study reports. In western South Dakota, a study of the effects of urban runoff on water quality in Rapid Creek was conducted by Goddard and others (OFR 87–45, 1989) as part of the U.S. Environmental Protection Agency's Nationwide Urban Runoff Program (NURP).

The contamination of Whitewood Creek and the downstream rivers by the long-term discharge of mine tailings into Whitewood Creek resulted in the designation of an 18-mile reach as a Superfund site in 1983. The Toxic Substances Hydrology Program (Toxics) and the South Dakota District were involved in process-oriented research to investigate the contamination of Whitewood Creek. Although District involvement with this study primarily ended in 1989 with publication of a summary report by Goddard (WRIR 87–4051, 1989), numerous ancillary questions and considerations continued to arise in subsequent years.

In response to nationwide concerns about harmful effects of irrigation drainage on human health, fish, and wildlife, the Department of the Interior initiated the National Irrigation Water Quality Program (NIWQP) in late 1985 to identify the nature and extent of potential irrigation-induced water-quality problems. Selenium, which can be concentrated by irrigation operations, was a special concern of NIWQP because of toxicity and prevalence in irrigation areas in the Western United States. Extensive studies of potential irrigation drainage were performed under NIWQP during the late 1980's by Greene and others (WRIR 90–4152, 1990) for the Angostura Reclamation Unit and by Roddy and others (WRIR 90–4192, 1991) for the Belle Fourche Reclamation Project. Results of a 1994 followup sampling effort were reported by Sando and others (WRIR 01–4103, 2001).

Bedrock aquifer studies.—Many studies of bedrock aquifers in western South Dakota were conducted during 1979–94. Two studies were for the High Plains aquifer in southern South Dakota. Kolm and Case published a ground-water model of the High Plains aquifer (WRIR 83–4175, 1983) as part of a regional study of the aquifer. Greene and others published a report on aquifer tests and water-quality analyses of the Arikaree aquifer near Pine Ridge (WRIR 91–4005, 1992); this study was performed in cooperation with the Oglala Sioux Tribe and the Bureau of Indian Affairs.

Other bedrock aquifer studies were conducted in the Black Hills area beginning in the 1980's. An important factor driving initiation of studies was proposed large-scale withdrawals from the Madison aquifer for a coal slurry pipeline proposed by Energy Transport Systems, Inc. (ETSI). The extremely complex hydrogeology of the Black Hills area and concerns associated with increasing population and other forms of resource development also were driving factors. The first study was conducted by Kathy Peter on the availability and quality of water from bedrock aquifers in the Rapid City area (WRIR 85–4022, 1985) to provide supporting information for the Bureau of Reclamation's water-supply needs investigation. Subsequent studies of bedrock aquifers in cooperation with the South Dakota Department of Environment and Natural Resources and the Black Hills Conservancy Sub-District were performed by Peter. These studies included a report on the bedrock aquifers in the northern Black Hills (WRIR 86–4158, 1987) and structure-contour maps showing the top of the Minnelusa Formation in the northern Black Hills (WRIR 85–4053, 1987) and southern Black Hills (WRIR 86–4167, 1991).

Population growth in the Rapid City area led to increasing demand for municipal water. Increased development of water resources in the Rapid City area in the 1990's led to the initiation of two studies in the area. A study of the hydraulic properties of the Madison aquifer was done by Greene in cooperation with the City of Rapid City (WRIR 93–4008, 1993). Anderson and others (WRIR 98–4214, 1999) investigated ground-water and surface-water interactions along Rapid Creek in cooperation with the City of Rapid City and the South Dakota Department of Game, Fish, and Parks.

Population growth, resource development, and periodic droughts in the Black Hills area led to the initiation in 1990 of the Black Hills Hydrology Study, which was the largest project in the history of the South Dakota District. This project was originally planned as a 10-year study of the quantity, quality, and distribution of surface water and ground water within the Black Hills area in cooperation with the South Dakota Department of Environment and Natural Resources and the West Dakota Water Development District, which represented various local and county cooperators. The study area included parts of six counties in the Black Hills area. The highest priority was placed on the Madison and Minnelusa aquifers. The study was planned for two phases. The first phase, which was continuing in 1994, consisted primarily of data collection. The second phase is planned to begin in 1998 and will consist primarily of analysis and reporting of results. Initial formulation of the study was guided by Goddard and Anderson, both of whom transferred to the Arizona District in the early 1990's. Driscoll became the Project Chief and published the plan of study (OFR 92–84, 1992). Selected hydrologic data collected for the Black Hills Hydrology Study were presented by Driscoll and others for data collected through water year 1992 (OFR 94–319, 1994) and through water year 1994 (OFR 96–399, 1996). Numerous additional reports were published during subsequent years.

Other studies.—Sediment studies using seismic-reflection methods were conducted by Sando for Lake Byron (WRIR 93–4206, 1994), and more studies were planned for subsequent years for eastern South Dakota lakes. Other studies in eastern South Dakota included artificial recharge potential of glacial aquifers. Emmons reported on artificial yield potential for the Elm and Middle James aquifers in the Aberdeen area (WRIR 87–4017, 1987) and initiated the Huron Project of the High Plains Ground-Water Demonstration Project in 1990. Data collection for the Huron Project was ongoing at the end of this period of WRD history. Hydrologic data through 1993 for the Huron Project were presented by Carter (OFR 95–313).

Headquarters NAWQA

A NAWQA National Synthesis Team study of volatile organic compounds began in 1993, and John Zogorski was selected as Project Chief. Greg Delzer was hired as an Environmental Engineer. Zogorski completed work plans and began recruiting of staff that would eventually include about 10 full-time hydrologists/engineers. Thus, plans were completed to expand the cooperator-rented space in Rapid City to accommodate the planned new staff members.

Hydrologic Data Collection

In 1994, the District's data program represented about 47 percent of the total District program. This 47 percent included funds for operating the regular network as well as for operating gaging stations, precipitation stations, and water-quality and sediment-sampling stations that were part of larger interpretive projects such as the large Black Hills Hydrology Study. About 20 gaging stations and 45 precipitation stations plus numerous water-quality sites were operated for the Black Hills Hydrology Study. Most of the short-term and seasonal data collection associated with other smaller interpretive projects, however, is not included in the 47 percent. About 75 percent of the data program funds were to operate 146 continuous-record gaging stations on streams and lakes; 33 crest-stage and early warning system partial-record stations on streams and lakes; and 53 precipitation stations. The remaining 25 percent of the data program funding was for water-quality and sediment sampling. About 16 percent of the total data program was funding by the Federal program; 26 percent was funded by other Federal agencies, and 58 percent was funded by State and local agencies as part of the State/Federal Cooperative program.

Many changes took place during 1979–94 in the operation of the Data Section. Only 4 of the 17 hydrologic technicians/aides that were employees of the District in 1979 were still working as District employees in 1994. In 1992, Ralph Teller was selected

as Data Section Chief, one of only a few technicians in the Water Resources Division to achieve this status.

Computer computations of daily streamflow records were accomplished on a mainframe computer in 1979 by sending punch cards to Reston. The acquisition of District minicomputers allowed for streamflow records to be completely processed in house. By 1994, electronic data loggers and Data Collection Platforms (real-time transmission of data via satellites) replaced the digital-tape and strip-chart recorders.

Streamflow generally was above normal during 1979–94, and flooding resulted in additional work for the staff. Presidential Disaster Declarations for parts of the State were declared in 1984, 1986, 1992, 1993, and 1994.

Streamflow stations.—The number of continuous-record streamflow stations remained fairly constant for 1979–86 with about 110 stations being operated. The number of stations increased to 147 by 1989, primarily because of stations added for the Black Hills Hydrology Study and a network of about 10 in cooperation with the Bureau of Indian Affairs. A few stations were discontinued by 1994 when the total was 142. The number of crest-stage partial-record stations funded by the South Dakota Department of Transportation varied considerably during 1979–94. The 97 crest-stage stations that were operated in 1979 were all discontinued by 1981. Nine crest-stage stations were installed in 1989, and the number of crest-stage stations had increased to 22 by 1994.

Data Collection Platforms for about 10 stations funded by the U.S. Army Corps of Engineers–Omaha and the Bureau of Reclamation during the middle to late 1980's brought real-time data to the computer screens of District Staff. Successful installation of a Ultrasonic Velocity Meter (UVM) on an inlet/outlet channel to Lake Kampeska near Watertown resulted in computation of discharge records for 1993–94.

Ground-water records.—A modest regular-network program was in place for 1979–94 in cooperation with the Water Rights Division of the State Department of Environment and Natural Resources. In 1979, continuous records of water levels were recorded at 16 sites. Annual water-quality samples also were collected on selected wells in 27 counties in the State. No water-quality samples were collected for this program after 1983. By 1994, continuous records of water levels were only obtained at seven wells for this program.

Periodic water levels were obtained for 20–27 wells in Hughes County near Pierre for 1984–89 for the Central Dakota Irrigation Project. In 1994, the ground-water data program was limited to publishing and archiving water-level data for about 60 wells (many of which were equipped with continuous recorders) as part of the Black Hills Hydrology Study and the High Plains Ground-Water Demonstration Project near Huron. The District also was cooperating with the Division of Water Rights in a data cleanup effort. The purpose was to verify, on a county-by-county basis, the accuracy and completeness of ground-water and water-quality data in the NWIS data bases. Additional well-inventory, water-level, and water-quality data were being obtained as parts of county and reservation studies.

Water-quality records.—Ten National Stream-Quality Accounting Network (NASQAN) stations accounted for a major part of the water-quality program in 1979. The NASQAN stations were reduced to five by 1994. The U.S. Army Corps of Engineers, Bureau of Reclamation, local irrigation districts, and the State Department of Environment and Natural Resources funded another 12 sites for periodic sampling in 1979. The District staff sampled Corps of Engineers reservoirs on the Missouri for 1980–83, but the Corps staff analyzed the samples. Annual water-quality samples at the USGS EROS Data Center and nearby wells were collected during 1983–94. In 1983, sampling began for two Whitewood Creek sites in cooperation with Homestake Mine, and this sampling was continuing in 1994. Sand Lake National Wildlife Refuge monitoring began in 1985 in cooperation with the Bureau of Reclamation proposed Garrison Diversion Unit. The refuge monitoring included continuous monitors logging up to seven parameters for Sand and Mud Lakes. Data were collected and compiled for Sand and Mud Lakes through 1988. In addition, mini-monitors were installed at three sites on the James River in 1985. The data for the James River sites included pH, dissolved oxygen, water temperature, and specific conductance; this effort was discontinued in 1988. A Bureau of Reclamation project for sampling in the Lake Andes area was started in 1983 and was continuing in 1994. Several lakes, stream tributaries to Lake Andes, and several sites on Choteau Creek were sampled for various parameters including pesticides and selected trace elements in the dissolved fraction and in the bottom material. In 1994, only 25 sites were sampled as part of the regular network,

including 13 in the Lake Andes area, 5 NASQAN sites, 6 Black Hills area sites, and 1 site on the Little White River. The above discussion does not include all of the short-term sampling associated with smaller interpretive studies in cooperation with other Federal and State agencies, water development districts, Indian tribes, and cities.

TEXAS

By Charles R. Burchett and Frank C. Wells

ORGANIZATION AND PERSONNEL

In 1979, the Texas District consisted of a District Office in Austin and large Subdistrict Offices in Fort Worth, Houston, and San Antonio. Three smaller Subdistricts were located in Austin, San Angelo, and Wichita Falls. Field offices were located in El Paso, Pampa, and Rockport. The Texas District staff was approximately 150 permanent and part-time employees. Annually increasing budgets and mandated personnel ceilings created major management problems throughout this period of history for the Texas District. The program changed from primarily a data program to a more balanced program, with more hydrologic studies, including projects for the U.S. Air Force, agriculture and urban investigations, and the National Water-Quality Assessment (NAWQA) Program. The Austin Subdistrict was converted to a Field Office in 1982. In 1990 the San Angelo and Wichita Falls Subdistricts were converted to Field Offices as a way to improve the overall management structure of the District. In 1991 the WRD established the Area Hydrologist concept for managing the National Program. The Texas District was placed under the direction of the Great Southwest Area. In 1993, in an effort to improve efficiency and service to our customers, it was decided that the El Paso Field Office and much of West Texas, west of the Pecos River, would be placed under the direction of the New Mexico District, which was also part of the Great Southwest Area.

Texas District budgets and personnel continued to increase during this period. In 1992 the District employed 169 hydrologists, technicians, and administrative staff, which was the largest number of personnel employed by the District during this period. At the close of the period the total number of employees was 141. Organization changes occurred in 1981 when Bill Boning became District Chief, and additional changes were made by Boning in 1989 and in 1990 when Charles Burchett replaced Boning as District Chief. In 1991, Richard O. Hawkinson became District Chief, and he made additional changes in 1992, 1993, and 1994. The District organization was not substantially altered during any of these changes. They were designed to fine tune the system as each of the new Chiefs wanted to place a little different spin on the District in an attempt to make it a little better and more efficient. The description of the Sections and Units within the District Office, Subdistrict Offices, and Field Offices will be described as they were in 1979 and how they evolved through this period of Texas District history to 1994.

THE GREAT BUYOUT OF 1994. The USGS offered all of their eligible employees an opportunity for early retirement with a $25,000 bonus to retire. This was part of the downsizing and reinventing of the Federal Government. These buyouts really changed the look of the District Staff as 16 employees, over 10 percent of the workforce, took the buyout offer.

District Headquarters, Austin

Office of the District Chief. In 1980 the District Office was in the Federal Building at 300 East Eighth Street in downtown Austin. The District occupied the entire sixth floor and used additional space on the eighth floor and the basement. Warehouse storage was offsite as the office was located downtown. The office space was provided by the General Services Administration. The location of this space was unsuited for a field-oriented operation such as the USGS–WRD. Also, rent was extremely high. In 1987 the office, laboratory, and warehouse were relocated to 8011 Cameron Road in North Austin. This location was better suited to the mission of the USGS–WRD as it was part of an Industrial Park, which made possible the consolidation of office and warehousing needs at a single location.

Ivan D. (Dale) Yost, the second District Chief of Texas, retired in 1980. The organizational structure included an Associate District Chief, Allen G. Winslow, who also retired in 1980. The Associate District Chief position remained unfilled until 1981, when Richard U. Grozier transferred from the San Antonio office, where he was Subdistrict Chief. Grozier was named Associate District Chief and Chief

of the Hydrologic Surveillance and Analysis Section. Jack Rawson served as Acting District Chief until Boning transferred in 1981 from the Subdistrict Chief position in Menlo Park, Calif. Boning remained the District Chief until 1989 when he was selected as Chief of the Office of Surface Water. Larry Land was selected to serve as Acting District Chief until Charles R. (Bob) Burchett arrived in Austin in January 1990 as the fourth District Chief of Texas. Burchett's previous position was that of the District Chief of Oklahoma. Burchett remained District Chief for a relatively short time as he was asked to assume the position of Area Hydrologist in March 1991. However, he filled both positions until Hawkinson transferred to Austin in October 1991 from the National Water Quality Laboratory in Denver, Colo., where he was Laboratory Chief, to become the fifth District Chief of Texas. Hawkinson remained the Chief through the remainder of this period of the Texas District history. The following Offices of the Associate District Chiefs, the Assistant District Chiefs, NAWQA, and the District Secretaries made up the Office of District Chief during this period.

Office of the Associate District Chief for Hydrologic Surveillance and Analysis. When Boning arrived in Texas he reorganized and established the position of Associate District Chief for Hydrologic Surveillance and Analysis in 1981. The previous Associate District Chief did not serve as the Chief of a Section. The first employee to hold this Associate District Chief position was Grozier. The surface-water and water-quality discipline units were placed under the direction of the Associate District Chief for Hydrologic Surveillance and Analysis. Grozier remained the Associate District Chief until his death in 1984. Jack Rawson, Chief of the Texas District Water Quality Unit, was selected to replace Grozier. Rawson remained as the Associate District Chief until he retired in 1989.The District reorganized after Rawson's retirement, and the Associate District Chief position was terminated and replaced with a new Assistant District Chief position.

Office of The Assistant District Chief for Hydrologic Systems Investigations and Research. Larry Land became the Assistant District Chief for Hydrologic Investigations and Research in 1981. The position of Assistant District Chief was new to the Texas District under the reorganization of 1981. Land was Chief of this Section before the position was upgraded to Assistant District Chief, and he remained Assistant District Chief for Investigations until 1989 when he was reassigned to the newly established position of Technical Adviser for Research and Development under the reorganization of 1989. The Section was renamed under this reorganization to Hydrologic Investigations and Research Section.

Office of the Assistant District Chief for Hydrologic Investigations and Research. Marvin G. Sherrill transferred from the Wisconsin District in1989 to replace Land as Chief of this newly renamed Section. Sherrill accepted the position of District Chief of Missouri in 1991. Lloyd H. Woosley, Jr., became Chief of this Section in 1992, transferring to Texas from the Kentucky District. Woosley remained as Assistant District Chief in this Section through the remainder of this period.

Office of the Assistant District Chief for Hydrologic Surveillance and Analysis. Bernard C. Massey moved from the Hydrologic Surveillance and Analysis Unit to replace Rawson as Assistant District Chief. Massey remained Assistant District Chief and Chief of this Section until it was renamed Hydrologic Data Collection and Management Section under the reorganization of 1990.

Office of the Assistant District Chief for Hydrologic Data Collection and Management. Massey remained in this position until he retired in 1994 and was replaced by Frank C. Wells. Wells' previous position was Water Quality Specialist for the Great Southwest Area.

National Water Quality Assessment Unit. This Unit was established in 1991 when the first NAWQA project was started in Texas. Land was selected to be the Project Chief.

Secretary of the District Chief. District secretaries, in chronological order, were Frances S. Price, Eleanor S. Chitwood, Barbara M. Skinner, and Margaret E. (Bettie) Joseph.

Administrative Services Section. Elizabeth S. Deavers became the District Administrative Officer (AO) in 1973 and served until she retired in 1992. Deavers was one of the stabilizing forces within the District as she served as AO for over a quarter century and worked with the first five Texas District Chiefs. Deavers was replaced by Patricia G. Clark, who was AO through the remainder of the period. Others who served in the Section were Mary E. Davis, Catherine J.H. Eibt, Carolyn V. Norton, Mary A. Christianson, Josephine E. Powers, Bettie C. Sheridan, A. Austin Bricker III, Niki V. Philip, Stella M. Brittnacher,

Easter R. Brake, Lois J. Harlan, Donna J. Weber, Karen A. Beers, Barbara A. Jenschke, and Valarie L. Schmidt.

Computer Operations Unit. One of the most notable changes during the period was the appearance of a computer terminal on every desk beginning in July 1983, when a minicomputer replaced the Headquarters mainframe computer. Workstations arrived in 1991 and began to replace the minicomputer. Throughout this period of Texas District history, Fred Stroman served as the Site Administrator for computer operations, Computer Specialist, and Chief of the Computer Operations Unit. Among those who assisted Stroman during these years were Evangelina R. Carrillo, Karen S. Steele, Joyce C. Stewart, Terry A. Wilson, and Dane Ohe.

Scientific Publications Section. The Publications Section had a staff of eight in 1979 and decreased to six by 1994. Ray J. Wall was Chief of the Publication Section until 1981 when he retired. The name of the Section was changed to Scientific Publications Unit under the 1981 reorganization.

Scientific Publications Unit. Harold D. Buckner served as Chief of the Publications Unit from 1981 until Dennis G. (Woody) Woodward transferred from Minnesota to become Reports Specialist and Unit Chief in 1984. Woodward remained Chief if the Unit until 1988 when he became State Office Chief of Washington. Lee H. Raymond replaced Woodward in 1989, transferring from the WRD National Headquarters in Reston, Va. Principal illustrators were Don L. Leslie, Stanley H. Crenwelge, and John P. Maguire. Technical Editors were Bobby D. Jones, Alicia A. Mitchell (later Ranzau), and Gail J. Sladek. Others assisting in the Publications Unit were Buckner, Ruth E. Jones, Ernest T. Baker, Gloria J. Smith, Judith A. Voigt, and Juanita C. Buenrrostro. Although the Gulf Coast RASA Project was managed out of the Central Region Office, the Texas District Publications Unit processed all of their reports. Overdue reports have always been a problem. However, the District has managed to keep these overdue reports to a minimum. The biggest changes in report processing in the District during 1979–94 happened as a result of revised thinking by the Division about what constituted an adequate report and technological advances in report production. For many years the typical WRD report was a thick tome written at the end of a multiyear project. The report contained all the data and interpretations generated during the life of the project and commonly a rehash of much information from previous studies. The review process, never known for speed and efficiency, often ground to a halt under the weight and bulk of some reports. During the mid-to-late 1980's, customer demands for timely information grew more insistent and competition from the public and private sectors became more apparent. Although report quality was never an issue, report timeliness became a critical issue. The Division and District response was a move to smaller reports focused on fewer than five objectives, with a minimum number of figures and tables. Data were commonly published in separate reports or not at all. Multiple small reports were published for large multiyear projects. The Texas District, in 1990, issued a policy statement that reports could be no more than 50 pages, contain no more than 10 illustrations, 4 tables, and no plates without the written permission of the District Chief. During the same period, the technology for producing reports leaped forward. Word-processing software became available to District authors at their desks; consequently, dependence of authors on typists for manuscript preparation ended. Pen-and-ink drafting of illustrations was replaced in a few short years by computerized digital techniques. Geographic information system technology revolutionized the making of map illustrations, and graphical data-management and statistical software did the same for graph illustrations. More professional-looking reports could be produced in less time with fewer people. Although focusing on smaller reports and embracing new technology did not entirely eliminate the problem of late reports, the two changes reduced report-processing time substantially. The name of this Unit was changed to Publications Unit under the 1990 reorganization.

Publications Unit. Lee Raymond remained in charge of the renamed Publications Unit. Working under her direction were Donald L. Leslie, Stanley H. Crenwelge, Gail J. Sladek, John P. Maguire, James P. Rounds, Valarie L. Schmidt, Kristy E. Uzcategui, Dianne C. Gilliam. In 1992 this Unit was renamed the Publications Section.

Publications Section. Lee Raymond remained in charge of the Publications Section. She was assisted by Sladek, Uzcategui, Rounds, Schmidt, and Gilliam. Raymond was Reports Specialist and Chief of the Unit until she retired in 1994. Peter W. Bush was selected as Publications Section Chief in 1994. The Graphics Unit and the Manuscript Preparation Unit were added to this Section in a reorganization in 1992.

Graphics Unit. The Graphics Unit was made up of Stanley H. Crenwelge and Warren E. Alverson. The Graphics Unit was renamed the Spatial Data Analysis Team in 1994.

Spatial Data Analysis Team. This team was composed of Stanley H. Crenwelge, Kristy E. Uzcategui, and Frank L. Brazile.

Manuscript Preparation Unit. Alicia A. Ranzau was the Supervisor of this Unit. Alicia was assisted by Judith A. Voigt and Gloria J. Smith. Under the continuing spirit of reorganization and name changes, this Unit was renamed the Manuscript Preparation Team in 1994.

Manuscript Preparation Team. This team was made up of Sladek, Voigt, and Smith.

Library. The District Library was under the direction of the Publications Unit throughout this period. The Library has been an important part of the District operation, housing over 15,000 volumes. The Library has provided material for research not only for the USGS/WRD personnel but also to the Austin community. In 1979, Jean T. Rosemarie was the District Librarian. In 1981 she was replaced by Shelby L. Anderson who served until 1983. Others who served as Librarians for the District were Patricia Tenner (1983–84), Cynthia A. Kehoe (1984–85), Vivian Carlson (1985–86), and Julie Menard (1986–94).

Project Office. This office was created in 1988 when Marshall E. Jennings was transferred from the Hydrologic Instrument Facilities (HIF) in Louisiana. This Project Office was funded partly by the WRD Headquarters because Jennings did work for the Division that affected the organization as a whole. He became a full-time District employee in 1991 when funding from the Office of Surface Water for the Project Office was terminated. Roger W. Lee transferred from the Tennessee District to join Jennings in the Project Office in 1989 when he was selected to participate in the USGS Graduate School Program at the University of Texas. When funding from the Office of Surface Water for the Project was terminated, the Project Office was closed and Jennings was reassigned to the Hydrologic and Hydraulics Unit. Lee was reassigned to the Environmental Studies Unit.

Edwards-Trinity RASA. Regional Aquifer-System Analysis (RASA) projects in the past had been managed from Regional Offices under the direction of the Regional Hydrologist. However, this RASA was placed under the direction of the Texas District Chief. Peter W. Bush was Project Chief for the duration of the 9-year project, which began in 1986. Bush was assisted by Rene A. Barker, John F. Busby, Eve L. Kuniansky, Ann F. Ardis, Kirby H. Wynn, and Robert A. Lowther. This team originally was under the direct supervision of Larry Land, the Assistant District Chief for Hydrologic Systems Investigations and Research. In 1990 the Edwards-Trinity RASA group was established and placed under the supervision of the District Chief. In 1992 the project was placed under the direction of the Assistant Chief for Hydrologic Investigation and Research. The project concluded in 1994.

National Water-Quality Assessment Units. Land was selected from the District Staff to be the Project Chief of the first Texas District NAWQA project in 1991. This project studied the water quality of the Trinity River Basin. Assisting Land were David C. Reutter, Randy L. Ulery, Peter C. Van Metre, Mariann F. Brown, Allison S. Crossfield, and Bruce J. Moring. In 1994 this Unit was renamed as the National Water-Quality Assessment Units because a second NAWQA study was to be started in the District.

National Water-Quality Assessment Study Unit. The Trinity River Study and the new South-Central Texas Study made up this Unit.

Trinity River. This team remained the same with Larry Land the Project Chief, assisted by Reutter, Ulery, Van Metre, Brown, Crossfield, and Moring.

South-Central Texas. This NAWQA project was to study the water-quality issues of the Edwards aquifer along with the surface water that recharges the aquifer and the water that discharged to the surface streams. The project was begun in 1993. Bush was selected as Project Chief but was replaced by Jennings in 1994 when Bush became the Texas District Reports Specialist. The team included Rene A. Barker, Charles E. Hornig, Linda J. McCormick, Ann F. Ardis, Patricia N. Ging, and Kirby H. Wynn.

Hydrologic Surveillance, Research* and *Analysis Section. The Section Chief, Clarence R. Gilbert, retired in 1980. Clarence was assisted by Francis S. Price. The Section Chief supervised a large support staff, including the Water Quality Unit and the Hydrologic Surveillance and Analysis Unit. Section Chiefs during the period were Dick Grozier, who transferred in 1981 from the San Antonio office, where he was Subdistrict Chief, to replace Gilbert. Grozier remained Chief of the Section and Associate District Chief until 1984, when he retired. Jack Rawson replaced Grozier and was Chief from 1984 to 1988 when he retired.

Rawson was Chief of the Water Quality Unit before becoming Section Chief and Associate District Chief. The Section was renamed Hydrologic Surveillance and Analysis Section under the reorganization of 1988.

Hydrologic Surveillance and Analysis Section. Bernie Massey was selected to be the Chief of this renamed Section and continued as Chief until he retired in 1994. Massey had previously held the position of Chief of the Hydrologic Surveillance and Analysis Unit. In 1989, Kenneth C. Grimm, Dee L. Lurry, and Jack Veenhuis were placed in this Section. During the reorganization in 1990, Grimm and Veenhuis were reassigned to the Hydrologic and Hydraulics Unit. Lurry was reassigned to the Environmental Studies Unit. Frank C. Wells replaced Massey as the Chief of the Hydrologic Surveillance and Analysis Section in 1994.

Water Quality Unit. The Water-Quality Unit had a long and strong history in the Texas District. This Unit helped to establish a very capable water-quality program in the District and the Division. Water Quality Unit Chiefs were Jack Rawson (1980–84) and Frank C. Wells (1984–90). This Unit was integrated into the Hydrologic Surveillance and Analysis Section as the Data Unit in 1991. Other personnel who played a major role in the Water Quality Unit were Heberto B. (Herb) Mendieta, Clarence T. Welborn, Marvin W. Flugrath, Emma M. McPherson, Freeman L. Andrews, Helen J. Davidson, Eugene Burse, Searcy M. Jacobs, Eleanor S. Chitwood, Fay VanZandt, Wanda J. Shelby, Jeffrey L. Strause, Dale L. Pate, Terry L. Schertz, Margaret S. Woodley, Eugene Burse, Norman F. Leibbrand, Willard J. Gibbons, Betty Hinds, Michael E. Dorsey, Robert Lynn Taylor, Yvonne R. Wray, Dane J. Ohe. In 1993 the Water Quality Unit was reestablished. Emma M. McPherson was named Supervisory Hydrologist. She was assisted by Freeman L. Andrews, Michael Dorsey, Betty Hinds, and Delfino Garcia. The Water-Quality Unit was eliminated in yet another reorganization in 1994.

Data Quality and Management Unit. This Unit was established in 1994. Susan C. Gandara was selected as Unit Chief. Others in the Unit included Michael Dorsey, James C. Fisher, Willard J. Gibbons, Freeman Andrews, Betty Hinds, and Ruth Jones.

Hydrologic Surveillance and Analysis Unit. Massey was the Unit Chief until he was selected to replace Associate District Chief Rawson as Section Chief and become the first Assistant Chief for the Hydrologic Surveillance and Analysis Section in 1988. Massey served as Chief of this Unit from 1984 until 1988. Others assigned to the Surveillance Unit were William E. Reeves, Walter A. Lear, Austin A. Bricker III, Felipe H. Tovar, Harold D. Buckner, Fran L. Ellis, Evangelina R. Carrillo, Joyce C. Stewart, Jack E. Veenhuis, and Frances L. Heintze. The Unit was renamed Surface-Water Unit in 1989 under a reorganization.

Surface-Water Unit. Buckner was named Chief of the newly named Unit in 1989. Others that joined him in this Unit, as well as those that were already in the Unit before reorganization, were Walter Lear, Felipe Tovar, Joyce Stewart, Dee Lurry, and Kenneth Grimm.

Data Unit. This Unit was created in 1990 during a reorganization by combining the Surface-Water and the Water-Quality Units. The Data Unit included all the old Water-Quality and Surface-Water Units. Frank Wells was named Unit Chief. Others in the Unit included Emma M. McPherson, Freeman L. Andrews, Wanda J. Shelby, Willard J. Gibbons, Betty Hinds, Michael Dorsey, Robert L. (Lynn) Taylor, Felipe (Phil) H. Tovar, Joyce Stewart, Dane Ohe, Ruth Jones, Delfino Garcia, Susan C. Gandara, and Dee Lurry. Wells remained the Chief until he was selected as the Area Water-Quality Specialist for the Great Southwest Area in 1992. The Unit was under the direction of the Hydrologic Surveillance and Analysis Section Chief, Bernie Massey. In 1992 this Unit was reorganized into the Water-Quality Unit, the Data Management Unit, and the Office of the Water-Use Specialist.

Data Management Unit. Susan Gandara was selected to supervise this Unit in 1992. She was assisted by Buckner, Gibbons, Lear, Phil Tovar, Ruth Jones, and Joyce Stewart. This Unit was renamed the Data Quality and Management Unit in 1994.

Data Quality and Management Unit. Gandara remained the Unit Chief and was assisted by Michael Dorsey, James Fisher, Willard Gibbons, Freeman Andrews, Betty Hinds, and Ruth Jones.

Office of Water-Use Specialist. Dee L. Lurry was named to head this office in 1992 as she was the water-use specialist for the District. This office was dissolved in 1994 and Lurry joined the Hydrologic Surveillance and Analysis Section.

Hydrologic Systems Investigations and Research Section. Larry Land was the Section Chief at the beginning of this period of the Texas District History and remained Section Chief until 1988 when

the District was reorganized. Working with Land were Sergio Garza, Ernest T. Baker, Jerry E. Carr, Elmer E. Schroeder, Austin A. Bricker III, Mary L. Bauer, Raymond M. Slade, Jack E. Veenhuis, George E. Groschen, Judson E. Veazey, Gary W. Mackey, George B. Ozuna, Peter W. Bush, Walter R. Rast, Paul D. Ryder, Ann F. Ardis, Brian J. Eggers, Eve L. Kuniansky, Rochelle L. Rittmaster, Paul M. Buszka, René A. Barker, and Bobby D. Jones. The Section was renamed Hydrologic Systems Investigations and Research Section under the reorganization of 1988.

Hydrologic Investigations and Research Section. Marvin Sherrill was selected to serve as Chief of this renamed Section. All of the employees that were in the old Section became part of this new Section except those that were named to the RASA Group. They are listed under the Edwards-Trinity RASA section of this report. Others that joined this Section were Randy L. Ulery and Kelly Q. Holligan and Lloyd Woosley as Chief of the Section in 1992. Reorganization in 1990 of this Section broke it up into two Units, the Environmental Studies Unit and the Hydrologic and Hydraulics Unit. The Edwards-Trinity RASA project was also placed under the direction of the Section Chief, Sherrill. The following personnel were placed into this Section as a result of closing the Environmental Studies Unit: Ernest T. Baker, Roger W. Lee, James R. Bartolino, Sonya A. Jones, Patricia N. Bauer, and M. Delores Williams.

Environmental Studies Unit. The Chief of this Unit was Sherrill. Others assigned to the Unit were Ernie Baker, Roger Lee, Walter R. Rast, Paul D. Ryder, Paul M. Buszka, Randy L. Ulery, Bobby D. Jones, Dee L. Lurry, Robert D. Brock, James R. Bartolino, Warren E. Alverson, and Patricia N. Bauer. The Environmental Studies Unit was closed in 1992 and the personnel were placed directly into the Hydrologic Investigations and Research Section.

Hydrologic and Hydraulics Unit. This Unit was established in 1990, and the Chief was Sherrill. Others assigned to the Unit were Marshall E. Jennings, Henry R. Hejl, Raymond M. Slade, Jr., Kenneth C. Grimm, Jack E. Veenhuis, Myrtle D. Williams, David D. Dunn, Lu L. Tan, Linda J. Jennings, and Karl E. McArthur. Marshall Jennings was selected as Unit Chief in 1991; the Unit was closed in 1994.

Construction, Instrumentation, and Map Unit. This Unit served the entire District. The Chief was Pat W. Skinner. Others in the Unit were Fred A. Hubbard, Milton M. Miller, Phil Tovar, Sylvester Pleasant, Jr., H. Paul Shanahan, Jr., Milton M. Miller, Kirby Wynn, John P. Maguire, and Keith R. Snider. The Unit was reorganized and renamed Technical Support and Safety Unit in 1982. The Unit included an electronics laboratory that was second to none. Two outstanding Electronic Technicians, Hubbard and Shanahan, kept the instrumentation used by the Texas District working at top performance. The Unit was renamed Support and Safety Unit in 1990 and was abolished in 1994.

The Subdistrict Offices. There were six Subdistrict Offices in Texas in 1979: Austin, Houston, Fort Worth, San Angelo, San Antonio, and Wichita Falls. Each of the Subdistrict Chiefs worked under the supervision of the District Chief. The Subdistrict's charge was to gather, analyze, and publish all the scientific data within their area of responsibility to describe the water resources of the State of Texas. The Austin Subdistrict was converted to a Field Headquarters in 1982. San Angelo and Wichita Falls were converted to Field Headquarters in 1990. Converting the Subdistricts to Field Offices was done in all three cases because these offices were basically data-collection organizations doing little or no interpretive studies. It was more efficient to do hydrologic studies either out of the District Office or out of the nearby larger Subdistricts.

Austin Subdistrict. Ernie Baker served as Subdistrict Chief until the office was converted to a Field Headquarters in 1982. Baker was assisted by Raymond M. Slade, Stephen J. Halasz, Wallace D. Robbins, John D. Gordon, James K. VanZandt, Michael E. Dorsey, Addis M. (Buddy) Miller, Raymond N. Mitchell, Niki V. Philip, Mark S. Brown, Dale L. Pate, Arthur D. Martin, and George D. McElhany. The organization and personnel of this office changed substantially after the office was converted to a Field Office in 1982 and will be discussed under the heading of Austin Field Headquarters. The area of responsibility for the Austin Office was the Hill Country west of Austin, about 30 miles south, 100 miles north, and 100 miles east of Austin. This office was collocated with the District Office in the Federal Building.

Houston Subdistrict. As this period began, Robert E. Smith was the Subdistrict Chief of this office. Smith retired in 1980. Robert K. Gabrysch was named Subdistrict Chief and served in that position until retirement in 1991. Gabrysch was replaced by Joseph D. Broadus in 1992. Houston had always been the largest of the Texas Subdistricts until the early

1990's. At the beginning of this period, the Houston Subdistrict had 33 employees. The Rockport Field Headquarters also reported to Houston. By 1994 the number of employees had decreased to 23 employees, mainly because of the completion and termination of the Bays and Estuaries Project. Data collection on this project was labor intensive and required many employees. It also required many boats for data collection, and at one time the USGS talked about the Houston Subdistrict's "Navy." Subsidence and Urban Hydrology were also a big part of the Subdistrict's program. Houston was the only Subdistrict in Texas that had a formal organization chart similar to the District Office. The area of responsibility included the coastal area to north of Corpus Christi to the south, all of east Texas, and 100 miles to the north. The office was located in downtown Houston at 2320 La Branch Street.

The Office of the Houston Subdistrict Chief. The Chief, his assistant, and an administrative clerk made up this office. In the beginning of this period Robert E. Smith was the Subdistrict Chief and Robert K. Gabrysch was the Assistant Subdistrict Chief. Smith retired in 1981 and was replaced by Gabrysch in 1981. The Assistant Subdistrict Chief position was filled by Fred Liscum in 1982. Gabrysch remained Subdistrict Chief until he retired in 1991 and was replaced by Joseph D. Broadus in 1992. Betty R. Miles was the Administrative Clerk from 1980 until her retirement in 1991. Kathleen H. Hayden became the Subdistrict Secretary in 1992. Cindy Billington joined the office in 1994 as Office Automation Clerk.

The Hydrologic Surveillance and Analysis Unit. The Chief in 1980 was Emil G. Kaminski, assisted by Richard L. Goss, Sharon A. Cotman, Bernice D. Poirier, and Florietta Gillis. Kaminski retired in 1987 and was replaced by Goss. This Unit was terminated in 1988. Goss moved to the Water Quality Unit as Chief of the Unit, and Poirier moved to the Urban and Data Network Unit.

The Urban and Data Network Unit. Fred Liscum was the Chief of this Unit from 1980 to 1982 when he was selected to serve as Assistant Subdistrict Chief. James C. Fisher was selected as Unit Chief in 1982. Others in the Unit included Donald E. Ferguson, Carl A. Heinrich, Chester J. Phillips, Stanley Baldys III, James S. Hutchison, Clarence E. (Ed) Ranzau, Jr., Joseph P. Bruchmiller, Jay F. Weigel, Lee B. Goldstein, Bernice D. Poirier, Michael B. Bowman, Laura S. Walther, Jerry G. Chandler, Steve J. Robinson, Donald H. Rush, George D. (Dan) McElhany, Ira G. Rathbun, Steven P. Preston, Mark C. Kasmarek, Donald J. Searles, Anthony L. Dworaczyk, Robin W. Ploss, Dexter W. Brown, Ralph D. Lites, James K. (Ken) VanZandt, Patrick O. Keefe, Vidal A. Mendoza, John S. Sawyer, Rick L. Shmidl, Michael R. Burnich, and Stanley R. Cole. Reorganization eliminated this Unit in 1993. The employees were placed either in the newly created Hydrologic Investigations and Research Section or in the Hydrologic Surveillance and Analysis Section.

The Hydrologic Systems Unit. The Chief of this Unit was Karl W. Ratzlaff until his transfer in 1980. Ratzlaff was replaced by Jeffrey L. Strause in 1982. James F. Williams became Unit Chief in 1984. Williams transferred in 1987, and Dana L. Barbie, formerly of the BLM in Utah, replaced him in 1988. This Unit also included William M. Sandeen, Charles W. Bonnet, William B. Lind, Clarence E. Ranzau, Roy S. Sonenshein, Ivy R. Atherton, Laura S. Coplin, Glenn L. Locke, Al Campodonico, Glen L. Locke, Mark C. Kasmarek, Horacio X. Santos, and Ivy R. Mclane. Robert Gabrysch, the retired Subdistrict Chief, worked WAE (when actually employed) in this Unit beginning in 1991. The Unit was eliminated in 1993 under the reorganization, and the employees were placed in the newly created Hydrologic Investigations and Research Section or the newly created Hydrologic Surveillance and Analysis Section.

The Hydrologic Investigations Unit. In 1991, this Unit was established and Fred Liscum was named Chief. Assisting Liscum were Dexter W. Brown, Jeffery W. East, and Glenn L. Locke. This Unit was eliminated in 1993 under the reorganization. The employees were placed in the newly created Hydrologic Investigations and Research Section.

The Bays and Estuaries Project. This project office was headed by James C. Fisher, assisted by Ira G. Rathbun in 1979. This project was completed in 1982, and Fisher and Rathbun moved into the Urban and Data Network Unit.

The Water Quality Service Unit. Edna M. Paul, Cervando S. Ramirez, and Alberta G. Swanson made up this Unit in 1980. Goss became the Chief of the Unit in 1988. Under the reorganization of 1993 the Unit was terminated. Goss transferred to the Colorado District, and the three other employees were placed in the Hydrologic Surveillance and Analysis Section.

Hydrologic Investigations and Analysis Section. This Section was established in 1993 under

the latest reorganization. Dana L. Barbie was named Chief of the Unit. Others in the Section included Mark C. Kasmarek, Dexter W. Brown, Jeffery W. East, and Laura S. Coplin.

Hydrologic Surveillance and Analysis Section. This Section was also created in 1993. A chief was not named for the Section. Those working in the Section were VanZandt, James S. Hutchison, Edna M. Paul, Joseph P. Bruchmiller, Lee B. Goldstein, Cervando S. Ramirez, Patrick O. Keefe, Michael R. Burnich, Al Campodonico, Vidal A. Mendoza, Horacio X. Santos, John S. Sawyer, and Alberta G. Swanson.

Fort Worth Subdistrict. The Subdistrict Chief at the beginning of this period was Ector E. (Gene) Gann. Gann remained Chief of this office until 1981 when he was selected to be District Chief of the Arkansas District. Lynn Harmsen transferred from the San Antonio Subdistrict in 1982 to replace Gann as Subdistrict Chief. Harmsen remained Chief of this Subdistrict until his untimely death in 1983. William J. Herb transferred from Pennsylvania District to become Subdistrict Chief after Harmsen's death. When Herb was named Chief of the Minnesota District in 1988, he was replaced by Harry C. McWreath, who transferred from the Louisiana District. McWreath remained the Subdistrict Chief throughout this period. The office was located on the Fort Worth Federal Center at 501 West Felix Street. This office operated essentially as a data-collection office through the years and included operating the GOES downlink for the Texas District. Surface-water and water-quality data collection was the mainstay of the Subdistrict. However, a very large project ($2 million) with the Dallas–Fort Worth Metroplex was developed in 1991 to collect and analyze stormwater runoff at over 30 sites in the Metroplex area. McWreath and Marshall Jennings were responsible for developing this program. The project had great importance to the District and to the Division in that the funding was unmatched by the District's Coop funds. This was the beginning for the District and the Division in moving away from the traditional 50-50 funding arrangement between the USGS/WRD and the local cooperators. The principal assistant in the office during this period was Ralph H. Ollman, who was named Assistant Subdistrict Chief in 1983. Others who worked in the office were Billie B. Hampton, Dennis R. Myers, Willard J. Gibbons, Thomas H. Hays, Erich E. Lotto, Charles M. Wood, Clyde T. Schoultz, J.M. Taylor, Jack D. Benton, Sue H. Butler, T. Roy Hastings, Glen D. Huckleberry, J.L. Worth, Judith H. Donohue, William S. Gain, Jon R. Gilhousen, Karla S. Henson, Benjamin J. Carr, Sonja D. Williams, Juan A. Reyes, David V. Tudor, Stanley Baldys, Ross B. Jennings, Glenn A. Rivers, Jeffrey T. Sandlin, Phillip W. Golden, Lucia G. Colangione, Timothy H. Raines, Ricky L. Couch, Martin J. Danz, Richard E. Faux, Vernon L. Hastings, Hamis Kamalpour, and Bradley L. Mansfield. In 1992 a formal organization chart was developed for the Subdistrict that included the Office of the Subdistrict Chief, the Water Quality Unit, the Hydrologic Surveillance Section, and the Hydrologic Investigations Section.

Office of the Subdistrict Chief. Harry C. McWreath remained the Subdistrict Chief. Stanley Baldys III was named the Assistant Subdistrict Chief and Donna J. Weber was named the Administrative Technician.

Water Quality Unit. Stanley Baldys III was the Chief of this Unit. Others working in this Unit were Clyde T. Schoultz, Jack D. Benton, Benjamin J. Carr, and Richard E. Faux. The Unit stayed in place only for 1 year then was eliminated in 1993. The employees were placed in the Hydrologic Surveillance Section.

Hydrologic Surveillance Section. This Section included Ralph H. Ollman, J.M. Taylor, Charles M. Wood, Sue H. Butler, Glenn A. Rivers, David V. Tudor, Martin J. Danz, Judith H. Donohue, Phillip W. Golden, Vernon L. Hastings, Clyde T. Schoultz, Jack D. Benton, Benjamin J. Carr, Richard E. Faux, Darryll G. Pinion, and Martha E. Stokley. Baldys became Chief of this Section in 1993.

Hydrologic Investigations Section. Personnel in this Section included Timothy H. Raines, Bradley L. Mansfield, Glenn A. Rivers, and Jeffrey T. Sandlin.

DCP Downlink Operation. The Texas Direct Readout Ground Station (DRGS) was purchased and installed by the U.S. Army Corps of Engineers (Corps) in the fall of 1981 at no expense to the USGS. It was installed at the Fort Worth Federal Center, USGS Office, because the managers of the Federal Building in downtown Fort Worth, where the Corps office was located, did not want the large antennas on top of the building. It also would have been very expensive to hire a crane for the installation. The two 5-meter dishes were installed on the ground at the Fort Worth Federal Center for a fraction of the cost of putting them on the Federal Building. The Corps managed the DRGS for about 1 year after installation. Then, because of the time and expense of driving from down-

town to the Federal Center, they began to rely more and more on the USGS to do the daily operations. After about 3 years, the entire DRGS (equipment and operation) was transferred to the USGS. The Corps' only stipulation was that the USGS would provide data to the Corps over a dedicated phone line. Dennis Myers and Sue Butler were in charge of the day-to-day operation of the DRGS in Fort Worth. Fred Stroman and Willard Gibbons, in the District Office, spent a lot of time keeping the USGS software operational, partly because the software was so new but also because there was such a tremendous volume of data generated by the downlink. The Texas DRGS was the only receive site in the Nation that had both and east- and west-looking antenna. As a result, the Fort Worth site could "see" every DCP in the Nation and consequently received requests from many Districts to "look" for data from one of their DCP's. Primary Districts using the Fort Worth DRGS site were Texas, Oklahoma, Arkansas, Iowa, and Kansas. The site served as the backup site for the Colorado, Arizona, Utah, and New Mexico Districts. The Colorado DRGS backed up the Texas western DCP's and the South Carolina DRGS backed up the Texas eastern DCP's. The DRGS remained in operation until it was replaced in 1993 by the Local Readout Ground Station (LRGS), which was operated by the Oklahoma District.

San Angelo Subdistrict. James H. Eade was the Subdistrict Chief at the beginning of this period. He remained Subdistrict Chief until 1991 when the office was converted to a Field Headquarters. Eade assumed the position of Field Headquarters Chief. This Subdistrict, which was at 1409 Knickerbocker Road, was made into a Field Headquarters because it was very strongly oriented to data-collection activities. Very few projects were run out of this office.

San Antonio Subdistrict. Richard U. Grozier was the Subdistrict Chief at the beginning of this period of Texas District history. He remained the Subdistrict Chief until 1981 when he became the Texas Associate District Chief for the Hydrologic Surveillance, Research and Analysis Section. Harmsen served as acting Chief of the office until October 1982 when Burchett transferred from the Tennessee District, where he had served as the Nashville Subdistrict Chief. Burchett remained Subdistrict Chief until 1986 when he was selected to become the third District Chief of Oklahoma. Howard D. Stephens was acting Subdistrict District Chief until Rodger F. Ferreira transferred from Helena, Mont., to assume the Office Chief responsibilities. Ferreira remained Subdistrict Chief until 1990 when he was selected to be the Associate District Chief in New Mexico. He was replaced by Robert A. Lidwin, who remained Subdistrict Chief through the remainder of this period. Throughout this entire period the Subdistrict was a very strong office with a well-rounded data and investigative program. Much of the work done out of this office was related to the Edwards aquifer, which is the sole source water supply for San Antonio. The office did not have an official organizational chart from 1979 through 1988, but in fact it was broken down into a data-collection unit and a ground-water studies unit. Harmsen was the Data Chief until Stephens transferred from Ord, Nebr., where he was the Subdistrict Chief. Stephens served until he retired in 1994. Roberto Perez was selected from within the office to take on the responsibilities of the Data Chief. Robert W. Maclay and Richard D. Reeves were the principal ground-water hydrologists. Reeves was responsible for the ground-water data collection and Maclay was Chief of the Edwards Aquifer Research Studies. Both hydrologists became known as experts concerning the Edwards aquifer. Employees working in the surface-water unit were William R. Roddy, Kenneth C. Grimm, John A. Tomlinson, Olga H. Munoz, Francis A. Wessels, James C. Wisecarver, Gregory B. O'Neill, Ronald P. Collins, Margarita Davis, Robert A. Storer, Jon R. Gilhousen, Gregory M. Nally, Stanley C. Skrobialowski, and Buddy Miller. In the ground-water unit were Theodore A. Small, Paul L. Rettman, Paul M. Buszka, Dianne J. Pavlicek, George E. Groschen, and John F. Stanford. Support and secretarial personnel included Mary M. Wolfe and Patricia L. Higle. In 1989 the office developed an organization chart that included the Office of the Subdistrict Chief, the Hydrologic Investigations and Research Section, and the Hydrologic Surveillance and Analysis Section. The area of responsibility included all of south Texas from San Antonio to the lower Rio Grande Valley, east to the coast and north of Corpus Christi, west into the Hill Country for about 150 miles, and north for about 50 miles to the springs that discharge the water of the Edwards aquifer. The office was at 435 Isom Road.

Office of the San Antonio Subdistrict Chief. When the Office of the Subdistrict Chief was established in 1989, the Subdistrict Chief was Rodger Ferreira and the Assistant Subdistrict Chief was Dean Stephens. This office also included Diane C. Gilliom,

Joan T. Patton, and Chiquita S. Lopez. Robert A. Lidwin became Subdistrict Chief in 1990.

Hydrologic Investigations and Research Section. Employees in this Section were George E. Groschen, George B. Ozuna, Theodore A. Small, Gregory M. Nalley, William G. Stein, Paul L. Rettman, William Stein, Michael W. Thomas, Scott I. McFarlane, David S. Brown, Ranko S. Pudar, Brian L. Petri, John A. Hanson, John G. Mosier, Rebecca B. Lambert, and Grant L. Snyder.

Hydrologic Surveillance and Analysis Section. This Section included Roberto Perez, John A. Tomlinson, Ronald P. Collins, Buddy Miller, Francis A. Wessels, Jon R. Gilhousen, Olga H. Munoz, Leo L. Saavedra, Charles R. Herrick, James M. Briers, Robert J. Ferris, Michael E. Torres-Pastor, Allen R. Furlow, John F. Wojcik, and Jorge O. Pena. Roberto Perez was named Chief of this Section in 1992.

Water Quality Unit. This Unit was established in 1992. George Ozuna, from within the office, was selected as Chief of the Unit. Others working in this Unit included Buddy Miller, Charles A. Hartman, Allan K. Clark, and Richard N. Slattery. Miller was named Lead Hydrologic Technician of this Unit in 1993.

Wichita Falls Subdistrict. The Wichita Falls office has always been a data-collection operation. The office was in the Post Office Building in downtown Wichita Falls. This office handled all the data-collection activity northwest of Dallas–Fort Worth, including the Texas Panhandle. In 1993 when the Area concept was in place, this office operated gaging stations in southwest Oklahoma. In 1979 John O. Joerns was the Subdistrict Chief. Upon his retirement, Joerns was replaced by Charles C. Kidwell. Kidwell was Chief of the office during most of this period. However, in 1990 the Subdistrict was converted to a Field Headquarters to reflect the data-collection activity of the office. Kidwell retired in 1994, and the office was placed under the direction of the Fort Worth Subdistrict. This office has maintained a staff of around five to six employees throughout the years and has included Willie F. Hastings, Gordon H. Martin, Doris F. Tipps, Karl G. Johnson, Sherwood B. Browning, Keith R. Karstetter, Glenn A. Rivers, and Jackie D. Kelly.

The Field Offices. The San Angelo and Wichita Falls offices were converted to Field Headquarters in 1990. Field Offices in the Texas District at the beginning of this period included El Paso, Pampa, and Rockport.

El Paso Project Office. The El Paso office was a ground-water data-collection oriented office. Donald E. White was the Chief of this office from 1979 through 1994, when he retired. The office was located in the City Water Board Office Building. In 1979 this office reported to the San Angelo Subdistrict Office. White served as the principal liaison between Texas west of the Pecos and the District Office in Austin. He worked very closely with the City of El Paso in keeping records on the City's water-supply wells.

Pampa. The Pampa office had two employees in 1979: Gene D. McAdoo was the Hydrotech-in-Charge and Wilda J. McGahen was the Clerk-Typist. The office was at 412 West Kingsmill Street. This office, which was under the direction of the Wichita Falls Subdistrict, was a surface-water data-collection office. It served the Texas Panhandle and saved many miles of driving from Wichita Falls to service gages and collect data. However, when McAdoo retired in 1985 the office was closed.

Rockport. The Rockport office, at 1807A Rath Street, was under the direction of the Houston Subdistrict for the Bays and Estuaries Project. Gail D. Driver served as Motor Boat Operator for the Bays and Estuaries Project in the Rockport area. This office was closed in 1982 when the project was terminated.

Austin Field Headquarters. The Austin Field Office was established in 1982 when the Austin Subdistrict was converted to a Field Office and placed under the direction of the Assistant District Chief of the Hydrologic Surveillance and Analysis Section. William E. Reeves was selected as the Field Office Chief. The Office was under the direction of the Assistant District Chief of the Hydrologic Surveillance and Analysis Section. Those assisting Reeves were John D. Gordon, James K. VanZandt, Milton M. Miller, Michael E. Dorsey, Raymond N. Mitchell, Dale L. Pate, Joseph L. Jones, Searcy M. Jacobs, Diana L. Slagle, Delores Williams, Kirby H. Wynn, Clarence E. Ranzau, Milton W. Sunvison, Kenneth C. Weiss, Venezia Shearer, and Keith R. Snider. Reeves died of a heart attack in 1993. Michael E. Dorsey was selected as the Field Office Chief. This office was collocated with the District Office.

San Angelo Field Headquarters. When the office was converted to a Field Office it was placed under the direction of the Assistant District Chief of the Hydrologic Surveillance and Analysis Section. Jim

Eade remained Chief of this Office until he died in 1991, and William H. Martin was named Field Headquarters Chief in 1992. Martin remained Chief of the office until he retired. He was always highly thought of by his fellow District Employees and was selected by secret ballot as the very first TEXAS DISTRICT EMPLOYEE OF THE YEAR, named in 1990. The data-collection responsibility of this office included all of West Texas, except for ground-water data in El Paso, until 1993 when everything west of the Pecos River was turned over to the New Mexico District to be managed out of the Las Cruces Subdistrict Office. Martin retired and was replaced by Jimmy G. Pond. Other employees who served in the Office include Jimmy N. Lee, Virgil L. Spiers, Wallace R. Carnes, Ernest Prochazka, Henry Jacques, Jr., James B. Schiller, Lawanna M. Kiser, and Tim E. Teagarden.

Wichita Falls Subdistrict Field Headquarters. When the Wichita Falls Office was converted to a Field Headquarters in 1990 it was placed under the direction of the Assistant District Chief of the Hydrologic Surveillance and Analysis Section. Kidwell remained Office Chief. Others who worked in this Office were Willie F. Hastings, Doris F. Tipps, Keith R. Karstetter, Jackie D. Kelly, William C. Damschen, and William P. Bennett.

FUNDING AND COOPERATION

The total program funding for the Texas District in 1979 was $5,841,321. Funding increased to $12,550,476 by the end of 1994. In fiscal year (FY) 1993, funding reached an all-time record level of $13,265,504. In other words, funding doubled during this period. The Federal program increased from $622,257 to $2,705,594 (335 percent) and increased steadily throughout the period with large amounts going to NASQAN sites and to the NAWQA projects. Other Federal agency funding increased from $1,010,660 to $2,461,504 (143 percent). Most of this increase was the result of a continuing rise in the cost of gaging-station operation. The Coop program increased from $4,212,485 to $7,383,378 (75 percent). However, the Federal side of the Coop only increased by 37 percent, whereas the local and State share increased from $2,085,561 to $4,466,644 (114 percent). The local and State side of the Coop program was $1,405,750 higher in FY 1993, standing at $5,873,394. This means that in 1993 the local and State governments were willing to place $2,933,828 in the USGS/WRD Coop program as unmatched money. This situation was created by the State's need for information and a lack of Federal dollars to match that need. A large part of the unmatched funds came from the Texas Water Development Board and the Dallas–Fort Worth Metroplex. The Texas District had a very large increase in funding in FY 1991, 1992, and 1993 with a decrease of $715,028 in FY 1994. Funding for the period is shown in the following table.

A new program that began in 1986 with the U.S. Air Force called the Installation Restoration Program (IRP) greatly increased OFA funds to WRD. The IRP Program for the WRD was initiated through an effort by Burchett, the San Antonio Subdistrict Chief, and Boning, the Texas District Chief. The initial project called for work on the IRP in Texas to begin in San Antonio at Kelly Air Force Base. Another six projects were started in other Districts across the country. This program grew to over $40 million a year by 1994.

Texas District funds, in thousands of dollars, for fiscal years 1980–94

[Source: District program documents for 1980–92; Administrative Information System records for 1993–94; e, estimated from funding graph in the 1990 Program Review Book; XXX, data not available. All figures rounded to the nearest $1,000]

Fund source	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop total	4,208	4,309	4,320	XXX	XXX	XXX	4,979	5,945	5,816	5,660	5,838	7,009	7,904	8,813	7,384
State	2,086	2,163	2,196	XXX	XXX	XXX	2,683	2,881	2,932	2,960	3,088	3,987	5,047	5,873	4,467
Fed	2,127	2,146	2,124	XXX	XXX	XXX	2,296	2,614	2,884	2,700	2,750	3,022	2,857	2,940	2,917
OFA	1,019	1,046	1,087	XXX	XXX	XXX	1,227	1,483	1,663	1,494	1,011	1,538	2,201	1,991	2,462
Federal	684	572	407	XXX	XXX	XXX	873	1,028	1,071	1,086	1,259	1,533	1,899	2,461	2,706
Total	5,916	5,926	5,814	e5,900	e6,200	e6,800	7,079	8,006	8,549	8,240	8,107	10,080	12,005	13,266	12,550

SUMMARY OF PROGRAMS

Hydrologic-Data Collection

During the early 1980's, the data-collection program in the Texas District remained fairly constant, and the District relied on the mainframe computer in Reston, Va., for the computation of data for the Annual Data Report. There were no computer facilities in the Subdistrict Offices, and stations that had digital recorders had to forward the digital punch tapes to the District Office for loading and processing of data. Stations that used strip-chart recorders were processed manually in the Subdistrict Offices. After final analysis of these data, they were forwarded to the District Office for input into the Reston computer. During the early 1980's it was not uncommon for the annual data report to be sent to the printer several months after the June 1 deadline established by Headquarters.

Streamflow Stations. In 1979 the Subdistrict Offices were operating about 548 continuous-record stream-gaging, reservoir-content, and stage-only stations. About 100 partial-record surface stations were in operation. Tide levels were measured on a continuous basis at about 33 stations as part of the Bays and Estuaries project operated out of the Houston Subdistrict Office.

By 1985 the number of continuous stream-gaging, reservoir-content, and stage-only stations had decreased to about 447 continuous-record stations. Of these, 89 were for lake and reservoir stage and contents. About 147 partial-record stations and 11 tide-level stations were in operation at this time.

By 1990 the Texas District data program for continuous-record stream-discharge, stage only, and lake and reservoir stage and(or) contents had decreased to approximately 423 continuous-record stations and 66 partial-record stations. No tide stations were operated in water year 1990.

By 1994 the Texas District surface-water data-collection programs had increased to 501 continuous-record stations for discharge, stage only, and lake and reservoir stage and(or) contents. The District operated about 66 partial-record stations during that year.

Three significant changes began in the surface-water data-collection activities during the 1980's and early to mid-1990's. First, the District began removing the mercury manometers and replacing them with instrumentation that did not require the use of toxic substances to monitor stage at the gaging stations. Many, if not most, of the mercury manometers were replaced with pressure transducers to measure the stage and electronic data loggers to record the measurements. Second, in addition to the electronic data loggers, many of the gaging stations were equipped with data-collection platforms (DCP's). The DCP's would collect and log stage data and transmit the data to a Geostationary Earth Orbiting Satellite (GOES). The satellite would in turn transmit the data to the District Office at approximately 4-hour intervals and enter the data automatically into the District computer data base. The computer data base was an Automated Data Acquisition Processing System commonly referred to as ADAPS. ADAPS was installed on the District minicomputer and was used to process data for the Annual Data Report. Third, many of our cooperators began to want their data on a near real-time basis. Our data base was made available to our cooperators so they could access the data they needed. Initially, this involved the cooperators actually making data retrievals using the ADAPS data base but eventually led to having almost all of the data collected by the Texas District available to cooperators and the general public over the Internet.

Water-Quality Stations. During water year 1980 the Texas District operated approximately 97 daily conductivity stations. Sufficient samples were collected for inorganic analysis at these stations to define the total daily loads of dissolved solids, chloride, and sulfate. The periodic chemical-quality network consisted of stations at 139 sites on streams and stations at 51 sites on reservoirs. Special periodic sampling was conducted at about 112 stations. These samples included the analysis of standard inorganic chemical quality, biochemical oxygen demand (BOD), dissolved oxygen (DO), nutrients, pH, minor elements and pesticides. The District also conducted water-quality surveys on 23 reservoirs throughout the State. Sampling frequency was generally done during the winter, spring, and summer, and specific conductance, DO, pH, and temperature were generally measured onsite at depths of approximately 10-foot intervals. During water year 1980 the District operated 7 four-parameter (temperature, specific conductance, DO, and pH) water-quality monitors, 14 conductivity recorders, and 3 temperature recorders.

In the mid-1980's the District operated about 80 daily stations for conductivity and temperature, 25 daily conductivity and temperature water-quality monitors, and 5 four-parameter water-quality moni-

tors. The District operated about 248 stations for either periodic or special periodic sampling on streams and reservoirs throughout the State.

By 1990, the District sampled about 185 stations on streams and 20 reservoirs in Texas. The decrease in the number of stations was primarily due to lack of Federal funds to match the cooperators' funds. The District operated approximately 70 daily stations for conductivity and temperature and about 8 water-quality monitors for conductivity and temperature. The District had a total of 3 (DO, temperature, and conductivity) monitors and 19 four-parameter water-quality monitors. The large increase in three- and four-parameter monitors was due to the need to monitor water quality on streams downstream from major urban areas in the State.

By the mid-1990's, the District water-quality program continued to decrease in regard to the number of stations operated. The District collected water-quality samples from about 150 streamflow stations and from about 21 reservoirs. The District operated 1 water-quality monitor for temperature, 18 monitors for temperature and conductivity, 3 three-parameter water-quality monitors, and 20 four-parameter water-quality monitors.

In 1990 Texas District personnel Frank Wells, Willard Gibbons, and Mike Dorsey also updated the publication "Guidelines for Collection and Field Analysis of Water-Quality Samples from Streams in Texas." This report was published as Open-File Report 90–127.

The early to mid-1990's also reflected a big change in the publication of the Annual Data Report. With the installation of DCP's at approximately one-half our gaging stations, data preparation was being conducted on a near real-time basis, which allowed the hydrologic technicians to prepare data on an up-to-date basis. In 1993 District personnel had all four volumes of the Annual Data Report to the printer before the April 1 deadline established by Headquarters.

Fluvial Sediment Stations. In 1980 the District operated nine stations for total daily suspended-sediment concentrations and for concentrations of suspended sand and suspended silt. In 1985 only two daily suspended-sediment stations were in operation. No daily sediment stations were operated following water year 1986. Periodic sediment samples were collected at 36 National Streamflow Accounting Stations (NASQAN) and at 2 Hydrologic Benchmark Network (HBN) stations through 1990 when the number of NASQAN stations was reduced to 19 and the number of HBN stations was reduced to 1.

Ground-Water Observation Wells. The Texas District did not operate a statewide observation-well network through this period. The Texas Water Development Board (TWDB) established the network and continued to operate and maintain it through this period of Texas history. However, The District did operate a large network of observation wells in El Paso for the City of El Paso to determine water-level declines. The District also operated a large number of wells in the Houston area to monitor water-level declines for the City of Houston and a number of wells used to monitor subsidence in the Houston area for the Houston Subsidence District.

Water Use. The Texas District began its Water Use data program in 1986. Water-use data in Texas were collected by the TWDB. The TWDB data were manipulated by the USGS to conform to U.S. Geological Survey water-use categories and water-resources regions. A one-page color hydrologic atlas was prepared to illustrate the 1985 water-use data for freshwater withdrawals. The 1990 water-use data were submitted for publication near the end of water year 1991.

Interpretive Studies

Interpretive studies were conducted out of the District Office and most of the Subdistrict Offices during this period. However, most of the studies were done by the District Office, the San Antonio Subdistrict, and the Houston Subdistrict. Most of the project activities were funded with USGS Coop dollars that were matched by either State or local agencies. Principal cooperators included the Texas Water Development Board, the Cities of Austin, San Antonio, Houston, El Paso, and the Dallas–Fort Worth Metroplex. A few studies were carried out in cooperation with county governments. Projects funded totally by Federal dollars included two RASA and two NAWQA projects. A few projects were funded by other Federal agencies including the U.S. Air Force, the U.S. Army Corps of Engineers, and the Bureau of Reclamation. The authors of this report requested that the current Reports Specialist, Peter Bush, supply us with examples of abstracts that would represent the cross section of projects that have been conducted in the Texas District during this period of history, and he supplied the following six abstracts to be included in this report.

Water-Resources Investigations 82–18 Techniques for Estimating the Magnitude and Frequency of Floods in the Dallas–Fort Worth Metropolitan Area, Texas

By Larry F. Land, Elmer E. Schroeder, *and* B.B. Hampton

Abstract

Equations for predicting the magnitude and frequency of floods in the Dallas–Fort Worth metropolitan area were developed from recorded data of streams with drainage areas ranging in size from 1.25 to 66.4 square miles. The U.S. Geological Survey urban rainfall-runoff model was used to generate long-term flood-discharge records for gaged streams in the area. Simulated and recorded annual-peak data were subjected independently to log Pearson Type III frequency analyses. The results were weighted to determine appropriate discharges for 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals. These T-year values were then used as the dependent variables in a multiple-regression analysis. The independent variables determined to be statistically significant and retained in the resulting equations were drainage area and an urbanization index that expresses the degree of urban development. Analysis of the results shows that a land-use change from rural to fully urbanized was accompanied by a 180-percent increase in discharge of a flood with a 5-year recurrence interval and about 100-percent increase in discharge of a flood with a 100-year recurrence interval.

Water-Resources Investigations 85–4259 Hydrogeologic Sections of the Edwards Aquifer and its Confining Units in the San Antonio Area, Texas

By Ted A. Small

Abstract

Twenty-seven hydrogeologic sections illustrate structural and stratigraphic relations within the 180-mile-long Edwards aquifer in the San Antonio area, Texas. These sections previously were used to interpret the location of barriers within the Edwards aquifer.

The sections are oriented generally south-southeast, which is approximately normal to both the east-northeast-trending Edwards aquifer and the strike of the major faults of the Balcones fault zone. Section lengths represent the distance necessary to cross the aquifer, which is 5 to 40 miles wide. The updip (north) end of the sections is drawn to indicate exposures of the Glen Rose Formation; from there the sections indicate downdip geologic conditions within the freshwater zone and the salinewater zone. The sections are approximately parallel and illustrate geologic conditions at 5- to 10-mile intervals. The sections indicate the geologic conditions from near the eastern boundary of the aquifer in Hays County to near the western boundary of the aquifer in Uvalde County.

Several sections show places where faults have sufficient vertical displacement to offset the entire, or almost entire, thickness of the aquifer. At these places the faults are barriers to ground-water flow directly downdip across the fault.

Water-Resources Investigations 86–4356 Effects on Water Quality Due to Flood-Water Detention by Barker and Addicks Reservoirs, Houston, Texas

By Fred Liscum, R.L. Goss, *and* E.M. Paul

Abstract

The Barker and Addicks Reservoirs, located about 16 miles west of Houston, Texas, provide flood-detention storage for storm runoff. Of interest are the water-quality characteristics in the study area and changes in water quality during detention. Study area sampling sites were selected upstream along Buffalo Bayou for Barker Reservoir and on Bear Creek and Langham Creek for Addicks Reservoir, within the reservoirs, near the reservoir outflows, and below the confluence of each reservoir outflow at the streamflow station Buffalo Bayou near Addicks. Flow data were available at all sites except in the reservoirs. Analyses of samples collected during both low flow and storm runoff show that, in general, the waters of the study area were low in mineralization, but the aesthetics of the water was a problem.

The inorganic constituents, trace metals, and pesticides rarely exceeded maximum contaminant levels recommended by the U.S. Environmental Protection Agency for public supply using 1976 and 1977 criteria for primary and secondary standards. All species of nutrients, except ammonia nitrogen and phosphorus, almost always were below the recom-

mended maximum contaminant levels. Phosphorus almost always exceeded these levels.

Esthetic problems are evident. Large values of suspended solids, turbidity, and color were common. Small dissolved-oxygen values commonly occurred in the reservoirs. Possible bacterial problems are indicated because coliform-bacteria densities exceeded recommended levels in about 25 percent of the samples.

The effects of the reservoirs on the water-quality characteristics of storm runoff were analyzed using three approaches. The first approach was a comparison of the discharge-weighted average values of nine selected constituents at each streamflow-gaging station during four storms. Reservoir effects on the quality of runoff detained 1 to 4 days in the two reservoirs were inconsistent. However, the reservoir consistently had an effect on the water quality of runoff that was detained the longest (more than 8 days). Biochemical oxygen demand, suspended solids, turbidity, color, total nitrogen, and total organic carbon discharge-weighted average values were consistently smaller after flowing through the reservoirs. Dissolved solids and total phosphorus values were consistently larger after flowing through the reservoirs.

The second approach was an analysis of the means of the discharge-weighted average values computed for the four hydrologic events using the Student t-test. Statistical results indicate that reservoir detention significantly reduced suspended solids (the mean decreased from 178 milligrams per liter at the inflows to 105 milligrams per liter at the outflows) and turbidity (the mean decreased from 119 nephelometric turbidity units at the inflows to 66 nephelometric turbidity units at the outflows).

The third approach was a comparison at each site of the mean, maximum, and minimum values computed for seven constituents that did not correlate with discharge. These constituents or properties of water were temperature, pH, dissolved oxygen, dissolved oxygen percent saturation, total-coliform bacteria, fecal-coliform bacteria, and fecal-streptococci bacteria. The only consistent water-quality changes observed were with the three bacteria groups, which were decreased by flood-water detention.

Water-Resources Investigations 87–4116 Relation of Water Chemistry of the Edwards Aquifer to Hydrogeology and Land Use, San Antonio Region, Texas

By Paul M. Buszka

Abstract

Water-chemistry data from the Edwards aquifer for 1976–85, consisting of nearly 1,500 chemical analyses from 280 wells and 3 springs, were used to statistically evaluate relations among ground-water chemistry, hydrogeology, and land use. Five land uses associated with sampled wells were classified on the basis of published information and field surveys. Four major subareas of the aquifer were defined to reflect the relative susceptibility of ground water to contamination originating from human activities using hydrogeologic and tritium data.

Water from an agricultural area over the unconfined zone of the aquifer had the largest median concentration of nitrite plus nitrate. Large nitrite plus nitrate concentrations were spatially associated with large tritium concentrations and nitrogen isotopic ratios characteristic of streamflow recharge. Detections of fecal-coliform bacteria were associated mainly with water from wells completed in the unconfined zone.

Most of the occurrences of tetrachloroethylene, 1,2-(trans)-dichloroethylene, trichlorofluoromethane, 1,1,1-trichloroethane, and 2,4-D in ground water were associated with wells completed in the unconfined zone of the aquifer. Fatty acids detected in water from some wells may commonly be present naturally in ground water.

The percentage of samples in which arsenic, barium, lead, and zinc were detected was similar among subareas; the samples were from the freshwater parts of the aquifer. Large lead and zinc concentrations were associated with volumes of pumpage less than 1,000 gallons.

In general, the quality of ground water in the freshwater parts of the aquifer (north of the "bad-water" line) is suitable for all uses including human consumption. Two areas that are exceptions are: (1) northeast of Garner Field in Uvalde, Texas, where PCE (tetrachloroethylene) has been detected in ground-water samples, and (2) north-central Bexar County near the former West Avenue landfill where PCE and benzene have been detected in ground-water

samples. Concentrations of these organic compounds in water from many wells in the two areas exceed the maximum contaminant level for human consumption set by the U.S. Environmental Protection Agency.

Water-Resources Investigations 93–4112 Hydrogeology, Geochemistry, and Quality of Water of The Basin and Oak Spring Areas of the Chisos Mountain, Big Bend National Park, Texas

By E.T. Baker, Jr., *and* Paul M. Buszka

Abstract

Test drilling near two sewage lagoons in The Basin area of the Chisos Mountains, Big Bend National Park, Texas, has shown that the alluvium and colluvium on which the lagoons are located is not saturated in the immediate vicinity of the lagoons. A shallow aquifer, therefore, does not exist in this critical area at and near the lagoons. Should seepage outflow from the lagoons occur, the effluent from the lagoons might eventually be incorporated into shallow ground water moving westward in the direction of Oak Spring. Under these conditions such water could reach the spring. Test borings that bottomed in bedrock below the alluvial and colluvial fill material are dry, indicating that no substantial leakage from the lagoons was detected. Therefore, no contaminant plume was identified. Fill material in The Basin does not contain water everywhere in its extensive outcropping area and supplies only a small quantity of ground water to Window Pouroff, which is the only natural surface outlet of The Basin.

Oak Spring, which is almost 2 miles downgradient from the lagoons, is the sole source of water for The Basin—the principal tourist area in Big Bend National Park. Test drilling in the Oak Spring area revealed that the aquifer in the immediate vicinity of Oak Spring is a 5-foot-thick sand bed hydraulically confined above and below by relatively thick, compact clay. The sand bed might be bounded locally by faults to the east and west of the spring. The test drilling and seismic surveys in the area also established the existence of a thick, extensive surficial layer of colluvium consisting of large rhyolite boulders. The colluvial layer, which overlies sedimentary bedrock containing the Oak Spring aquifer, was unsaturated at the borehole sites.

Information from drilling and from hydrogeologic observation indicates that the water from Oak Spring originates as precipitation in the Oak Spring area west of The Basin, with possibly a contribution originating as discharge from The Basin. The rhyolite boulder field in the Oak Spring area, which includes talus from Vernon Bailey Peak, is an effective receptacle for rapid recharge of precipitation. This water could then be efficiently routed into the Oak Spring aquifer in places to the east of Oak Spring where any shallow ground water in the boulder field might enter the subcropping truncated aquifer.

Water-chemistry data, hydrochemical facies, and isotopic data also indicate that water from Oak Spring originates principally from precipitation onto the land surface of the Oak Spring area. Tritium data indicate that Oak Spring water is "modern," with an average age of recharge less than 14 years. The flow rates recorded almost continuously at Oak Spring beginning in December 1986 show a close relation between precipitation and discharge. The highest recorded springflow of 167 gallons per minute in December 1986 is attributed to record high precipitation in the area during 1986. The lowest recorded flow of 22.4 gallons per minute, in December 1989, followed a period of 20 out of 26 months of below-normal precipitation. Flow at Oak Spring typically lags behind precipitation by about 1 month. This fairly rapid response indicates the spring is fed by a shallow aquifer having good permeability and effective recharge areas with the ability to absorb precipitation rapidly.

Water-Resources Investigations 94–4213 Sources of Trends in Water-Quality Data for Selected Streams in Texas, 1975–89 Water Years

By Terry L. Schertz, Frank C. Wells, *and* Dane J. Ohe

Abstract

Sources of trends in water-quality data for selected streams in Texas for water years 1975–89 were investigated in this study. The investigation of sources was confined to distinct geographic patterns in the trend indicators for one constituent or for a group of related constituents.

The probable source of trend patterns in nutrients and measures of oxygen in the Trinity River Basin was changes in the wastewater treatment facilities in

the Dallas-Fort Worth metropolitan area. A pattern of increased concentrations of inorganic constituents in the upper Colorado River Basin resulted from emergency releases of water from the Natural Dam Lake, a salinity control structure. Trend patterns in inorganic constituents in the Rio Grande Basin were a result of increasing concentrations in the Pecos River and, to a lesser extent, the Rio Grande above the Amistad Reservoir, combined with the effects of reservoir regulation. A pattern of increasing concentrations of organic plus ammonia nitrogen and ammonia nitrogen was detected for water years 1975–86 for stations with low concentrations (generally less than 5 milligrams per liter) of these nitrogen species. The trends were no longer evident when the period of trend analysis was extended to water year 1989. A positive bias in the data caused by the addition of mercuric chloride tablets to preserve nutrient samples during 1980–86 was the probable source of this trend pattern. A pattern of increasing concentrations in dissolved sulfate in the eastern part of the State was a result of a positive bias in the analytical results of a turbidimetric method of sulfate analysis. The source of a statewide pattern of increased pH in streams could not be identified.

Other Major Studies.— The District began two RASA studies, two NAWQA studies, two Urban Stormwater Runoff Projects, and one U.S. Air Force Installation Restoration Project during this period.

Regional Aquifer-System Analysis.—Two RASA projects were done in Texas. The Gulf Coast RASA included not only the State of Texas but also the States of Louisiana., Arkansas, Tennessee, and Mississippi. Hayes Grubb was the Project Chief, and the project was managed out of the Central Region Office in Denver rather than the Texas District Office. Project Chief of the Edwards-Trinity RASA was Peter Bush.

Stormwater Runoff.—These two projects areas were located in the Dallas–Fort Worth Metroplex and the City of San Antonio. Both studies were funded in the Coop program with 100-percent funding coming from the local side and funding at over $3 million. The results of the studies satisfied the needs of the cities to meet the NPDES requirements of USEPA.

Installation Restoration Project. This project was funded by the U.S. Air Force and was conducted at Kelly Air Force Base in San Antonio. The study identified areas of contamination that required cleanup.

Acknowledgments. The authors wish to thank the Publications Unit for their assistance in gathering information for this report, including supplying abstracts of published reports that describe the general tone of research that was done in the District during this period of Texas District history. The Publications Unit also opened the District library for our use. Special thanks are given to Peter Bush, Gail Sladek, and Judy Voigt. The District Chief, Jeff Weaver, supplied us with program review books from his office, which were extremely valuable in writing this history.

WYOMING

By James F. Wilson, Jr., *including information provided by* Thomas L. Quinn, *and reviewed by* Marvin A. Crist, Sharon L. Green, Cheryl Eddy Miller, *and* Kathy Muller Ogle

ORGANIZATION AND PERSONNEL

As the period began, the Wyoming District consisted of a Headquarters Office in Cheyenne and Field Offices in Buffalo, Casper, Cheyenne, Green River, Riverton, and Worland. These offices were staffed by approximately 75 permanent employees. Annually decreasing personnel ceilings and the end of most energy and Regional Aquifer-System Analysis (RASA) funding resulted in major changes. By 1987, four Field Offices had been closed and the number of employees reduced to 37—the fewest since the District was formed in 1967. In 1988 a large new investigation for the U.S. Air Force in Cheyenne began, and by 1994 the number of permanent staff again exceeded 70.

District Headquarters, Cheyenne

Office of the District Chief.—In 1979 the District Office was in the O'Mahoney Federal Center at 2120 Capitol Avenue, and the water-quality laboratory was in the old Federal Office Building across the street on Carey Avenue. In May 1989 the office and laboratory were relocated to 2617 East Lincolnway, a former grocery store remodeled to the District's specifications.

William W. Dudley, Jr., the fourth Wyoming District Chief, having transferred from Denver in April 1979, served until he transferred back to Denver in 1982. He was replaced the following year by Richard

M. Bloyd, who transferred from California. Bloyd transferred yet again to Atlanta in 1987 and was replaced by James E. Kircher, from Denver. After Kircher went to Lawrence, Kansas, in 1991, Barney D. Lewis arrived from Denver in 1992 to become the seventh District Chief.

Assistant District Chiefs were James F. Wilson, Jr. (1970–88), Stanley A. Druse (1989–90), Marion L. (Spike) Maderak (1991–93), and Hugh W. Lowham, beginning in 1994.

District Secretaries during the period, in chronological order, were Elnora E. Johnson, Mary Ann Henkels, L. Kay Bedlan, Daisie M. Oden, Kathleen M. Reed, Barbara L. Devoe, and Janell R. Nelson. The secretarial staff also included Susan J. Buchanan, Carol J. Jensen, Linda (Ostic) Montoya, Tausha L. Reitmeyer, and Cynthia E. Terry.

Helen M. Clark, who began her administrative work in 1962 during the Branch District era, was Administrative Services Section Chief until she retired in 1983. She was succeeded by Katherine E. Wilson (1983–88), Alice E. Lykins (1988–91), Don R. Spry (1991–93), and Doris J. Adair, beginning in 1993. Others who served in the section were Bedlan, Frances F. Birchell, Jan A. Dorrenbacher, Henkels, Linda M. (Jackson) Hill, Karen A. (Castaneda) Lott, Cora E. Louie, Margareda C. Masden, Pamela I. (Degner) O'Daniel, Cynthia A. Pettus, Laura K. Rissler, Renay J. Sagmeister, Judith L. Snyder, Linda J. (Watanabe) Spencer, Patricia D. (Dubois) Sprangers, and Janet D. Walgren.

The most visible evidence of change during the period was the appearance of a computer terminal on every desk after July 1983, when a minicomputer replaced the terminal that had been in use. Workstations arrived in 1991, but the minicomputer would remain in use for hydrologic records work until 1997. Throughout the period Charles A. (Skip) Eshelman was District Computer Specialist, Site Administrator, and Chief of the Computer Services Section. Others who served in the Section were Richard W. Hansen, Jr., Deborah M. Longs, Joel R. Schuetz, Deborah A. Trefren-Miller, and Janet Walgren.

In 1980, the Publications Unit had a staff of five, which increased to 10 by 1994 in response to the huge reports output from the Air Force project. Edward R. Cox was Reports Specialist and Chief of the Unit until he retired in 1983 and was replaced by William B. Borchert. The duties were separated in 1990; Borchert continued as Reports Specialist, and Jon W. Raese was named Unit Chief. In 1993 Philip R. Bowman replaced Raese, who transferred to Denver. Principal illustrators were Lynn F. Cunningham, until he retired in 1988, and Suzanne C. Roberts, thereafter. Others who served in the Unit were Lois M. Castellow, Paul B. Christensen, Valerie K. Cook, Pamela B. Daddow, Ruth V. Foresman, Marjorie E. Gookin, Gwen M. (Olson) Hatten, Carol J. Jensen, Diane V. Lecki, Karen L. Mora, Emily A. Sabado, Cynthia J. Shattuck, Pamela Spencer, Deborah Trefren-Miller, Maria E. Turner, Deborah K. Wells, and Katherine Wilson.

Hydrologic Surveillance (Data) Section.—The Section was made up of a small support staff and Water Quality Unit in Cheyenne and all of the Field Offices. Section Chiefs during the period were Ernest S. Denison, until 1984; Stanley A. Druse, 1984 to 1994; and Joel R. Schuetz, beginning in 1994. Water Quality Unit Chiefs were Schuetz (1976–80), Samuel J. Rucker IV (1980–87), David A. Peterson (1987–92), and George F. Ritz (1992–94). Others assigned to the Surveillance Section in Cheyenne were Brian F. Beaton, David L. Butler, Darrell D. Carlson, Melanie L. Clark, Roxie A. Cook, Gordon S. Craig, Jr., Franklin L. Feeler, Sharon L. Green, Hugh I. Kennedy, Jess O. Ragsdale, Trefren-Miller, Betty J. Tucker, Walgren, and Alberta L. Wicklow.

Hydrologic Investigations (Studies) Section.—Approximately 65 people (mostly hydrologists) served in the Section during the period. Section Chiefs were James R. Marie (1975–80), Hugh W. Lowham (1983–89), Nancy E. Driver (1990–91), and Randolph B. See, beginning in 1992.

Other personnel who served in the Hydrologic Investigations Section were Gerald W. Armentrout, Jr. (stationed in Casper), Charles F. Avery, D. Steven Barker, Borchert, Bruce T. (Tim) Brady, Rebekah Brooks, Breton W. Bruce, Earl W. Cassidy, Melanie Clark, Maurice E. (Spade) Cooley, Craig, Marvin A. Crist, Thad W. Custis, Pamela Daddow, Richard L. Daddow, Lewis L. DeLong, Druse, Philip L. Fitzwater, James L. Fogg (assigned from BLM, 1985–87), Kent C. Glover, Dennis N. Grasso, William J. Head, Dwight T. Hoxie, Craig L. Joy, Richard W. Knottek, L. Rodney Larson, Leslie W. (Lee) Lenfest, Jr., Marlin E. Lowry, Juli B. (Jaye) Lunsford, Marion L. (Spike) Maderak, Lawrence J. Martin, Cheryl Eddy Miller, Kirk A. Miller, David L. Naftz, Bernard T. (Tom) Nolan, Daisie M. Oden, Kathy Muller Ogle, David Peterson, Maria Plafcan, Charles L. Qualls, James G. Rankl, Bruce H. Ringen, Ritz, Rucker, Schuetz,

Myron L. Smalley, Mark E. Smith, David D. Susong, Trefren-Miller, Joe C. Wallace, Shawn G. Welch, and Everett A. Zimmerman.

Environmental Studies Section.—This Section derived from the Investigations Section in 1988, with Lowham as Section Chief. By 1992 the Section had grown substantially, and the staff worked exclusively on the growing hydrologic investigation at F.E. Warren Air Force Base. At the peak of the Air Force project, the Section had more than 24 District members and 8 contract personnel. Also, approximately 67 short-term detailees from many WRD Districts assisted with the work.

Other members of the Section during the period were Theodore C. Bartke, Timothy T. Bartos, Kent D. Becher, Gregory K. Boughton, Brent W. Bouley, Robert A. Boyd, Crist, R. Daddow, Hugh L. Darling, Kim R. Fisher, Elaine S. Gee, Grasso, Dirk A. Hargadine, Larson, Lunsford, Ivars A. Mikelsons, Kirk Miller, Nelson, Ogle, Peterson, Qualls, Thomas L. Quinn, Linda R. Roberts, Amy L. (Rodman) Summer, Susong, Trefren-Miller, Kathy Ann Voytko, and Wallace.

Rocky Mountain Area Drilling Project.—The Air Force project in Cheyenne required so much test drilling that in January 1994 two drilling operations—one from the Colorado District and one from Geologic Division—were combined as the Rocky Mountain Area Drilling Project and attached to the Wyoming District. Supervised by Arthur C. Clark, the unit provided drilling and coring operations throughout the United States. Other members of the unit were Brian H. Bretz, Jeffery D. Eman, Robert Gilman, Stephen J. Grant, Todd Hunter, John Palmer, David Rehder, and Daniel Sweeney.

The Field Offices

As the period began, responsibility for collection of hydrologic data in Wyoming was distributed among six Field Offices that were organizationally part of the Hydrologic Surveillance Section. After closure of four offices during 1982–84, data collection in the eastern one-half of the State was assigned to the Casper office and to the Riverton office in the western one-half.

Buffalo Field Headquarters.—In 1979 the office was at 381 North Main Street. Keith G. Polinoski was Technician-in-Charge. The office was relocated to the Harrell Building at 9 Spruce Street in 1980. Established in 1977, the office was closed in September 1983 after Polinoski transferred to the California District. Gerald J. Metzer transferred to Casper, and Janet M. Hepp declined a transfer and resigned. Other staff during the period were Clinton D. Nagel and Bruce C. Pedersen.

Casper Subdistrict/Field Headquarters.—In 1979 the office was located at 215 North Lincoln Street; William R. Glass was Hydrologist-in-Charge. The office was redesignated as a Field Headquarters in 1982 and was relocated to the Plaza West Building at 2020 Fairgrounds Road in 1984. When Glass retired in 1994, he was replaced by Raymond E. Woodruff, a member of the staff. Other staff during the period were Gerald Armentrout (Investigations Section), Kent Becher, Norbert R. Duet, Linda Hill, Daniel E. Hitch, Thomas J. Leman, Metzer, Joseph F. Meyer, Kirk Miller, Pamela O'Daniel, Pedersen, Leonard L. Reed, Irene Rodgers, Michael C. Rowan, Laverne G. (Lucky) Sultz, Cynthia Terry, Gilbert J. Van Deventer, Jeff C. Vigil, and Karen R. Watson.

Cheyenne Field Unit.—Donald J. Pangburn was Technician-in-Charge. He retired in January 1983, at which time the Field Unit was discontinued. Mark A. Lyverse also served in the Unit.

Green River Field Headquarters.—In 1979 Delmer J. O'Connell was Hydrologist-in-Charge of the office, located at 489 East Fifth Street South. Established in 1976, the office was closed in September 1984. O'Connell had transferred to the Tennessee District the previous July. Only two employees were left: Thomas F. Werth transferred to Riverton, and Mary K. (Kathy) Tucker declined a transfer and resigned. Others assigned to this office were William C. Bunderman, Thomas A. Herrett, and Philip B. McCollam.

Riverton Field Headquarters.—In 1979 Charles F. Obert was Technician-in-Charge of the office, located at 509 South Federal Boulevard. Obert retired in 1981. In 1982 McCollam transferred from Green River to take charge. The office was relocated to 1225 Market Street in October 1983. In 1984 McCollam was promoted to Supervisory Hydrologic Technician GS–12, the only Wyoming technician ever to achieve that grade. When McCollam retired in 1989, Myron Smalley was appointed Hydrologist-in-Charge, transferring from Cheyenne. Other Riverton staff included Robert C. Baumann, Laura K. Bohmert, Nolan Friday, Kenneth J. Hedmark, Glenn A. Laidlaw, David J. Peyton, Thomas A. ("Red") Pointon, Nancy

K. (Kathy) Ruby, Wilfrid J. Sadler, Renay Sagmeister, Kevin L. Sattler, Mark Smith, Douglas S. St. Clair, Werth, and Laurel D. Young.

Worland Subdistrict.—The Worland office and sediment laboratory were located at 1214 Bighorn Avenue from shortly after the office was established in March 1946 until September 1982, when the office was closed. Harold B. Fabricius was Technician-in-Charge. The closure was necessary partly because of centralization of the Division's sediment laboratories and partly because of the need to reduce operating costs. During its final years the sediment laboratory also served the Montana, North Dakota, and Alaska Districts. A strong sense of loyalty to the Worland office on the part of many sediment and water-quality specialists and technicians who had served there through the years made the closure especially painful. Fabricius and technician Donna W. Brownell retired, Myron Smalley transferred to Riverton, and Sharon L. (Huhnke) Fech and Raymond L. Muench declined transfers and resigned.

FUNDING AND COOPERATION

As indicated in the funding table, the Federal-State Cooperative (Coop) program more than doubled during the period. The Coop program kept pace with inflation, but the other Federal agencies (OFA) program (with one notable exception) and Federal (Fed) program did not. In fact, with the end of Federal funding for coal and oil-shale hydrology and regional aquifer-system studies, funds for collection of hydrologic data decreased, and during 1992–94 no Federal funds were allocated for interpretive studies.

Beginning in 1987, what had been a small investigation in 1985 at F.E. Warren Air Force Base in Cheyenne became a very large investigation. This project, in cooperation with the U.S. Air Force, accounted not only for the substantial growth of the Wyoming District (see funding table) but perhaps for its survival as well.

Excluding the Air Force project (part of the OFA funds in the table), total annual funds were nearly constant during the period—about $2.8 million in 1980 and about $2.9 million in 1994, a substantial decrease in constant dollars. By 1994, Air Force funding was about $6 million. Funds listed in the table for 1994 include approximately $0.67 million for work by the Rocky Mountain Area Drilling Project in other States.

Long-term cooperative programs ended with the National Park Service (1950's–1980); City of Cheyenne (1940's–1983); Wyoming Department of Transportation (previous name, Wyoming Highway Department, 1958–87); and Wyoming Economic Development and Stabilization Board (previous name, Department of Economic Planning and Development, 1940–88). Energy-related programs with the Environmental Protection Agency ended in 1982 and with the Bureau of Land Management (BLM) in 1988. (Cooperation with several of those agencies would resume during the late 1990's.)

In spite of the large fluctuations in Federal and OFA programs, long-term cooperation with several agencies—most notably the Wyoming State Engineer (WSE)—continued without interruption. Others include the Wyoming Departments of Agriculture (WDA) and Environmental Quality (DEQ), the Bureau of Reclamation (BOR), and the U.S. Army Corps of Engineers.

Long-term cooperative investigations began with a new State agency, the Wyoming Water Development Commission (WWDC), in 1983 and resumed with the City of Cheyenne in 1987. In 1988 the Northern Arapahoe and Shoshone Tribes replaced the Bureau of Indian Affairs as cooperators for investigations on the Wind River Indian Reservation. Investigations also were carried out in cooperation with approximately 20 other local, State, and Federal agencies.

Wyoming District funds, fiscal years 1980–94

[Source: District program documents for 1980–92, Administrative Information System records for 1993–94, fiscal year funds, in thousands of dollars]

Fund source	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	859	1,051	1,382	1,343	1,650	1,686	1,703	1,954	2,129	2,077	2,454	2,449	2,410	2,050	2,135
OFA	666	649	493	682	488	279	539	886	1,179	1,685	797	2,687	5,445	7,432	6,861
Fed	1,259	1,259	912	827	548	546	451	430	494	318	423	423	303	322	612
Total	2,784	2,959	2,787	2,852	2,686	2,511	2,693	3,270	3,802	4,080	3,674	5,559	8,158	9,804	9,614

Summary of Programs

Hydrologic-Data Collection

During the mid-1980's, the data-collection workload did not decrease in proportion to the personnel decreases. In spite of that, station records were completed on time every year, and during 1984–94 the District met every WRD target date for transmitting the camera-ready copy of the annual data report to the printer. Throughout the period—one of rapidly changing computer technology—Sharon Green prepared the annual data reports for publication, and Janet Walgren monitored the status of water-quality samples and retrieved the tables of water-quality data for the reports.

Streamflow stations.—The Field Offices were operating approximately 165 continuous-record stations and 98 crest-stage gages in 1980. The WRD experiment to use private contractors to construct and operate gaging stations in areas of energy minerals was terminated in 1981, and the number of other stations for the energy-hydrology programs began to decline. The last of the crest-stage gages were discontinued in 1984. The network remained at about 140 stations until new cooperation in 1989 increased the number to approximately 160. By 1994 the network again stood at 140 stations. Throughout most of the period the WSE operated an additional 24–26 stations. In 1985, District hydrographers were computing records currently for 10 stations equipped with data-collection platforms (DCP's), whereby river-stage and other data were transmitted by satellite telemetry. By 1994 approximately 50 stations were equipped with DCP's—some operated for the National Weather Service, others installed by the BOR and operated by the District, and a few operated by the Corps of Engineers.

Approximately 40 stations had been operated during 1974–79 for measuring streamflow changes across outcrops of the Madison Limestone in northeastern Wyoming; 14 were in operation in 1980. In 1991 Glass and Sultz analyzed all data, including new measurements at all stations and 71 other sites. Peterson also used data from a few of the stations to evaluate streamflow recharge to the Madison Limestone and Casper Formation near Glenrock.

After the 1988 wildfires in and near Yellowstone National Park, the Secretaries of the Interior and Agriculture petitioned Congress for funds with which to study the effects of the fires. When that failed, the District, in cooperation with the U.S. Forest Service and DEQ, installed stations on a pair of small adjacent basins (one burned, one not) in the Shoshone National Forest, adjacent to the eastern boundary of the park. Streamflow, chemical-quality, and sediment data were collected for 5 years (1989–93).

Water-quality stations.—The surface-water-quality network comprised about 150 stations in 1980. The primary cooperating agencies for baseline water-quality data were WDA, DEQ, and BOR, but many other agencies at various times were important participants in the District's water-quality programs. The station network was modified in 1981, based in part on changing water-quality objectives and in part on the results of statistical analyses of long-term station data by Rucker and DeLong.

By 1982 the number of stations had decreased to 125, of which 15 were equipped with monitors and recorders. Sampling of selected streams for herbicides had ended. At times during the mid-1980's, sampling frequency at many stations was reduced because funding did not keep pace with rising costs. Substantial decreases occurred in 1987, when 65 stations were discontinued as a result of State funding cuts, and in 1994, when the network plummeted to 50 stations because of temporary funding curtailments by some agencies.

In 1986 systematic monitoring of ground-water quality was added to the program with WDA. Samples were collected from 25 wells in a different quadrant of the State each year and analyzed for common ions and nutrients (and later, pesticides). The program was discontinued after 1992, as emphasis had begun to shift to monitoring ground water in selected areas for specific contaminants.

A program to sample pesticides in ground water began in 1993 in cooperation with WDA, and the WDA part of the long-term surface-water-quality program ended. Use of the State laboratory in Laramie for analysis of water samples collected in the Coop program also ended in 1993. WDA had been given direct-services credit each year since the 1960's for participation of the State laboratory in the Division's water-quality program.

Data-collection activities during the period included sampling in 1984 for a study of Fremont and New Fork Lakes by the District and the Branch of Regional Research in Colorado, sampling during 1989–93 at the paired stations for evaluating the

effects of the 1988 wildfires near Yellowstone National Park, and assisting the Idaho District in the 1994 synoptic sampling for the Upper Snake River National Water-Quality Assessment.

Fluvial-sediment stations.—Eight daily and 66 monthly sediment stations were in operation in 1980. Within 5 years the network had decreased to 2 daily (pumping samplers) and 10 monthly stations, as the USGS and BLM energy programs ended. Most of the discontinued stations were in the Green River Basin. Long-term sediment-data programs ended in 1985 with the BOR and with the WSE in 1989. New programs began with the DEQ in 1982 and with the WWDC in 1986. But by 1994, no daily stations were in operation.

Special data collection during the period included sampling with automatic samplers to define the relation of total sediment load to peak discharge during floods in three ephemeral streams and during snowmelt runoff from three perennial streams in the Sierra Madre. Sediment data also were collected during 1989–93 at the paired stations for evaluating the effects of the 1988 wildfires near Yellowstone National Park.

After closure of the Worland laboratory in 1982, Wyoming sediment samples were analyzed in Iowa City, Iowa. By 1988 a Wyoming sediment laboratory once again was in operation, this time in Cheyenne, with Kennedy, who began his Survey career in the Worland laboratory, in charge. Work for the Colorado District began in 1989 and for the Utah District in 1990. The laboratory was closed again when Kennedy retired in 1994.

Ground-water observation wells.—In 1980 the Statewide network, maintained primarily in cooperation with the WSE, included 310 wells, of which 47 were equipped with digital recorders. In 1982, 133 wells in heavily irrigated Laramie County were dropped, and in 1983 a program begun in the 1940's to measure water levels in the City of Cheyenne's well fields was discontinued. By 1984 nearly all of the 87 wells remaining were equipped with digital recorders. During most of the period, WSE personnel measured water levels in about 61 additional wells for annual direct-services credit. Ten-year hydrographs of water levels in the network wells were published in Open-File Reports biennially, beginning in 1982.

Water-use data.—A water-use data program, suspended in 1981, was resumed in 1984, in cooperation with the WSE. During 1985–88 the State Engineer's Office received direct-services credit for computing consumptive use and related water-use information for the Wind River Indian Reservation and the Green River Basin. Later, water-use data were collected as a component of the investigations of county water resources. The data were used mainly for national reports on use of water in the United States.

Interpretive Studies

Cooperative ground-water investigations.—Availability of water for irrigation and the long-term effects of withdrawals continued to be the focus of most ground-water investigations in cooperation with the State Engineer. Digital flow models were used by Crist (Laramie County and the Wheatland area), Hoxie (Wheatland area), Borchert (LaGrange aquifer), and Glover (Bates Creek alluvium near Casper). Glover also simulated interchange of surface water and ground water in the Upper Bear River Valley by using a finite-element model.

Other investigations were by Cooley and Head (alluvial deposits along Owl Creek) and Cooley (Paleozoic aquifers near Ten Sleep; Water-Supply Paper 2289, 1986), Lenfest and Crist (ground water in the Saratoga Valley), Borchert (water table in part of the Sweetwater River Basin), and Crist (water-level changes near Gillette). Studies of the geology and ground-water resources of Bighorn, Hot Springs, Park, Washakie, and Weston Counties were completed; Project Chiefs were Lowry, Cassidy, Plafcan, and Susong. Studies of Fremont, Teton, and Lincoln Counties were begun by Plafcan, Nolan, and C. Miller.

In 1984 Cox completed his investigations of movement of wastewater effluent at selected sites in Yellowstone and Grand Teton National Parks, ending a continuous series of ground-water studies in cooperation with the National Park Service that began in 1966. In 1991 Hedmark began a followup data-collection program at four wastewater-treatment facilities in Grand Teton National Park.

Flood investigations.—The flood-investigations program ("highway program"), in cooperation with the Wyoming Highway Department since 1958, was completed in 1988 with publication of a detailed summary report by Druse and others. The report, published by the Highway Department, included a new report by Lowham on determining flood magnitudes and other streamflow characteristics at ungaged sites

in Wyoming (Water-Resources Investigations Report 88–4045).

The most damaging flood during the period occurred on August 1, 1985, in Cheyenne; 12 people lost their lives. Druse and others documented the flood, the result of a thunderstorm that produced State record precipitation (Hydrologic Atlas 699, 1986). Through the efforts of the District and Region staff, the atlas was released less than 7 months after the flood. Also, Lunsford analyzed historical records of flood-producing storms for Cheyenne. Because of the flood, a network of gaging stations and precipitation gages was installed in and around the city in 1987 in cooperation with the City of Cheyenne. Rankl was Project Chief.

Work on limited-detail flood-insurance studies for the Federal Emergency Management Agency was completed in 1986 by Schuetz. Four sites were studied: North Platte River at Glenrock and at Orin, Little Snake River at Baggs, and Tongue River at Ranchester. Also, floodway-hydraulics maps were prepared by Ritz for Childs Draw near Cheyenne and by Rankl and Wallace for Swift Creek at Afton.

Energy-minerals programs.—The USGS and BLM coal-hydrology programs, begun in 1975, ended during the mid-1980's. The USGS oil-shale hydrology program also ended. During 1980–94 the District produced approximately 40 reports of investigations for those programs. Included were reports to provide information about the regional hydrologic setting in major "coal areas" of the Powder River Basin, Green River Basin, and part of the Wind-Bighorn River Basin, and contributions to a Colorado District report that includes the Hanna and Carbon Basins. All investigations completed for the USGS and BLM coal-hydrology programs are summarized in Professional Paper 1464 (1989).

Work in the Green River Basin was carried out by a team led by Lowham, with funding mainly by the oil-shale hydrology program. Results were published in reports by Lowham (streamflow and channels), Ringen (suspended sediment), DeLong (water quality), Zimmerman (ground water), Kircher (sediment transport, Big Sandy River Basin), and DeLong and Wells (dissolved-solids yields from ephemeral streams).

In a study at the experimental in-situ oil-shale retort area near Rock Springs, Glover developed and applied a digital dual-porosity model for simulating solute-transport of shale leachate through fractured and layered rocks (Water-Supply Paper 2322, 1988). In 1990, Ogle assessed the ground-water-flow system by using head data from selected wells.

Many of the coal-hydrology studies in the Powder River Basin were carried out by a team led by Lowry. Investigators include Rankl and Lowry (shallow ground-water-flow systems), Larson (water quality), Armentrout, (low flows in streams), Peterson and Wangsness (aquatic biology), and Lowry and others (hydrology of the White Tail Butte area, with respect to reclamation potential). Studies of small, ephemeral-stream basins, typical of areas underlain by coal, were completed by Glover (storage analysis of streamflow), Rankl (infiltration component of a rainfall-runoff model; Water-Supply Paper 2366, 1990), Rankl (sediment production), and Lenfest (recharge to bedrock through channel alluvium).

Project chiefs of other coal-hydrology studies in the Powder River Basin were Pamela Daddow (potentiometric-surface map of the primary coal bed), Ringen and Pamela Daddow (Powder River alluvium), Fogg (potential effects of surface mining at 12 coal-lease tracts), Naftz (geochemical processes in coal-spoil aquifers), Larson (coal-spoil data for two mines), and Lunsford (summary of published reports on shallow ground water).

The DEQ was the cooperator for three investigations of the effects of surface mining of coal in the Powder River Basin, led by Bloyd (effects on hydrology and land stability), Naftz (geochemical processes controlling selenium), and Martin (cumulative hydrologic impacts). In 1991, See collaborated with scientists from the Wyoming Water Research Center and the University of Wyoming in a study of natural organic solutes and the mobility of selenium in coal-mine backfills.

The coal-hydrology investigation in the Hanna and Carbon Basins in Carbon County, quite small compared to the investigations in the Green and Powder River Basins, ended in 1980. Pamela Daddow compiled data for 105 wells, most of which are in the coal-bearing formations.

Reports that covered all major coal and oil-shale areas were completed by Peterson (adequacy of surface-water-quality data), and Lowham (fluvial geomorphic processes for land-use planning and design of post-mining drainage systems).

In 1979, Marie began an assessment of potential hydrologic problems associated with developing uranium resources. The following year, that study was

merged with a new investigation in cooperation with the WSE and the DEQ, led by Lowry. The study addressed concerns of residents of Converse County about potential changes in quantity and quality of shallow ground water caused by extensive exploration drilling during the 1970's and by increasing surface and underground mining in the area.

Regional aquifer studies.—The multi-District Madison Limestone Study and Northern Great Plains (NGP) Regional Aquifer-System Analysis (RASA) ended in 1981, and the High Plains RASA ended in 1982. Primary reports were Professional Papers prepared mainly by regional project staff. The District contributed hydrologic data and several secondary reports; senior authors were Cooley (maps of potential fracture permeability); Lenfest (evapotranspiration, NGP); Larson (ground-water-quality data, NGP); and Avery (potentiometric-surface map, High Plains).

In 1988 a network of wells in the High Plains aquifer was established in cooperation with the WSE to provide data for an annual report to Congress. In 1991 Cooley and Crist mapped the geohydrology of the aquifer in the Cheyenne area.

Wyoming District participation in the Upper Colorado River Basin RASA began in 1982. The investigation was divided stratigraphically among the Colorado District (Paleozoic aquifers), Utah District (Mesozoic), and Wyoming District (Tertiary). Zimmerman was Project Chief for the Wyoming part; he was replaced by Glover in 1984. Four reports, by Glover, Martin, and Naftz, were published, with assistance from William R. Hotchkiss of the Central Region staff.

F.E. Warren Air Force Base.—The largest project in the history of the Wyoming District began in 1985 with a water-table map prepared by Crist for F.E. Warren Air Force Base, Cheyenne. Base environmental officials next requested the Survey to conduct investigations under the Air Force Installation Restoration Program (IRP). When the U.S. Environmental Protection Agency designated the base a "Superfund" site in 1990, the project became a full-scale Remedial Investigation (RI) and began to increase in magnitude and scope.

The project required a very large team effort from the scientific staff and the Publications Unit. Lowham was overall manager, Larson was Project Chief, and Quinn prepared project work plans to meet regulatory requirements. Project staff completed remedial investigations for 20 hazardous-waste sites, including landfills, underground storage tanks, and solvent disposal/spill sites; 13 limited environmental investigations; and 76 workplans and administrative reports.

Irrigation-drainage investigations.—District hydrologists conducted five investigations of the effects of drainage from Federal irrigation projects, in cooperation with the Office of the Secretary of the Interior. Peterson led teams from the USGS, U.S. Fish and Wildlife Service, and BOR in reconnaissance investigations of the Kendrick Reclamation Project area near Casper and the Riverton Reclamation Project area. Grasso and others completed a field-screening investigation of the Wind River Federal Irrigation Project, entailing four separate areas of the Wind River Indian Reservation; the Tribes also were cooperators. In a followup study of the Kendrick area, See and others evaluated selenium and other constituents; that investigation continued after 1994. In a study national in scope, Nolan evaluated water-quality data from 25 irrigation-drainage study areas.

Glacial-ice research.—During 1988–92 Naftz and others from the District and the Branch of Regional Research studied the geochemistry of glacial ice from three glaciers in the Wind River Range to evaluate the climatic record present in the glaciers. The initial reconnaissance was funded by the Office of Water Quality; the detailed study was in cooperation with the WWDC, the WSE, and the Tribes.

Wind River Indian Reservation.—Studies on the Reservation in cooperation with the Northern Arapahoe and Shoshone Tribes began in 1988. These include the previously described irrigation-drainage and glacial-ice investigations. Project Chiefs for other studies were Ogle (water quality in the Owl Creek Basin), Richard Daddow (water resources of the Reservation), K. Miller (seepage and sedimentation in irrigation canals), Ogle (radon concentrations in water in the Owl Creek Basin), Rankl (monthly streamflow characteristics), and Lunsford (use of electric logs to estimate ground-water quality).

Other investigations.—Water-quality studies were led by Peterson, with Robert C. Averett and William W. Emmett, Branch of Regional Research (chemical and biological health of Fremont and New Fork Lakes); Rankl, with Michael A. Carnevale, DEQ (solute transport and waste assimilation in the North Platte River); Naftz, with C.S.V. Barclay, Geologic Division (selenium at the site of a proposed reservoir in Carbon County); Lunsford, in collaboration with the

Montana District (flow and chemical quality model of the Powder River); and Ritz (physical and chemical data at Goose Egg Spring, Natrona County).

In August 1983 McCollam, Rankl, and J. Wilson assisted the staff of Sinks Canyon State Park in performing the first-ever successful dye test between the Sinks, where the entire flow of the Middle Popo Agie River disappears into a cave, and the Rise, where surface flow resumes downstream. Results are permanently documented in exhibits at the park.

Bedload-transport and channel-geomorphology investigations include studies by Rankl and Smalley (transport capacities of three streams in the Sierra Madre); Smalley, Emmett, and A. Mainard Wacker, Wyoming Department of Transportation (annual replenishment of sand and gravel in the Wind River near Riverton); and Smith and Maderak (hydraulic and geomorphic characteristics of the Bear River channel in and near Evanston).

Overdue reports.—District authors completed more than 160 reports of investigations during 1980–94 (in addition to the many reports prepared for the Air Force), but not without great difficulty. The continual reduction of programs and staff during the early 1980's caused a backlog of unfunded "overdue" reports that plagued the District for more than a decade. In 1984 Bloyd assigned James Wilson as special reports specialist to help complete the overdue reports. Finally, by 1994 the count was down to one. That report would be completed in 1995.

WESTERN REGION

By Andrew M. Spieker, *including information provided by* Pete Anttila, John Bredehoeft, Dave Camp, Phil Carpenter, John Conomos, John Costa, Sharon Doung, Gary Gallino, Joe Gates, Ed Hubbard, John Klein, Mike Nolan, Tom Pierson, Keith Prince, Kevin Scott, Marc Sylvester, Janet Thomas, Dick Whitehead, and Loren Young. Support was provided by Gail Spieker and Margaret Stockhill.

INTRODUCTION

From 1979 until 1991, the Western Region consisted of the eight westernmost States: Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, and Washington. In 1991, Utah was reassigned to the Western Region from the Central Region. The Western Regional Office is located at the Geological Survey's Western Regional Center in Menlo Park, Calif. Throughout 1979–94, referred to as "the reporting period," the office was in a single-story leased building at 110 Linfield Drive, formerly an insurance company office. On March 23, 1994, newly appointed Director Gordon Eaton presided over the ground-breaking ceremony for the Vincent E. McKelvey Federal Building, which a few years later would house the Regional Office.

In 1980, following the retirement of Regional Hydrologist William H. Robinson, John Bredehoeft was named as his successor. Whereas most Regional Hydrologists had risen through the ranks of the District programs, Bredehoeft's background was in research. He came to the Region as a noted ground-water geologist who, among his many accomplishments, had pioneered in the development of numerical simulation of ground-water systems.

Bredehoeft left the position of Regional Hydrologist in 1984 to return to his research. After an interval of several months during which Benjamin Jones served as Acting Regional Hydrologist, John Conomos was selected for the position. Conomos, like Bredehoeft, came from a research background. He had been Chief of a multidisciplinary study of the hydrodynamics and ecology of San Francisco Bay. From 1980 to 1985 he had served as Chief of the Branch of Regional Research for the Western Region. As would be expected, he was to continue and augment the role of research in District programs.

MAJOR INITIATIVES, PROGRAMS, AND A SIGNIFICANT ACTIVITY

Initiatives

As part of efforts during the 1980's to improve the scientific quality of projects funded in the Federal-State Cooperative (Coop) Program, two initiatives were introduced: the Merit Project Competition and the opportunity for District scientists to have their performance evaluated under the Research Grade Evaluation Guide (RGEG, sometimes shortened to RGE).

Merit Project Competition.—The Merit Project Competition was introduced in 1981 to encourage Districts to bolster and upgrade the scientific content of projects in the Federal-State Coop Program. Previ-

ously, each region was allocated its share of the Coop matching funds based on the share it had received in the previous year, regardless of changing priorities or advances in science. The WRD had come under criticism for this practice. Under the Merit Project Competition, a percentage of Federal matching funds was to be set aside for Merit Projects, and Districts were encouraged to submit proposals for projects to be funded under this process. The proposals were evaluated and ranked by the Regional Staff. The successful proposals were further evaluated at Headquarters and the winners selected by the WRD Senior Staff. Because of disagreement as to how the funds were to be allocated, the competition was not implemented until fiscal year 1983.

A byproduct of this process, perhaps unintended but nonetheless real, was a spirited competition among the four regions to see who could get the most Merit Projects. The "winners" of this competition changed from year to year, but the Western Region held its own and sometimes led the pack.

The process was not without controversy. Some critics believed that the selection process involved an inordinate amount of time and effort to gain a relatively modest increase in funds. Others, however, held that the process caused all those involved to give more thought to project planning, a process that would result in a better product.

Following are examples of projects in the Western Region funded through the Merit Competition during the reporting period. For each project, the title and State are given: Hydrology and Geochemical Processes at a Sub-Arctic Landfill at Fairbanks, Alaska; Predictive Accuracy of Ground-Water Models, Arizona; Estimating Tidal and Residual Circulation in San Francisco Bay, California; Investigations of Ground-Water Evapotranspiration Mechanisms and Rates in Southern Nevada; and Iron Geochemistry of the Dunes Aquifer near Coos Bay, Oregon.

Research Grade Evaluation in District Programs.—Another change in process that has resulted in greater scientific merit in District programs was making District scientists eligible for evaluation under the RGEG. This process was implemented in District programs in 1982. Previously, only scientists in the National Research Program had been eligible for RGEG. Under the process, eligible scientists are evaluated, on the basis of published research, by a panel of their peers and are promoted on the basis of the merit, scope, and importance of their research. Scientific content of District programs was enhanced, and there was a significant increase in articles by WRD District scientists published in the refereed scientific literature. Collaboration with universities was further encouraged and enhanced.

New Regional Programs

By 1979, some of the significant and highly visible Regional programs of the 1970's had ended or were winding down. Examples are the Trans-Alaska Pipeline project, the Redwoods National Park project, and the Geothermal Program. New programs were started during the reporting period, some in response to natural phenomena and others as part of WRD's continuing effort to extend and enhance our understanding of hydrology. Four examples follow.

Volcano Hazards Program.—On May 18, 1980, Mount Saint Helens had a major pyroclastic eruption, after several weeks of seismic and minor eruptive activity. Damage in the vicinity was intense and extensive. The large volume of debris caused major modifications of the surrounding terrain and altered the flow characteristics of the Toutle and Cowlitz Rivers.

The U.S. Geological Survey's response to the eruption and its consequences was prompt and thorough. Geologic and Water Resources Divisions both had teams of scientists making observations and collecting data from the beginning of eruptive activity.

Richard Janda was leader of the WRD team, but much of the data collection was done by personnel from the Washington District. These efforts intensified after the major eruption. A Project Office staffed by scientists and support staff from WRD and Geologic Division was established in Vancouver, Wash., late in 1980. Janda, a research geomorphologist with the NRP in Menlo Park, agreed to move to Vancouver and serve as leader of the WRD group. This Project Office was, and remains, probably the most successful example of collaboration between WRD and Geologic Division scientists.

Geologic Division staff began to refer to the facility as the Cascades Volcano Observatory from the start, although the name was not formalized until the late 1980's. The official name is the David A. Johnston Cascades Volcano Observatory, named after a Survey geologist who was killed in the May 18, 1980, eruption.

The WRD group initially operated as a Subdistrict of the Washington District, although scientific oversight was largely from the Regional Office. Janda served as Office Chief until 1986, when he was succeeded by John Costa. In 1991, management of the Vancouver office was transferred from the Washington District to the Regional Office.

The Mount Saint Helens eruption heightened concerns about potential hazards of the other Cascade Range volcanoes. These concerns led to studies of the geologic and hydrologic hazards associated with Mount Rainier, Mount Hood, and Mount Shasta.

Western Region Drilling Operation.—In 1980 the Western Region established a research drilling operation with the purpose of developing new techniques in exploratory drilling, obtaining geologic cores in difficult geologic environments, and the emplacement of sampling devices and subsurface sensors for hydrologic investigations. These services are provided on a repay basis, mostly for District programs in the Western Region. John Singer was selected as the Drilling Operations Manager. He and his team worked out of the Santa Barbara, Calif., Field Office, but were managed by the Western Regional Office.

It soon became apparent that the available funding was inadequate for conducting research in developing new techniques, but the program has successfully met the other objectives of drilling in difficult environments and emplacement of instruments. Singer remained in charge throughout the period.

National Irrigation Water-Quality Program.—In 1983, incidents of reproductive failures, deformities, and mortality of aquatic birds were reported at Kesterson Reservoir, a National Wildlife Refuge on the west side of the San Joaquin Valley in California. The WRD was requested to conduct an investigation. The investigation was managed by the Western Regional Office and coordinated by Marc Sylvester. The cause of these adverse effects was determined to be poisoning by selenium transported by irrigation drainage into the refuge area. During the course of the investigation, a new method for quantitative analysis of selenium was developed by Theresa Presser of the WRD National Research Program, Western Region.

Because of the possibility that similar effects could be widespread in the Western States, in 1985 the Department of the Interior implemented the National Irrigation Water Quality Program (NIQWP), also informally known as the Irrigation Drainage program. Reconnaissance investigations were done in 26 areas; in 8 of these areas, selenium concentrations sufficiently high to cause problems similar to those at Kesterson were discovered. Detailed studies then were done in the eight areas. Marc Sylvester was Western Regional coordinator for WRD's part of the program, as well as other investigations concerned with toxic and hazardous wastes, from 1985 to 1991. From 1991 to 1994, he was succeeded in these activities by Janet Hren.

National Water-Quality Assessment.—The National Water Quality Assessment (NAWQA) Program was funded and started in the late 1980's. NAWQA is a National Program designed to describe the status and trends in the quality of the Nation's ground- and surface-water resources and to provide a sound understanding of the natural and human factors that affect the quality of these resources. The investigations are being conducted in 59 areas, known as study units.

In the Western Region, pilot investigations began in 1986 of ground-water quality in the Carson River Basin of California and Nevada, and of surface-water quality in the Yakima River Basin of Washington. Full funding of the NAWQA Program began in 1990. The initial study units in the Western Region were the Central Columbia River Basin of Washington and Oregon; the Willamette River Basin of Oregon; the Upper Snake River Basin of Idaho; the San Joaquin River Basin of California; and in the Nevada Basin and Range area.

Marc Sylvester coordinated NAWQA studies in the Western Region from the Regional Office. In 1990 he was named Assistant Regional Hydrologist for NAWQA.

Significant Activity

WRD National Conference.—The Western Region hosted the 1985 WRD National Conference, held in San Diego, Calif., November 18–22. About 150 key WRD personnel and guests attended. Director Dallas Peck and former Director William Menard were among the distinguished guests. Numerous presentations were made on a wide range of scientific and programmatic topics. Notable guest speakers included Roger Revelle and Abel Wolman. A field trip was held to visit sites of hydrologic and geologic interest in Southern California.

ORGANIZATION AND STAFFING

In 1979, the Western Region comprised the eight westernmost States: Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, and Washington. In 1991, as part of a realignment of the four Regions, Utah was reassigned from the Central Region to the Western Region.

Organizational Changes

Several changes were made in the organization and management structure of the Western Region during the reporting period. Following is a summary of the more significant ones.

National Research Program.—At the start of the reporting period, the WRD Research Program was considered a part of the Regional Office. The Regional Research Hydrologist reported to the Regional Hydrologist. Frank Trainer held that position in 1979. Upon Trainer's retirement early in 1981, John Conomos was appointed his successor. Late in 1981, the research program was reconstituted as the Branch of Regional Research, Western Region, and was separated from the Regional Office.

Merged Districts.—During the early 1980's WRD engaged in an experiment of merged Districts. Some WRD managers believed that some smaller Districts lacked the critical mass needed to function effectively. This belief led to the conclusion that these smaller Districts could function better if merged with a larger, stronger District. As a consequence, Regions were encouraged by WRD Senior Management to experiment with merged Districts. Bredehoeft took the initiative and selected Idaho-Nevada and Washington-Oregon as the two merged Districts. The latter was named the Pacific Northwest District.

The Idaho-Nevada merger took effect in 1982 and ended in 1987. The District Chief was headquartered in Boise, Idaho, and State Offices were in Boise and Carson City, Nev. The Washington-Oregon merger took effect in 1984 and ended in 1991. The District Chief was located in Tacoma, Wash., and State Offices were in Tacoma and Portland, Ore.

The experiment could best be judged as a mixed bag of successes and problems. Staff interaction within the merged Districts was a benefit; on the other hand, cultural clashes developed. The long distances between the State offices posed problems. Managing funds of some cooperative projects was complicated by the mergers. Also, the merger concept was not accepted by all cooperators.

Of the two merged Districts, the Pacific Northwest District was the more successful. Washington and Oregon are hydrologically similar. The locations of the State offices, Tacoma and Portland, are relatively close (about 140 miles apart), and transportation is good. The merger resulted in more efficient operation of the data program by closing the Field Office in La Grande, Ore., and transferring its functions to the Pasco, Wash., office. This arrangement worked largely because of the good faith of the participants, who wanted to make it work.

The Idaho-Nevada District was more problematical. The two States are hydrologically dissimilar. The State offices, in Boise, Idaho, and Carson City, Nev., are 300 miles apart, and transportation was difficult.

In retrospect, the merged Districts concept was not as well suited to the large Western States is it was to some smaller Eastern States. For example, Maryland-Delaware-District of Columbia and the New England States are well suited for merger. Some of these Districts were already merged before the experiment, and remain so.

Area Organization.—After the merged Districts were dissolved, the WRD Senior Staff sought alternate means to improve Regional management of the District programs. Some senior WRD managers felt that, as District programs were growing ever larger and more complex, the regional management teams, as they then existed, were unable to manage these programs effectively. The Western Region management did not adhere to this concept.

After considerable debate, the WRD Senior Staff voted to implement an area management structure, in which each Region would be subdivided into several areas, each headed by an Area Hydrologist, who would report to the Regional Hydrologist. The Area Hydrologist would supervise the District Chiefs.

Accordingly, in 1991 two areas were established in the Western Region: the Pacific Northwest Area, which included Alaska, Idaho, Oregon, and Washington, and the Great Basin Area, which included Arizona, Nevada, and Utah. At that time California and Hawaii were not included in the areas. A year later, in 1992, the California-Pacific Area was established to comprise these two Districts. In 1993, when Great Basin Area Hydrologist Bill Carswell left to become Northeastern Regional Hydrologist, the California-Pacific and Great Basin Areas were merged.

The effectiveness of the area organization in the Western Region is difficult to evaluate. On the whole it worked because the regional managers were determined to make it work. Whether this organizational change was really necessary could still be debated.

Regional Office Staff

During the decade prior to 1979, the Regional Office Staff had remained fairly constant, with about nine key professional positions plus support staff. During the 1979–94 period, however, several staffing changes occurred, largely as a result of technological, organizational, and programmatic changes. The chronology of the Western Regional Staff is listed in table 1. Following is a brief discussion of the more significant changes.

Table 1. Chronology of key WRD Western Regional Office staff positions, 1979–94

[Note: Dates are given only for the reporting period, 1979–94. Names shown for 1979 held the position prior to that date, and those shown for 1994 held it thereafter]

REGIONAL HYDROLOGIST
W.H. (Bill) Robinson 1979–80
John D. Bredehoeft 1980–84
Benjamin L. Jones 1984–85 (Acting)
T. John Conomos 1985–94
ASSISTANT REGIONAL HYDROLOGIST
John W. Wark 1979–82
Benjamin L. Jones 1983–88
J. David Camp 1989–92
ASSISTANT REGIONAL HYDROLOGIST/NAWQA
Marc Sylvester 1991–94
ASSISTANT REGIONAL HYDROLOGIST/ GREAT BASIN PROGRAMS
William J. Carswell 1991–93
John M. Klein 1993–94
ASSISTANT REGIONAL HYDROLOGIST/ PACIFIC NORTHWEST PROGRAMS
Garald G. Parker, Jr. 1991–92
Marvin O. Fretwell 1992–94
ASSISTANT REGIONAL HYDROLOGIST/ CALIFORNIA-PACIFIC PROGRAMS
John M. Klein 1992–93
(California-Pacific and Great Basin Program areas were merged in 1993)
REGIONAL RESEARCH HYDROLOGIST
Frank W. Trainer 1979–81
T. John Conomos 1981
(National Research Program separated from Regions in late 1981)
PROGRAM OFFICER
Lawrence E. Newcomb 1979–81
Loren E. Young 1981–86
J. David Camp 1988–89
Peter W. Anttila 1991–94
GROUND-WATER SPECIALIST
Edward R. Leggat 1979–81
Gilbert L. Bertoldi 1982–85
William D. (Dave) Nichols 1986–88
Keith R. Prince 1988–94
REGIONAL DRILL RIG SUPERVISOR
John Singer 1985–94
SURFACE-WATER SPECIALIST
Howard F. Matthai 1979–80
Donald O. Moore 1981–83
Byron N. Aldridge 1984–88
Kenneth M. (Mike) Nolan 1989–94
WATER-QUALITY SPECIALIST
G. Douglas (Doug) Glysson 1979
Marvin O. Fretwell 1979–85
Robert C. Bubeck 1986–94
IRRIGATION DRAINAGE AND HAZARDOUS WASTES PROGRAM COORDINATOR
Marc Sylvester 1985–90
Janet Hren 1991–94
REPORTS IMPROVEMENT ADVISER
John H. (Jack) Feth 1979
Roy Newcome, Jr. 1979–81
John H. Feth 1982–84 (Re-employed annuitant, part time)
Andrew M. Spieker 1984–94
COMPUTER SPECIALIST
Alfred Janssen 1980–84
Richard E. Smith 1985–90
Graig A. McHendrie 1991–94
WATER-USE SPECIALIST
R. John Burt 1982–94
ADMINISTRATIVE OFFICER
John J. Lysaght 1979–88
Martha K. Burbidge 1988–94
HUMAN RESOURCES SPECIALIST
Hallard B. Kinnison 1979–82 (Re-employed annuitant)
(Duties performed by Assistant Regional Hydrologist and Administrative Staff 1983–88)
Janet Hren 1988–94
SECRETARY TO REGIONAL HYDROLOGIST
Catherine A. Marvin 1978–83
Sandra J. Clarke 1984
Vacant 1984–85
Martha E. Zaccor 1986–88
Mary S. Conger 1989–94

The rapidly expanding use of computers in all aspects of WRD activities created the need for expertise that the existing staff did not fully possess. Accordingly, a new staff position, Regional Computer Specialist, was established in 1980. The first person to hold this position was Alfred Janssen (table 1).

The Water-Use Program has been a key part of WRD's activities for many decades. During the 1980's and 1990's it was given increased emphasis and visibility. In 1982 the position of Regional Water-Use Coordinator was established. John Burt was named to this position; he held it through the rest of the period.

Several new programs—the Irrigation-Drainage Program, Hazardous Wastes Program, the Regional Drill Rig, and NAWQA—as well as the area organization, resulted in new staff positions. These programs/activities and their staffing are discussed in the appropriate sections of this chapter.

ALASKA

By Liska Snyder. *reviewed by* Bob Burrows, Gordon Nelson, Leslie Patrick, Dick Snyder, Gary Solin, *and* Pat Still.

INTRODUCTION

The period 1979 through 1994 was a time of great upheavals in both the State of Alaska and the Alaska District Office of WRD. Several major hydrologic events occurred, while at the same time, the State was undergoing rapid economic changes because of the completion of the Trans-Alaska Pipeline. During this period, personnel in the District Office were wrestling with enormous and continual changes in scientific and computer technology.

Major Hydrologic Events

From 1979 to 1982, no major floods took place in Alaska. In November 1983, significant floods struck the lower Kenai Peninsula and Kodiak Island. In July 1985, several small streams near Tok flooded. A major flood that hit southcentral Alaska in October 1986 caused extensive damage in Seward and along the Susitna River tributaries that cross the Parks Highway. Total damage was estimated to be more than $20 million; a large part of that damage was to the Alaska Highway system and the Alaska Railroad. In July 1987, a large thunderstorm complex near Black Rapids caused flash floods and mass movement of sediment. Erosion exposed sections of the Trans-Alaska pipeline, and damage to the nearby Richardson Highway was estimated at nearly $1 million.

The year 1989 had several disasters. In March, the *Exxon Valdez* oil tanker spilled nearly 11 million gallons of North Slope crude oil in Prince William Sound. The effects of this spill had a great impact on the State of Alaska and its economy for many years. A severe flood in the eastern Yukon Basin in June damaged roads, placer mines, and buildings. A major flood hit southcentral Alaska at the end of August. Most of the $10 million damage was caused by the inundation of low-lying residential and commercial areas in the Municipality of Anchorage. Seward and other areas of the Kenai Peninsula were also flooded, and damages were estimated at about $1 million. In December, Redoubt Volcano, 110 miles southwest of Anchorage, had the first of its 26 eruptions. These eruptions resulted in large debris flows down the length of the Drift River and into Cook Inlet. Although the debris flows did not damage the Drift River oil terminal, the terminal was shut down until new flood-control dikes were built.

The early 1990's saw some additional hydrologic events. In 1991, Juneau experienced its wettest year on record. In October, major floods near Kodiak were accompanied by landslides and slumping. Damage to public facilities was about $5 million. During the spring of 1992, hundreds of homes in the Fairbanks area were flooded as a result of snowmelt runoff in the Chena and Tanana Rivers. In addition, storage of floodwater behind the Moose Creek Dam caused ground-water levels to rise, also flooding homes. In July, August, and September 1992, Crater Peak, a flank vent on Mount Spurr Volcano, erupted, causing snow and rock avalanches. The August eruption covered the Anchorage area with a heavy dusting of volcanic ash. The last major flood of this period was during August 1994, when several storms caused serious flooding in the Noatak, Kobuk, and Koyukuk River drainages. This storm washed out parts of the Dalton Highway and forced evacuation of the villages of Allakaket, Alatna, and Hughes on the Koyukuk River. Total damages, including eventual relocation of Allakaket and Alatna out of the flood plains, cost more than $100 million.

Effects of Oil Revenues

From 1979 to 1994, Alaska WRD programs were affected by the events in the oil industry in Alaska. In 1977, the Trans-Alaska Pipeline was completed from Prudhoe Bay to Valdez. Suddenly, the State became prosperous from the oil royalties. In the early 1980's, the WRD offices in Anchorage and Fairbanks grew as a result of new programs associated with oil and gas development and with resource appraisals for State, borough, and municipal governments. However, in 1986, the price of oil dropped significantly, causing Alaska oil revenues to plummet. By 1987, the economic doldrums caused by low oil prices devastated both the oil industry and State and local governments, causing many people to lose their jobs and leave the State. (The population of Alaska went from 550,700 in 1985 to 535,000 in 1987.) In 1987, the District funding level had decreased to about $2.9 million from a high of $4.3 million in 1984. From 1979 to 1984, the Alaska District had an average of about 72 employees, but by the late 1980's the average number of employees had decreased to about 50. Repeated attempts to develop new cooperative studies with borough and city governments failed or succeeded in developing only small programs that were not cost effective to operate. However, by 1994, a brief peak in Department of Defense programs and a strong ground-water program in Fairbanks raised the number of Alaska WRD personnel back up to about 65.

Changing Technology

The period 1979–94 saw great changes in the technology in Alaska District offices. Word processing, data processing, and information technology made quantum leaps. In 1979, word processing still relied on "mag-card" typewriters, large machines that recorded the text on magnetic strips on computer cards. They were soon followed by a desk-size word processor with a screen. During the 1979–94 period, three milestones stand out in computer processing. The first was the introduction of the Wylbur operating system on the mainframe computer and relatively reliable communications between dumb terminals in the District and the mainframe in Reston, Va. The second milestone was the installation of minicomputers in the early 1980's. Scientists could finally run models, write reports, and process data on local, reasonably efficient machines. These computers also brought the advent of a national computer network, with e-mail that actually worked across the Nation for all WRD employees. The third major advance was the installation of the workstations in late 1991. This new capability spelled eventual doom for the centralized WATSTORE data base on the mainframe and the beginning of a truly distributed information system, NWIS (National Water Information System). Although some District personnel insisted on using microcomputers, these machines could not compete with the workstations for modeling and data-base management. By 1994, typists and secretaries were becoming rare because scientists began doing their own typing into computer memory.

ANILCA

In 1980, the Alaska National Interest Lands Conservation Act (ANILCA), Public Law 96–487, created more than 100 million acres of new national parks, refuges, monuments, conservation areas, recreation areas, forests, and wild and scenic rivers in Alaska, for the preservation of "nationally significant" natural resources. The act contained numerous provisions and special rules for managing Alaska's public lands and nationally important resource development potential. These provisions profoundly affected the Alaska District's Federal cooperators and, subsequently, District programs.

Organization and Personnel of the Alaska District

Organization

During the period of 1979 to 1989, the Alaska District was composed of a District Office and three Subdistrict Offices in Anchorage, Fairbanks, and Juneau. In 1989, these Subdistrict Offices were redesignated as Field Headquarters. The Anchorage office oversaw the data program and hydrologic investigations in the southern half of the main part of Alaska, whereas the Fairbanks office did the same for the northern half of the State. The Juneau office was in charge of southeast Alaska (the "panhandle"). In 1993, WRD transferred the Ice and Climate Project Office in Tacoma from the National Research Program to the Alaska District, although the scientists and staff remained in Tacoma.

In 1979, the Alaska District Office was located in downtown Anchorage at 218 E Street. A year later it moved nearby to 733 West Fourth Avenue. The

Anchorage Subdistrict had been at 1209 Orca Street since the early 1970's. In 1982, The District Office moved again, to a one-story building at 1515 East 13th Street, immediately adjacent to the Anchorage Subdistrict. This move toward consolidation was interrupted in 1984, when a building to house "all of USGS" was built at Alaska Pacific University (APU), adjacent to the USGS Branch of Alaska Geology building. Unfortunately "all of USGS" did not include the Anchorage Subdistrict Office. The District Office has been in Grace Hall on the campus of APU since then. Grace Hall also houses National Mapping Division offices.

The checkered history of the Fairbanks Field Office began in 1965 when a project office was established to study glaciers. In 1966, the Fairbanks project office was converted to a Field Office with the addition of a surface-water program and, eventually, interpretive hydrologic programs. The Field Office was considered part of the Anchorage Subdistrict until 1970, when it was designated as the Fairbanks Subdistrict. In the mid-1980's, the office moved from the Federal Building to a quaint little old house on the campus of the University of Alaska, where it remained until the late 1990's. The Juneau office was housed in the Federal Building during most of this time period.

Personnel

Many people worked for the Alaska District throughout the years 1979–94. Some worked only for a year or two. The employees listed below are those who worked for at least a few years or who transferred to other Districts where they may have become long-term employees.

Alaska District Office. District Chiefs: In 1979, Harry Hulsing was in his fifteenth year as Alaska District Chief. He retired in 1980 and was replaced by Philip A. Emery, who served for about 9 years. Philip J. Carpenter became District Chief in late 1989, and he retired in 1994. During this time period, Richmond Brown and Ray George were Associate District Chiefs. In 1990, two new positions were created: Assistant District Chief for Hydrologic Investigations (Gordon Nelson) and Assistant District Chief for Data (Ken Thompson). A third Assistant District Chief for Management Operations was established in 1991 (Leslie Patrick). Nelson replaced Carpenter as District Chief in 1994.

From 1979 to 1994, Administrative Officers were Kam Alexander, Debi Munsey Treseder, and René Seymour. Through the years, they were assisted by Tammy Bagley, Marsha Castleman, Paula Miller, Katie Novcaski, Joan Roberts, Velma Sackett, Denise Sewell, Sharon Shaw, Eleanor Stackhouse, Mary Ann Ward, and Sherrie Averill Wark. During this time, the Computer Section was headed by Jill Brunett, Nancy Nicolaisen, and Leslie Patrick, assisted at various times by Penny Ebling, Donna Harding, Glen Jackson, Karen Jones, Larry Roberts, and Carla Simpson. The Reports Unit was headed by Kitty Reed, Chet Zenone, and Liska Snyder. Bob Gilmore and Linda-Lee Harris put in many years as illustrators. Through these years, versatile Lisa Tennison assisted in the Administration, Computer, and Reports Units.

Hydrologic Investigations. From 1979 until about 1990, most hydrologists were based in the District Office; a few were based in the Anchorage, Fairbanks, and Juneau Subdistrict Offices. In 1990, most Anchorage-area hydrologists were moved to the District Office. From 1979 to 1994 the Anchorage hydrologists included Paul Agrimis, Tim Brabets, Jill Brunett, Mark Carr, Joe Childers, Derrill Cowing, Wes Danskin, Larry Dearborn, Joe Dorava, Dick Emanuel, Al Feulner, Geoff Freethey, Roy Glass, Paula Johnson, Stan Jones, Jim Knott, Bob Lamke, Steve Lipscomb, Bob Madison, George McCoy, Dave Meyer, Gordon Nelson, Leslie Patrick, Ron Rickman, Tim Rowe, Chuck Savard, Dave Scully, Charlie Sloan, Gary Solin, Pat Still, Wes Swanner, Chris Waythomas, Loren Wittenberg, and Paul Woods.

Anchorage Subdistrict Office. Chiefs of the Anchorage Subdistrict/Field Office during this time were Ray George, Larry Leveen, and Bruce Bigelow. Hydrologic technicians and other support staff in the Anchorage Subdistrict/Field Office were Bonnie Bailey, Tom Brennan, Francis Cummings, Tim Hansen, Glen Jackson, Karen Jones, Don Kernodle, Eric Kletka, Adolph Kuhn, Mike Lee, Rob MacNaughton, Ben May, Jackie McIntire, Jack McKechnie, Rod Murray, Larry Myers, Katie Novcaski, Greg Pope, Andy Records, Chad Smith, Dick Snyder, Forrest Sondrud, and Pat Strelakos. Records, Sondrud, and Swanner all worked in Juneau before transferring to Anchorage.

Fairbanks Subdistrict Office. Chiefs of the Fairbanks Subdistrict/Field Office during this time were Bruce Parks and Bob Burrows. Fairbanks hydrologists from 1979 to 1994 included Burrows, Joe Downey, Philip Harrold, Richard Kemnitz, Jon Kostohrys, Andrea Krumhardt, Mike Lilly, Eddie

Vaill, Jim Vanderwaal, and Dorothy Wilcox. Support staff and hydrologic technicians included Dave Flynn, Joe Gillis, Gary Hopkins, Maurice Nelson, Sheryl Runberg Parks, Matt Schellekens, Steve Swingle, Richard Tarkiainen, Steve Torrence, Kristi Varney, and Carol Ann Varner. The Glaciology Project Office was staffed during these years by Larry Mayo, Dennis Trabant, and Rod March, and later by Tom Heinrichs and Ben Kennedy.

Juneau Subdistrict Office. Harold Seitz was the Subdistrict Chief from 1980 until the mid-1990's. He was assisted by hydrologists Gary Balding, Ed Bugliosi, and Jim VanMaanen, hydrologic technicians Kevin Linn, Don Thomas, and Jessie Skrzynski, and clerk Virginia Robertson.

The untimely deaths of Adolph Kuhn, Dave Scully, and Steve Swingle in the 1980's deeply saddened Alaska District personnel. Tragically, Kuhn was killed in a plane crash during a USGS field trip.

COOPERATION AND FUNDING

Cooperators

During the period 1979–94, Federal cooperators were principally involved with the interpretive programs. The main ones included the U.S. Army Corps of Engineers, Bureau of Land Management, U.S. Department of Agriculture Forest Service, and U.S. Air Force. Others were the U.S. Environmental Protection Agency and the National Park Service. Major programs were also started in cooperation with the U.S. Coast Guard and the U.S. Navy.

State cooperators participated in both the data-collection and interpretive programs. During this time, the largest cooperative (Coop) program was with the Alaska Department of Natural Resources, specifically the Divisions of Geological and Geophysical Surveys, and Land and Water Management. Two other major cooperators were the Alaska Department of Fish and Game and the Department of Transportation and Public Facilities (with the Federal Highway Administration). Additional State cooperators were the Alaska Power Authority (later Alaska Power Administration) and the Alaska Department of Environmental Conservation.

Local cooperators also participated in both data-collection and interpretive studies. Major ones throughout this time period were the Municipality of Anchorage, Fairbanks–North Star Borough, City and Borough of Juneau, Kenai Peninsula Borough, and the Matanuska–Susitna Borough. Smaller programs were done with the City and Borough of Sitka. In the early 1990's a major ground-water study in Fairbanks enlisted the cooperation of the Fairbanks International Airport, the Alaska Railroad, and the University of Alaska.

Funding

The funding table demonstrates the fluctuations in the Alaska District programs during this time period.

Hydrologic Data Collection

During the time period of 1979–94, the data-collection program consisted mainly of records of stage, discharge, and water quality of streams and water levels in wells and on lakes. All the data were published in the annual "Water Resources Data for Alaska" reports.

Surface Water

Surface-water data, including those for streams and lakes, provide information for research purposes,

Alaska District funds, fiscal years 1979–94

[FY, fiscal year; OFA, other Federal agencies; Coop, cooperative program]

FY	Funds, in thousands of dollars (rounded)				
	Federal	OFA	Coop	Federal matching	Total
1979	900	700	750	700	3,050
1980	950	800	900	800	3,600
1981	1,000	700	1,100	800	4,000
1982	800	600	1,700	1,200	4,300
1983	600	600	1,600	1,400	4,200
1984	600	450	1,600	1,500	4,300
1985	600	400	1,550	1,450	4,000
1986	800	400	1,300	1,000	3,500
1987	700	400	950	850	2,900
1988	900	1,800	1,000	900	4,600
1989	800	1,500	1,000	950	4,250
1990	1,900	600	1,000	900	4,400
1991	2,200	600	1,500	1,200	5,500
1992	1,900	850	1,300	1,100	5,150
1993	2,000	1,100	1,250	1,100	5,450
1994	2,300	2,900	1,400	1,100	7,700

planning, design, hazards warning, accounting systems, operation, and management. Stream gaging during the period 1979–94 was characterized by changes in technology and by fluctuating numbers of stations. Of the 111 stream-gaging stations in 1979, only 15 had satellite or other telemetry, and none were used for primary computation of discharge records. Eight of the stations were nonrecording gages, either staff gages or wire-weight gages read by an observer once or twice daily. Most sites were equipped with mercury manometers or were stilling wells, and the data were recorded by strip-chart or punch-tape recorders. The oil-related economic problems that affected Alaska in the mid-1980's reduced the network to 83 sites by 1987.

Although the number of gaging stations increased slightly in 1991–92, by 1994 the network was down to 81 sites. Two of these were nonrecording gages, and 14 were equipped with satellite or other telemetry. By then, nearly all the manometers had been replaced with pressure transducers, and data loggers began to be used as the primary recording instrument. Telemetered data were still not used as the primary record, but soon would be.

The funding table reflects the changes in the surface-water data-collection program for selected years. A large interpretive study of lakes in the Matanuska-Susitna Valley in the mid-1980's explains the lake data collected then.

Type of data collected	Number of streamflow stations for selected years					
	1979	1982	1984	1987	1990	1994
Discharge	111	108	112	83	85	81
Partial record stations						
Low flow	62	43	64	16	--	--
Crest stage	89	67	49	86	66	78
Lake levels	--	26	37	20	21	0

Ground Water

During this time period, ground-water levels were measured and data were collected at both observation wells and wells that were studied for specific projects. Therefore, the number of wells for which data are available fluctuated. The increase in wells in 1987 was due to a study of landfill wells in south-central Alaska and on the Kodiak Coast Guard Station. The 1994 increase is attributed to the intensive ground-water study that began in Fairbanks in the early 1990's. Many more wells were eventually drilled during this project.

Water-level measurements	Number of wells for selected years					
	1979	1982	1984	1987	1990	1994
Observation well (continuous)	30	38	34	32	27	55
Other wells	--	59	62	105	48	--

Water Quality

The types of data collected at streamflow stations include temperature, specific conductance, pH, dissolved oxygen, suspended-sediment, bedload, inorganic-constituent, organic-constituent, radiochemical, and biological data. During this time period, a number of stations were designated as part of the National Stream-Quality Accounting Network (NASQAN).

Surface-water-quality data	Number of stations or sites for selected years					
	1979	1982	1984	1987	1990	1994
Continuous-record stations	58	59	18	12	25	19
Partial-record stations	24	--	23	14	--	--
NASQAN	--	10	9	5	5	4
Benchmark	1	1	1	1	1	1

Water Use

A program was started in 1978 to establish an effective and coordinated system to collect, store, access, and disseminate water-use data in Alaska. The primary cooperator in the early years was the Alaska Department of Natural Resources. By 1984, several reports were published jointly with them, summarizing a variety of water-use issues in Alaska. After that time, the primary activity associated with this project was to acquire, estimate, and summarize the information needed for the Alaska section for "Estimated Use of Water in the United States," which was published every 5 years.

Hydrologic Investigations

During the 1979–94 time period, about 75 new interpretive hydrologic investigations were started. Some highly specialized projects lasted only a year,

some continued for many years, and a few were never completed. During this 15-year period, about 90 Open-File Reports and about 50 Water-Resources Investigations Reports were published, in addition to a couple of formal USGS reports and numerous abstracts, conference proceedings, and journal articles. All reports published during this time period are listed on the Alaska District Web page.

Areal Studies

Anchorage. In 1966, major projects began in cooperation with the City of Anchorage and Greater Anchorage Area Borough (which later combined to become the Municipality of Anchorage) to collect and monitor surface- and ground-water data to measure the effects of human activities on water resources. Additional studies evaluated the effects of urban development on the natural environment. The project finally ended in the late 1980's after dozens of reports were written. The following reports were published since 1979: North of the Anchorage Bowl, reports were written on Eklutna Lake (Brabets), Peters Creek (Brunett), and the Eagle River Valley (Dearborn). In the Anchorage Bowl, urban runoff studies were done on Chester and Campbell Creek (Brabets) and sediment discharge in Campbell Creek (Lipscomb). Ground-water studies were done on Klatt and Connors Bogs (Glass). In addition, Patrick and Glass wrote various other ground-water reports. Merrill Field ground water was described by Nelson and by Brunett. South of Anchorage, studies were done at Potter Creek (Emanuel and Cowing) and at Girdwood (Glass).

Kenai Peninsula Borough. In the late 1960's, a long-term project began with the Kenai Peninsula Borough to locate and evaluate the availability and quality of municipal and industrial water supplies and develop an inventory of hydrologic data to aid in water-resources development. Many reports were published between 1967 and 1979. This cooperative project continued throughout the 1980's. In the early 1980's, the lower Kenai Peninsula was the focus of a ground-water study (Nelson and Johnson) and a surface-water study (Savard and Scully). In addition, the lake levels in the Kenai-Nikiski area were tabulated in reports by Bailey (1983, 1993). The town of Seward was the subject of several studies: water resources (Dearborn, Anderson, and Zenone), a hydrologic reconnaissance near Fourth of July Creek (Nelson), a study of the Exit Glacier area (Sloan), and a large report describing the severe flood in 1986 (Jones and Zenone). In the early 1990's Glass began a comprehensive study of the quality of ground water in the western part of the Kenai Peninsula; however, the report was not published until 1996. Studies in the Kachemak Bay area included a hydrogeologic study of Seldovia (Nelson and Danskin). In the early 1990's long-term studies began on the Bradley River across the bay from Homer (Rickman) and on the Kenai River (Dorava).

Fairbanks–North Star Borough. In the mid-1970's, an extensive cooperative project began with the Fairbanks–North Star Borough, which focused mainly on various ground-water issues. In the 1980's, several reports described the arsenic, nitrate, iron, and hardness in various areas of the borough (primary authors were Krumhardt, Johnson, and Hopkins). Hydrologic information for land-use planning was described for the Badger Road area (Krumhardt), and the geohydrology of the Delta-Clearwater area east of Fairbanks was also studied (Wilcox). A study of the geohydrology and ground-water geochemistry in the landfill was done by Downey. In the late 1980's a major study was begun to determine the water-table configuration at various stages and flow durations of the Chena and Tanana Rivers (Glass). In the early 1990's, several major ground-water studies began with various cooperators to define the geohydrology of the Fairbanks Airport, the University of Alaska, the Railroad industrial area, and Fort Wainwright (Lilly).

Northern Alaska. In the early 1970's a program started in the Arctic region of Alaska to study the environmental conditions in selected frontier areas where development had begun or was planned. In the late 1970's and early 1980's reports described the hydrology of the following river basins: Noatak, Kobuk (both by Childers and Kernodle), Togiak (Kernodle), and Unalakleet (Sloan and Kernodle). Sloan also evaluated and reported on potential water-supply sources of the North Slope to provide information for planning the development of oil and gas resources.

Copper River Basin. During this time period, several projects studied the hydrology of the Copper River Basin. Emery, Jones, and Glass described the water resources of the basin in USGS Hydrologic Atlas HA–686. Jones and Glass delineated the hydrologic and mass-movement hazards near McCarthy in Wrangell–St. Elias National Park.

Glaciology

Since the early 1960's the USGS has been operating a long-term "benchmark" glacier program to intensively monitor climate, glacier motion, glacier mass balance, glacier geometry, and stream runoff at a few selected sites. The data collected are used to understand glacier-related hydrologic processes and improve the quantitative prediction of water resources, glacier-related hazards, and the consequences of climate change. Long-term mass-balance monitoring programs at three widely spaced glacier basins in the United States clearly sample different climate/glacier-runoff regimes. Two of these glacier basins are Gulkana and Wolverine Glaciers in Alaska. The third, South Cascade Glacier in Washington, was temporarily under Alaska District auspices when the Ice and Climate Office was transferred in 1993. Between 1979 and 1994, Mayo, March, and Trabant published numerous reports describing the data and interpretations of these glaciological studies. Bob Krimmel published reports on South Cascade Glacier. The glaciologists also studied and published reports on other glaciers in Alaska, such as Bering, Columbia, Hubbard, Knik, and Taku Glaciers.

Sediment Transport

During the 1979–94 time period, a series of sediment transport studies was done on various rivers in Alaska.

Tanana River: A long-term study defined the sediment transport characteristics and documented the significant changes in these characteristics between 1977 and 1982 on the Tanana River in the vicinity of Fairbanks. This project was done in cooperation with the U.S. Army Corps of Engineers and generated six reports describing the results (Burrows, Emmett, Parks, and Harrold).

Susitna River: In the early 1980's a major study began in cooperation with the Alaska Power Authority that studied the total sediment transported by the Susitna River and selected tributaries below Devils Canyon. Four reports described the sediment discharge data, sediment transport characteristics, and trends in bedload discharge from 1981 to 1985 (Knott and Lipscomb).

Copper River: In the early 1990's a major program, in cooperation with the Alaska Department of Transportation and Public Facilities, centered on the geomorphology of the lower Copper River. The purpose was to document the lateral migration and vertical scour of channels. Brabets published several reports describing the hydrologic data, bridge-scour characteristics, and surface geophysical methods. Findings eventually were reported in USGS Professional Paper 1581.

Contaminated Sites Hydrology

Starting in the late 1980's, several programs were begun to study ground water, surface water, and soil at sites around Alaska that may have been contaminated by various pollutants.

Kodiak Coast Guard Support Center. From 1987 to 1988, Brunett headed a study in cooperation with the U.S. Coast Guard. The purpose was to determine the extent and severity of contamination by a wide variety of petroleum products from fuel tanks, pipelines, and waste storage containers that may have contaminated soil and water at several locations on the center. Published reports described wells (Carr) and surface-water resources (Solin) and compiled the hydrologic and water-quality data (Glass).

Clear Air Force Station. A study from 1987 to 1990 was done in cooperation with the U.S. Air Force to acquire data to confirm the presence or absence of environmental contamination on the station and to describe a remedial action appropriate for mitigating any confirmed contamination. Decision documents were provided to the Air Force.

National Petroleum Reserve, Alaska (NPRA). From 1989 to 1990, Brunett headed an intensive assessment of the water and soil quality at 28 exploratory well sites on the NPRA. The well sites had been constructed from 1975 through 1981. In addition to the text, the massive final report includes 108 large plates that describe the well sites, survey locations and elevation, physical and chemical properties of water, earth conductivity readings, and soil-gas readings. All the data collected for the report are contained in 13 accompanying diskettes.

Navy sites. In 1992, a project began in cooperation with the U.S. Navy to provide hydrologic overviews at several Navy sites in Alaska. One report describes the geology of northern Adak Island (Waythomas). Solin, Trabant, and K.A. McCarthy (Oregon District) described the subsurface hydrology of a Navy camp near Barrow.

Fort Wainwright. In 1993, Lilly headed a study in cooperation with the U.S. Army to collect geohydrologic data to support Superfund cleanup efforts.

Other Interpretive Studies

Flood and streamflow studies. Several flood studies were done in the mid-1980's in cooperation with the Alaska Department of Transportation and Public Facilities. Lipscomb headed a study to determine floodflows for the Knik and Matanuska Rivers. Jones spent many years compiling information and statistics for a comprehensive popular report describing the magnitude and frequency of floods in Alaska and conterminous basins of Canada. He also published a report describing floods from small drainage basins in Alaska. In the mid-1980's, Parks and Madison estimated selected flow and water-quality characteristics of Alaskan streams in a frequently requested report. Lamke researched the cost-effectiveness of the stream-gaging program in Alaska.

Lake studies. In the mid-1980's, Woods headed several lake studies in Alaska in cooperation with the Alaska Department of Natural Resources. A detailed study investigated the limnological characteristics of Big Lake to ascertain its trophic state and susceptibility to cultural eutrophication. This study culminated in USGS Water-Supply Paper 2382. In addition, Woods studied the limnology of nine small lakes in the Matanuska-Susitna Borough and the survival and growth rates of rainbow trout. He also coauthored an index to limnological data for southcentral Alaskan lakes.

Volcano studies. Alaska has about 40 active volcanoes. In 1988, a program was begun to identify and describe the hydrologic and hydraulic hazards posed by glacier-clad volcanoes, several of which are close enough to population centers to be considered potential threats to life and property. The eruptions of Redoubt Volcano in 1989 and Crater Peak on Mount Spurr in 1992, both near Anchorage, intensified the activities on this project, which are ongoing. However, no reports had been published by 1994.

Coal-bearing areas. In the mid-1970's a study was begun to provide baseline reconnaissance hydrologic information for coal-bearing areas in Alaska. Several reports in the early 1980's described the results of the study: Beluga, Peters Creek, and Healy coal areas (Scully, Krumhardt, and Kernodle); Capps coal field (Nelson); and Healy and Lignite Creek Basins (Parks).

Federal Aviation Administration study. In 1993, a massive project headed by Dorava in cooperation with the Federal Aviation Administration (FAA) began to study environmental and hydrogeologic conditions at about 60 FAA sites in Alaska. By the end of 1994, 13 of the eventual 45 reports had been published.

ARIZONA

By J. David Camp, *including information provided by* Fred Boner *and reviewed by* T.W. Anderson, F.C. Boner, and R.D. MacNish.

ORGANIZATION AND PERSONNEL

In 1979, the Arizona District consisted of a District Office, four Subdistrict Offices, and two Field Offices. The District Office was located in Tucson; the Subdistrict Offices were in Tucson, Phoenix, Flagstaff, and Yuma; and the two Field Offices were located in Thatcher (administratively under the Tucson Subdistrict Office) and Blythe, Calif. (administratively under the Yuma Subdistrict Office). There were project and hydrologic data-collection personnel in each Subdistrict Office. The two Field Offices were strictly data-collection units; both were closed in the mid-1980's. There were approximately 99 permanent employees in the District in 1979. In 1989, the District was reorganized into a Hydrologic Investigations and Research Section and a Hydrologic Data Management and Review Section. The Subdistrict Offices became Field Offices with the data-collection and project personnel answering to their respective section chiefs. There were more than 120 permanent employees in the District in 1994.

District Headquarters, Tucson

Office of the District Chief. In 1979 the District Office was located at 301 West Congress Street in the Federal Building. It was moved to 375 South Euclid Avenue in 1990.

Robert D. MacNish served as District Chief until his reassignment in August of 1993. He was replaced by Nick Melcher who reported in July 1994. The principal assistants were J. David Camp (1974–87) and Rickard D. Hutchinson (1988–89). In

1989, there was a reorganization showing two Assistant District Chiefs serving concurrently—Rick Hutchinson (retired in 1990), Edwin McGavock (1990–), and Mark T. Anderson (1991–). Alicia M. Hinds was the District Secretary for the entire period.

Fred Boner and Lester Kister were in charge of operations and projects, respectively, in 1979. In 1981, a Quality-Assurance Unit was created. Kister was transferred to that Unit and served as Unit Chief until his retirement in 1985. Boner remained as Operations Chief until his retirement in 1988. Edward Davidson was a staff hydrologist in 1979. He served on detail to the Land Information Analyses Unit in WRD Headquarters until his retirement.

Marian V. Logan came on board as Chief of the Administrative Services Section just as this period began. She was succeeded by Jean Y. Dowdy (1989–90), Cynthia L. Matus (1990–93), and Patricia Vallance (1993–). Frank Laguna and Sally Weiner served in the Administrative Services Section for the entire period, and Irma D'Angelo, who started as a Clerk-Typist in the front office, transferred to the Section in 1984.

The Computer Services Section became more highly visible as the District moved into the "computer age" in the early 1980's. Colleen Babcock served as District Computer Specialist and Chief of the Computer Services Section during this entire period. The size of the Section varied from four employees in 1979 to a high of nine employees at the close of the period. People who served in this Section include Randy Fields, Darwin Warrior, Rebecca Lopez, Mark Werley, and Tim McElhone.

The Interpretive Reports Unit had five employees in 1979. Carol Hicks served as Reports Specialist and Chief of the Interpretive Reports Unit until her medical retirement in 1982, at which time Laura Spicer assumed this responsibility. Spicer, Ellen Van De Vanter, and Patsy Martinez served in this Unit during the entire period, as did Barbara Favor except for the short period of time she was assigned to the Tucson Subdistrict. The Drafting Unit was a separate unit from 1979 until 1989 when it merged with the Interpretive Reports Unit to become the Reports and Drafting Section. George Smith was in charge of the Drafting Unit. Sid Alwin served in the Drafting Unit during this entire period. Others who later joined the Unit were John Callahan and Carolyn Moss.

The Hydrologic Data Processing, Review, and Reports Section (later renamed the Hydrologic Data Management and Review Section) was responsible for final review of the annual data publication and served as the contact and distribution point for hydrologic data requests by the public. People who served in this Section include Natalie White, William Garrett, Richard Wilson, Alice Konieczki, Chris Smith, and Pat Rigas.

A Quality Assurance Unit was created in 1981 and was made up of the three District Discipline Specialists. The initial assignments to this Unit were Les Kister, who served as Chief and Water-Quality Specialist; Byron Aldridge, Surface-Water Specialist; and Larry Mann, Ground-Water Specialist. Dean Radtke transferred in as Water-Quality Specialist when Kister retired; Hjalmar J. Hjalmarson moved into the Surface-Water Specialist job when Byron Aldridge transferred to Menlo Park, Calif.; and James Marie moved into the Ground-Water Specialist job when Larry Mann transferred to Idaho. This Unit was disbanded in 1992.

The Special Hydrologic Studies Unit was primarily a surface-water studies unit in 1979. In 1981 it was reassigned administratively to the Tucson Subdistrict, its scope was expanded, and it was renamed the Projects Section. Byron Aldridge had served as Chief of this Section but was detailed to the Land Information Analysis Unit in Headquarters at the beginning of the period. Others who served in this Unit were Larry Mann, Bob Myrick, Richard Wilson, Jim Eychaner, Steve Anderson, Joanne Garrett, Stuart Brown, Pat Stiehr, Ken Hollett, Jim Marie, Stan Leake, and Sandra Owen-Joyce.

Southwest Alluvial Basins—Regional Aquifer-System Analysis. District participation in this study (SWAB–RASA) began in 1979. Tom Anderson was the Project Chief. Others who participated in this study were Walter Meyer, Geoffrey Freethey, Patrick Tucci, Frederick Robertson, Randall Fields, Donald Pool, and John Dolegowski.

Tucson Subdistrict Office. In 1979, the Tucson Subdistrict was primarily a hydrologic data-collection unit with Hjalmar J. Hjalmarson serving as Subdistrict Chief. The office was at 1639 E. 18th Street in Tucson. In 1981, the special Hydrologic Studies Unit was administratively reassigned to the Tucson Subdistrict and was renamed the Projects Section. The Subdistrict Chief's office was relocated to the District Office in the Federal Building as a part of the Projects Section, Tom Anderson was named Chief of the Tucson Subdistrict, and Hjalmarson was reassigned to the

Quality-Assurance Unit. The field operations office remained at the 18th Street address until 1983 when it was moved to the Federal Building. In 1989, the District was reorganized into two major Sections: the Hydrologic Investigations and Research Section and the Hydrologic Data Management and Review Section. The Hydrologic Investigations and Research Section was moved to the new location at 375 S. Euclid Avenue along with the Office of the District Chief in 1990, and Rick Hutchinson was designated as Chief of this new Section with the title of Assistant District Chief and Chief, Hydrologic Investigations and Research.

Some of the people who served in the Special Hydrologic Studies Unit/Projects Unit and the Tucson Subdistrict/Field Office during this time were Larry Mann, Bob Myrick, Richard Wilson, Jim Eychaner, Steve Anderson, Joanne Garrett, Stuart Brown, Ken Hollett, James Marie, Stanley Leake, Sandra Owen-Joyce, John Gray, Julia Graf, Randy Hansen, Rodney Roeske, Michael Carpenter, David Graham, Don Pool, James Brown, Laurie Wirt, Samuel Jones, Charles English, Neil Carmony, Alice Konieczki, Stanley Baldys, Jan Doughman, Eugene Buell, and Greg Pope.

Thatcher Field Office. This office was strictly a hydrologic data-collection unit administratively assigned to the Tucson Subdistrict Office. It was located at 239 Stadium Avenue in Thatcher. There were four full-time employees and two part-time employees in 1979. When it was closed in 1988, there were two full-time employees and one part-time employee. Milton (Buck) Eddington was the Hydrologic Technician in charge of the office until his retirement. Ben Bryce replaced Eddington.

Phoenix Subdistrict Office. The Phoenix Subdistrict Office was located in Suite 1880 on the 18th floor of the Valley Center Building in downtown Phoenix in 1979. Paul Rohne, Jr., was the Subdistrict Chief. Project work and hydrologic data collection were conducted out of this office. In 1981 Rohne transferred to the International Boundary and Water Commission and was replaced in 1982 by Edmund Nassar. In 1984, the office was moved to 3738 N. 16th Street in Phoenix. In 1989 it was moved again to 1545 West University Drive in Tempe and became the office of the Chief for Hydrologic Data Programs. Edwin McGavock transferred in as an Assistant District Chief and Chief, Hydrologic Data Programs, and Nassar was reassigned to the Hydrologic Data Management and Review Section. Doris Constant served as Secretary for the Phoenix Subdistrict Office until her retirement in 1986 when Cora Louie moved into that position. In 1989 as part of the District reorganization, Thomsen, Schumann, and Baldys were assigned to the Studies and Research Section.

Some of the people who served in the Phoenix Subdistrict Office for all or part of this period as project or data-collection personnel were Bert Thomsen, Robert Laney, Herbert Schumann, Chester Zenone, Lee (Applegate) Raymond, Alex Pupacko, James Brown, Beth Wrege, Leonard Werho, Ronald Stulik, Edward Dennis, Francis Jelinek, Jack Blee, Bobby Wallace, Henry Sanger, Ruth Bellinoff, Wilfred Johnson, David Pawelek, Robert Babenroth, Greg Littin, Harry Sleeper, Roy S. Darnell, Scott Knowles, Shirley Cook, John Gordon, Albert Pendleton, Jeff Phillips, and Kenneth Fossum.

Flagstaff Subdistrict Office. Charles K. Bell was Chief of the Flagstaff office in 1979. The office was located at 2255 N. Gemini Drive in the USGS Field Center. The Flagstaff office was primarily a hydrologic data-collection office with an occasional small project being conducted. Bell transferred to Hawaii in 1980 and George W. Hill replaced Bell as Chief. Hill retired in 1986 and Robert J. Hart was selected to replace Hill. In 1989, as part of the District reorganization, Hart was reassigned to the Studies and Research Section and Donald Bills was put in charge of the Hydrologic Data-Collection Unit. Frank Brewsaugh assumed this position in 1991. Others who served in this office were Eugene Buell, Wilma Smith, Philip Ross, Arthur Geldon, Marlin Whetten, Gary Weesner, John Kuzmiak, Kent Sherman, John Rote, Robert Gauger, John Sottilare, and Curtis Crouch.

Yuma Subdistrict Office. Robert D. Livesay was Chief of the Yuma office in 1979. The office was at 1940 South Third Avenue. Livesay transferred in 1979 and was replaced by Leonard Werho who transferred in from Phoenix. Werho retired in 1983 and was replaced by Howard McCormack who transferred in from Utah. The Yuma office was primarily a Hydrologic Data-Collection Unit with some personnel assigned to the Colorado River Return-Flow Project. Others who were stationed in the Yuma office during this period were Angelo Dalcerro, Thomas Davey, Richard Trenck, William Dorries, William Webb, Rudolph Westphal, Mathew Pierce, William Roberts, David Clay, Ann Gordon, Thomas Hales, David Bivens, Jan Doughman and Kathleen Hansen. Omar Loeltz and Stanley Leake worked on the Colorado River Return-Flow Project from the Yuma Office until

1981 when Loeltz retired and Leake transferred to the Tucson office.

Blythe Field Office. This office was strictly a hydrologic data-collection unit administratively assigned to the Yuma Subdistrict Office. It was located in the Federal Building in Blythe, Calif., until it was closed in 1985. James Watkins, Technician in Charge, retired in 1979 and was replaced by George Scarbrough (retired in 1985). David Bivens was assigned to this office until his transfer to Yuma when the Blythe office closed.

FUNDING AND COOPERATION

Inflation for this time period was slightly in excess of 50 percent. The Federal-State Cooperative (Coop) program and the other Federal agency (OFA) program actually grew beyond the rate of inflation while the Federal (Fed) program decreased when inflation is considered. One of the major reasons that the Coop program growth rate exceeded inflation was the contribution of unmatched funds by cooperating agencies, which increased from $54,000 unmatched in 1979 to a high of $1,284,000 unmatched in 1992. Cooperators supplied over 60 percent of the funding for the Coop program from 1986 to 1994 with a high of 68.9 percent in 1992.

The funding table shows a fairly steady growth rate over each of the fiscal years shown, with the notable exception of the big increase from 1982 to 1983 and the decline in 1984 and the decrease in 1992 from 1991. The significant increase in 1983 (about 37 percent) was due primarily to high startup costs for the Grand Canyon Sediment study, which was new in 1983 and entailed construction of three new gaging stations and cableways in the canyon, and a 1-year increase for the Land Subsidence project. Funding for both of these projects decreased in 1984. Almost all of the reduction in 1992 can be attributed to a drop in funding for the Grand Canyon sediment project.

Long-term cooperation with several of the State agencies, notably the Arizona Department of Water Resources (ADWR), Salt River Project (SRP), and the Arizona Department of Health Services (later the Department of Environmental Quality), continued throughout this entire period. The Bureau of Reclamation (BOR), the Bureau of Indian Affairs (BIA) and the U.S. Army Corps of Engineers (Corps), all of which are Federal agencies, also provided program support for this entire period. Many other Federal, State, and municipal agencies provided program support for various projects during this period

PROGRAM SUMMARY

Hydrologic-Data Collection

Streamflow Stations. A network of surface-water stations was maintained to collect and provide streamflow data needed for assessment of surface-water resources; operating reservoirs for power, flood control, and irrigation; flow forecasting; monitoring of flow for instream-use requirements; water-quality estimates; waste disposal and pollution control; compact and legal requirements; and defining statistical streamflow characteristics needed for research, planning and design of dams, bridges, culverts, canals, flood-management projects, and ground-water recharge facilities. In 1979, the District was operating approximately 140 continuous-record discharge stations, excluding stations on diversions and return flows. Peak-flow data were also being collected at about 70 crest-gage sites.

In support of the Supreme Court Decree of 1964, Arizona v. California, which mandated a determination of consumptive use of Colorado River water, flow data were collected and published at 5 daily

Arizona District funding for fiscal years 1979–94

[Funds, in thousands of dollars]

Fund source	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	1,726	2,321	2,162	2,047	2,099	2,253	2,195	2,240	2,808	3,008	3,031	2,880	3,113	3,403	2,978	3,204
OFA	799	918	798	1,146	2,720	1,771	1,900*	2,096	1,168	1,496	1,681	3,044	3,605	2,762	2,749	2,563
Fed	1,354	1,460	1,574	1,240	1,270*	1,024	1,350*	1,390	1,400	1,320	1,554	1,464	1,284	1,051	1,773	1,464
Total	3,879	4,699	4,534	4,434	6,089*	5,048	5,445*	5,727	5,376	5,824	6,266	7,388	8,002	7,216	7,500	7,231

*Some uncertainty in these numbers.

diversion stations between Davis and Imperial Dams and at 7 daily and 46 monthly diversion and return-flow sites at, and below, Imperial Dam and the International Boundary between Arizona and Mexico. Diversion records were collected at 12 other sites in the State.

Stage, contents, and(or) elevation records were collected and published for 10 lakes and reservoirs during this entire period.

In 1994, the District was operating 117 continuous-record discharge stations and approximately 25 crest-stage gages. The daily diversion and return-flow sites operated for the Supreme Court Decree remained the same as was operated in 1980, but the monthly diversion and return-flow sites had been reduced to 34. Diversion records collected elsewhere in the State had been reduced to five sites. The reduction of monitoring sites was due partly to a reduction in funding from State and Federal agencies and partly to the discovery that streamflow volume for numerous streams having 20 or more years of records could be estimated using statistical comparison with other streamflow records in the same or nearby drainage basins.

The desert Southwest is noted for its localized severe rainstorms, which produce flash floods. Mountainous areas also are subject to heavy rainfall which, combined with snowmelt, can cause severe flooding. Several storms during the period 1978–80 produced record-high peak flows in the Salt, Verde, and Gila River Basins. After the 1978 flooding, a flood-warning network was considered necessary to warn residents in flood-prone areas of possible danger. The Arizona Flood Warning Office in Phoenix was established and was operated jointly by the National Weather Service (NWS) and the ADWR.

To satisfy the need for real-time river-stage data required to make realistic flood forecasts, data-collection platforms utilizing satellite telemetry were installed in 1979 at eight gaging stations in flood-prone drainage basins. By 1983, 66 gaging stations equipped with platforms were operated by the Arizona District in Arizona and western New Mexico. Forty-four of these stations, each transmitting river-stage and rainfall data by satellite telemetry, were in the flood-warning network.

Receiving stream-water-level data by satellite telemetry proved so successful that nearly all of the streamflow stations in Arizona were equipped with a platform by 1994. Computation of daily streamflow records was done by using telemetry data with digital tape recorders providing backup data.

Water-Quality Stations. The surface-water-quality network consisted of approximately 87 stations in 1979, 60 stations during the 1980–83 period and 40 stations from 1984 to 1991; only 26 stations remained in 1994. Water-quality samples were collected at three to nine miscellaneous sites each year. Increasing analytical costs and static funding were primarily responsible for the reduction in the size of the network.

Ground-water-quality sampling at observation wells varied considerably during the period. Approximately 650 wells were sampled in 1979, approximately 750 wells were sampled in 1980–81, and well samples varied from a low of 116 to a high of 345 between 1982 and 1994, with sample numbers for most of these years ranging from 240 to 270.

Ground-Water Observation Wells. Annual measurement of ground-water levels provide a long-term data base that can be used to monitor the general response of the hydrologic system to natural and manmade stresses and can provide a data base against which the short-term records acquired in areal studies can be analyzed.

Before 1987, water levels were measured at approximately 95 observation wells annually. As part of an increase in direct-services credit from the ADWR, the State began monitoring additional wells. The number of measured water levels increased to over 1,000 after 1986. These data were published annually in "Water Resources Data, Arizona."

A map summarizing the ground-water conditions in Arizona was published annually through 1987 (except for 1986). The maps show measured depth to water in selected observation wells, 5-year change in water levels, annual and historical pumpage, and the current status of ground-water inventories. For the calendar years 1985–86 and 1987–90, maps were prepared summarizing only ground-water withdrawals.

Cooperative Ground-Water Basin Studies. This program started in about 1977 with the objective of systematically obtaining detailed ground-water data in 68 basins in the State. The plan was to map the entire State at an equal level of intensity, with same-scale maps being published for each of the basins. The program was conducted as a part of the ground-water basic-data program in cooperation with the ADWR. The entire project was turned over to ADWR in the

mid-1980's as a direct-services program. Personnel involved in this project included T.W. Anderson, S.G. Brown, N.D. White, L.J. Mann, Gary Levings, Chris Farrar, R.L. Laney, B.L. Wallace, David Wilkins, R.P. Wilson, R.S. Stulik, and H.W. Sanger. At least 40 Water-Resources Investigations Open-File Reports (maps) were published.

Water Use. A comprehensive water-use data base is needed to provide (1) data for planners or governmental agencies that need generalized information relating water use to irrigated acreage, ore production, municipal use, and other uses; (2) data with area and temporal detail that can be used to model and evaluate management alternatives; and (3) easy accessibility. Data on ground-water withdrawals and surface-water diversions and return flows were obtained directly from companies or other government agencies whenever possible. Where flow meters were not in use, power records and pump-efficiency data were obtained to compute withdrawal. Richard Wilson and Saed Tadayon worked on this program. A shift in emphasis was made in 1984 when a new State ground-water law required the installation of flow meters in State-designated Active Management Areas and Irrigation Non-Expansion areas. The ADWR provided much of the data through a direct-services program.

Interpretive Studies

Regional Aquifer Studies. The Southwest Alluvial Basin Regional Aquifer-System Analysis was started in 1979. It was part of a nationwide effort to assess the ground-water quantity and quality in regional aquifer systems of the United States. This study included the alluvial basins in south-central Arizona and small parts of adjacent States. The project was completed in 1984, and the last two Professional Papers were published in 1992. Results of the project included publication of 53 reports, journal articles, abstracts, and contractor reports. Major contractor contributions included a map of depth to bedrock, a compilation of data on regional recharge, and a program for analysis of driller's logs. Reports included four Professional Papers, three Hydrologic Atlases, and one book published by the American Water Resources Association. The remainder were chiefly journal articles. Personnel involved in this project include T.W. Anderson, W.R. Meyer, G.W. Freethey, Patrick Tucci, R.L. Fields, D.R. Pool, B.K. Powell, and E.F. Vetter.

Vekol Valley Study. This study was performed in response to Public Law 95–328, which directed the Secretary of the Interior to determine if sufficient ground water was available to deliver water for irrigation to the Ak-Chin Indian Reservation. Richard Wilson made the initial assessment of the hydrologic conditions in the Vekol Valley, the Waterman Wash area, and the Bosque area. Ken Hollett did geologic and geophysical studies in the north and south basins of the Vekol Valley as these areas held more promise than the Waterman Wash or the Bosque area. An extensive array of monitoring wells was installed to monitor the effects of a 30-day, 2,000-gallon-per-minute aquifer test. J.R. Marie was the Project Chief. The study showed an ample supply of water to meet the requirements of the Ak-Chin Tribe, but the well field was not further developed because Central Arizona Project water was made available to the Tribe. The principal products of this study were two reports for the Bureau of Indian Affairs, a Water-Resources Investigations Report, and a Water-Supply Paper.

Land Subsidence and Earth Fissures along Proposed Salt-Gila and Tucson Aqueducts. This project was started in 1977 at the request of the BOR. The purpose was to evaluate the potential for development of earth fissures caused by land subsidence along the path of the Central Arizona Project canal between Phoenix and Tucson. Reflection and refraction geophysical surveys, test drilling, subsurface hydrogeologic mapping, historical water-level declines, and analysis of land surveys were used to accomplish the objective. In crossing Pinal County, where subsidence was widespread and substantial, results of the study were used in locating the canal alignment along the western flank of the Picacho Mountains. R.L. Laney was the initial Project Chief. H.H. Schumann became Project Chief when Laney transferred. B.M. Wrege and B.L. Wallace worked on this project.

Monitoring Land Subsidence and Determining Earth Fissuring Potential in the Tucson Basin. This project was initiated at the request of the City of Tucson. Land is subsiding in many of the alluvial valleys in Arizona because of long-term decline of ground-water levels. In many cases, earth cracks (fissures) occur in or on the fringe of these basins. The City of Tucson is concerned about land subsidence and the resultant damage to structures as well as threats to the water supply of Tucson. A monitoring network was established, subsidence recorders were placed on selected extensometer wells, and second-order land

levels using a globally positioned satellite-surveying system (GPS) were established. Compaction models were used to estimate subsidence. S.R. Anderson was Project Chief.

Lower Colorado River Studies. The Supreme Court Decree of 1964 required an accounting of the consumptive use of Colorado River water—diversion minus return—for each State. This program was begun in the late 1960's as a result of a request by the States of California and Arizona that they be given credit for return flows to the Colorado River. An extensive network of data-collection points was established in the initial phases of this study, led by Omar Loeltz, and a cross-sectional ground-water model was prepared by Stan Leake to simulate observed gradients and calculate subsurface return flows. In the early 1980's, Lee Raymond, with assistance from a visiting scientist from the Peoples Republic of China, developed a means of accurately estimating evapotranspiration (ET) from agricultural lands by using remote-sensing techniques. Larry Mann developed a means of combining the products of the ET study with measured surface flows to obtain estimates of return flows with greater accuracy than the ground-water model approach. This method was used to complete the return-flow estimation from all agricultural lands in the Lower Colorado River valley. This work led to the development of an "Accounting Surface" to identify wells that were withdrawing Colorado River water from the flood-plain aquifer. S.K. Leake, S.J. Owen-Joyce, and R.P. Wilson were also major contributors to this project. Several Water-Resources Investigations Reports and at least two Open-File Reports were published from this project.

Glen Canyon Environmental Study. In 1983, at the request of the BOR, the Arizona District established five streamflow- and sediment-monitoring stations along the Colorado River in its course through the Grand Canyon. The BOR was in the process of uprating all of the turbines at Glen Canyon Dam in order to increase the peaking discharge. The resultant flows through the canyon had the potential to increase beach erosion and channel degradation. The data collected would allow the BOR to refine and expand their sediment-transport model. Three cableways were constructed across the river, and crews to man the stations on a 24-hour-a-day, 7-day-a-week basis were recruited and trained. Initiation of the project was set for June of 1983, but this was delayed by a couple of months due to a major flood on the Colorado River. The first station was at Lees Ferry, and the other four were scattered throughout the Grand Canyon. The raft with one crew and supplies for four stations left Lees Ferry every 10 days. The raft would drop off the crew at the next downstream station along with their supplies for the 10-day period, pick up that crew and drop them off at the next downstream station with more supplies until it reached the most downstream station, where the last crew and all of the sediment samples and streamflow measurements and stage data from all five stations were taken out of the canyon by road. The last crew had a 10-day rest period before starting the next rotation. Larry Mann helped plan and start this project, and he was replaced by Julia Graf in late 1983. In addition to the data collection, studies were done to determine the hydrochemical behavior and the dynamics of the fluid structure of Lake Powell resulting from dam operation and the contribution of sediment by debris flows in canyon tributaries. Another study was done to identify the physical conditions and processes that control sandbar changes along the river in Grand Canyon National Park and to relate the location and magnitude of bar changes to flow in the main channel. A dye study was done to measure the velocity of flow through the canyon at different release rates. Personnel involved in the various studies were Graf, W.B. Garrett, J.C. Schmidt, R.H. Webb, R.P. Wilson and M.C. Carpenter. A Professional Paper, at least two Open-File Reports, and numerous journal articles resulted from this project.

Occurrence and Movement of Radionuclides and Other Trace Elements in the Puerco and Lower Little Colorado River Basins. During a storm in the early 1980's, a tailings pond at a uranium-processing plant overflowed and dumped a large quantity of radioactive contaminants into the Puerco River. The objective of our study was to determine variability of radionuclides and other potentially unsafe trace elements in surface water, ground water, and sediments in and near the Puerco and Little Colorado Rivers and to provide a health-risk assessment associated with use of the regional water resources. Analyses of mine discharges indicated that 300 times more uranium and 6 times more gross-alpha radiation were released by mine dewatering than by the tailings pond spill. J.R. Gray was the initial Project Chief. R.H. Webb, P.C. Van Meter, and Laurie Wirt worked on this project. Two Open-File Reports, one Water-Resources Investigations Report, and numerous journal articles were produced from this project.

Hydrologic Investigation of the Gila River Indian Reservation. Water supplies of the Gila River Indian Reservation are affected by upstream control and diversion of surface water and nearby pumping of ground water. Information on predevelopment hydrologic conditions was necessary to support Indian water-rights claims in Arizona's adjudication of water rights along the Gila River. Data were collected and a steady-state model was constructed. Historical data indicate that the Gila River was perennial in both the eastern and western one-third of the reservation, and aquifers were filled to capacity prior to development by non-Indian settlers. B.W. Thomsen was Project Chief. Eychaner and Baldys also worked on this project. Two Water-Resources Investigations Reports were published.

Hydrology of the Salt River Indian Reservation. Water-rights adjudication for the Gila River will affect water availability for the Salt River Indian Reservation. Verification and documentation of the hydrologic conditions that existed prior to developmental activities are needed to support Indian claims. Data were collected and a steady-state ground-water model was constructed to assist in evaluating predevelopment conditions. B.W. Thomsen was Project Chief. Two Water-Resources Investigations Reports were published.

Movement of Contaminants in Ground Water, Lower Miami Wash and Pinal Creek Basins. An acidic plume of contaminated ground water was discovered in a shallow alluvial aquifer along Miami Wash and Pinal Creek, downstream from a major copper-mining district. The plume had pH values of 3 to 4 and large concentrations of dissolved metals. Flow from the aquifer is forced to the surface at the downstream end of the study area, immediately upstream from a reservoir used for public water supply. Objectives of the study were to (1) determine the extent, hydraulic characteristics, and water budget of the aquifer; (2) determine the extent and chemical characteristics of the contaminant plume; and (3) simulate the flow of ground water and surface water and the transport of chemical constituents through the study area. An estimated date of contaminant breakthrough at the public water supply was needed for planning and possible mitigation measures. Eychaner was Project Chief from 1984 to 1991, then J.G. Brown took over in 1991. Numerous National Research Program investigators were involved in this study. At least two Water-Resources Investigations Reports, four Open-File Reports, and numerous journal articles were produced from this study.

Central Arizona Basins National Water-Quality Assessment Program. This project was begun in 1993 and is a part of an assessment of water quality nationwide. The objectives are to provide a consistent description of current water-quality conditions in the study area, to define long-term trends in water quality, and to identify, describe, and explain, if possible, the major natural and human factors affecting the observed water-quality conditions and trends. G.E. Cordy was the Project Chief. A USGS Fact Sheet was published in 1994.

Indian Reservation Investigations. The District conducted a number of studies for various Indian Tribes during this period. In 1978, the Papago Tribe (later renamed Tohono O'Odham) made plans to develop an agricultural area of about 10,000 to 12,000 acres and was concerned about development in Mexico, some 10 miles south of their proposed development. The ground-water system that would provide the irrigation water was common to both the Mexican development and the Papago Farms area. K.J. Hollett was Project Chief, and J.M. Garrett assisted on this project. An Open-File Report, a Hydrologic Investigations Atlas, and a Water-Supply Paper were published.

A study was begun in 1988 to assist the San Carlos and Fort Apache Indian Tribes in determining the distribution, quality, and quantity of available water resources on their respective Reservations. J.G. Brown was Project Chief with assistance from Baldys. Two Water-Resources Investigations Reports were published. A similar study was begun in 1992 on the Hualapai Indian Reservation. The objectives of this study were to determine the quantity and quality of water available, to evaluate currently defined and potential water resources, and to suggest alternatives for development of their water resources. D.J. Bills was Project Chief of this ongoing study.

Other Investigations. Water-resources appraisal studies were conducted in the Upper Verde River area by G.R. Litten and in the Agua Fria Basin by R.P. Wilson. Population growth in both areas required better definition of the available water resources. The State of Arizona published reports for both studies.

Geohydrologic reconnaissance for the Lake Mead National Recreation Area was completed for seven of nine areas. R.L. Laney was Project Chief for this study, the purpose of which was to aid in the

development of recreational sites along Lake Mead and Lake Mohave. The work was done for the National Park Service. Reports were released as Water-Resources Investigations Reports.

Withdrawal of water from the N aquifer on the Black Mesa to supply a slurry pipeline delivering coal to a powerplant created concerns for the Navajo and Hopi Indian Tribes. Five observation wells were drilled and a monitoring network was established to determine the effects of the withdrawals on the water levels and the chemical quality of the aquifer. Eychaner constructed a ground-water model, later updated by James Brown, to simulate projections of various withdrawal rates from the aquifer. G.W. Hill, R.J. Hart, J.P. Sottilare, G.R. Littin, and others served as Project Chief at various times. Annual data reports were published as well as one Water-Resources Investigations Report and a Water-Supply Paper.

Arizona experienced major flooding along various watercourses in 1977, 1978, 1979, 1983, and 1993. Aldridge and Eychaner published a report on the "Floods of October 1977 in Southern Arizona and March 1978 in Central Arizona" (WSP 2223); Aldridge and Hales published a report on "Floods of November 1978 to March 1979 in Arizona and West-Central New Mexico" (WSP 2241); Hjalmarson published "Flood of October 1983 and History of Flooding along the San Francisco River, Clifton, Arizona" (WRIR 85–4225-B); Roeske, Garrett, and Eychaner published a report "Floods of October 1983 in Southeastern Arizona" (WRIR 85–4225–C); MacNish, Smith, and Goddard published a report "Floods in Arizona, January 1993" (USGS OFR 93–54).

Various water-quality studies were undertaken during this period. A project to evaluate the solute balance and geochemical interactions in Roosevelt Lake was initiated in 1990. Roosevelt Lake is the largest reservoir in a system that provides water for Phoenix, and it is vulnerable to contamination from upstream mining operations. The objective of the study was to evaluate the system and establish a baseline condition. —L.K. Ham, Project Chief.

Signature and mapping of nitrates in ground water in west Salt River Valley, a project to delineate the extent of ground-water contamination and aid in the development of management strategies to deal with the contamination, was initiated in 1990. Geochemical and geostatistical methods were applied. —J.G. Brown, Project Chief.

A geochemical investigation in and near abandoned uranium mines, Cameron and Monument Valley Mining Districts, was initiated in 1991. Uranium was mined in this area from about 1950 to 1969, and the surface pits were not reclaimed. Some filled with water, presenting potential health hazards. An assessment of selected geochemical properties of uranium-mine pit water, nearby shallow ground water, and mine-spoil material will be valuable in assisting the Navajo Nation to reclaim this area properly. —Project Chief, S.A. Longsworth.

A study to determine the chemical characteristics of water in the N aquifer in the Black Mesa area was initiated in 1992. There have been many studies on the geohydrology of the aquifer but none to define the chemistry and geochemical processes that control the aquifer. Purpose of the study was to provide important information about ground-water movement and the response of the aquifer to pumping. —Project Chief, T.J. Lopes.

A study on toxicity and chemistry of urban stormwater and bed material, Maricopa County, was initiated in 1992. Few data exist on toxicity of stormwater in arid regions. These data are needed for establishing standards and regulating the quality of streams in Arizona. The Department of Environmental Quality funded this study. —Project Chief, T.J. Lopes.

OTHER ACTIVITIES

National Water Information System (NWIS) Program. Hydrologic data for the WRD have been stored in several data bases. Newer technology provided for better integration of data through the use of a relational data model. Objective of the project was to provide data-base management for the Ground Water Site Inventory subsystem and aid in planning and design for the new NWIS. Colleen Babcock was the Project Chief and was instrumental in development and implementation of the new NWIS for the WRD. An Open-File Report was published in 1994.

Satellite Telemetry. When satellite telemetry was first installed in 1979 at eight stream-gaging stations, the data were received at a National Weather Service facility in Maryland. Problems in moving these data to Arizona on a real-time basis for flood-warning purposes precipitated the installation of a receive site in Phoenix in 1980. Efforts of John William Henry (Jack) Blee, along with assistance from Headquarters personnel, were instrumental in the

development of near-real-time capability, not just in the Arizona District but throughout the Water Resources Division. Blee designed vandal-resistant installations of antennas and solar panels and developed software to make data-transmission platforms built by different manufacturers look the same for the person servicing the platform in the field. Cooperative funding of the Phoenix receive site was provided by the SRP, the BOR, the Corps, and the ADWR.

CALIFORNIA

By Gilbert L. Bertoldi, *using information provided by* Alan P. Rankin, Robert W. Meyer, *and* Mary Kay Witter, *with special acknowledgment for typing and editing* by D'An M. Brent, *and graphic work by* Cathy M. Munday *and* Jason T. May.

ORGANIZATION AND PERSONNEL

In 1979, the California District consisted of a District Office located at 855 Oak Grove Avenue in Menlo Park. Subdistrict Offices were located in Laguna Niguel, with one Field Office in Santa Barbara; Menlo Park, with Field Offices in Eureka, Salinas, and Santa Rosa; and Sacramento, with Field Offices in Sacramento, Redding, Merced, and Tahoe City. In 1981, a new Field Office was opened in San Bernardino, which reported to the Laguna Niguel Subdistrict. In 1982, another Field Office reporting to the Laguna Niguel Subdistrict was opened at Santee and another in 1983 in Laguna Niguel. In 1982, under the leadership of Timothy J. Durbin, District Headquarters moved to the Sacramento Federal Building at 2800 Cottage Way in Sacramento, and the general organization changed from a District/Subdistrict/Field Office structure to an organization without the duplicative administration of three Subdistricts. The Subdistrict Chiefs were replaced initially by two Assistant District Chiefs, one for Data Operations and one for Investigations. In 1986, a third Assistant District Chief for Internal Operations was added. These positions remained until January 1981, when Peter Anttila (Assistant District Chief for Investigations) transferred to the Western Region and Frank Giesner (Assistant District Chief for Internal Operations) retired. In 1992, four Assistant District Chiefs were established to replace the previous three positions. The position of Assistant District Chief for Internal Operations was abolished, and two Assistant District Chiefs for Projects and Operations (one Northern California, one Southern California) assumed the duties. Under the streamlined organization, the Santa Rosa Field Office moved to Ukiah and the San Bernardino Field Office moved to Redlands, then was closed in 1992. The Santa Barbara and Merced Field Offices were closed by 1994, and part of the operations of each was shifted to the Bakersfield Field Office while other operations were assigned to the Sacramento Field Office.

Staffing of the District in terms of numbers of employees varied in the 1979–94 period from a low of 170 in 1983 to a high of 228 in 1986. The average was about 200 employees per year for the entire period.

District Headquarters

Office of the District Chief

Richard M. Bloyd served as District Chief from 1980 to 1982 when he transferred to the Conservation Division and later to Minerals Management Service. He was replaced by Timothy J. Durbin, who served until 1984 when he left the Survey. Gilbert L. Bertoldi, who was serving as Regional Ground-Water Specialist (Western Region), was appointed District Chief in 1984 and served until 1985. Following Bertoldi were John M. Klein, 1986 through 1992, and Michael V. Shulters, who currently (2001) occupies the office. Assistant District Chiefs, in chronological order, were Loren E. Young, Roy Newcome, Jr., Winchell P. Smith, Andrew M. Spieker, Peter W. Anttila, E. Jerre McClelland, Frank W. Giesner, Anthony Buono, and Frederick J. Heimes.

District Secretaries, in chronological order, were Janet A. Wong, Charlotte Muldoon, Connie J. Handewith, and Eilene L. Porter, who has occupied the position since 1986.

District Administrative Officers, in chronological order, were John L. Lysaught, Randy O. Rodriquez, June E. Cox, Alan P. Rankin, Elaine A. Gockel, David C. Madril, and Jane Edwards. Others who served in the District Administrative Unit were Linda L. Soria, Mary Jane Neal, Rochelle L. Earl, Margaret D. Jones, Silvia Weishaupt, Julie Kindner, Joyclyn Young, Margaret Jones, Eilene L. Porter, Esther Mendez, Leslie Okamura, Debra Arnett, Cynthia S. Morrison, Diane L. Schuermann, Benjamin Weston, Monica Rapp, Elaine Siebert, Connie Jones, Anelia J. Lott, Kay Straw, Lori Bukpitt, David O'Hara,

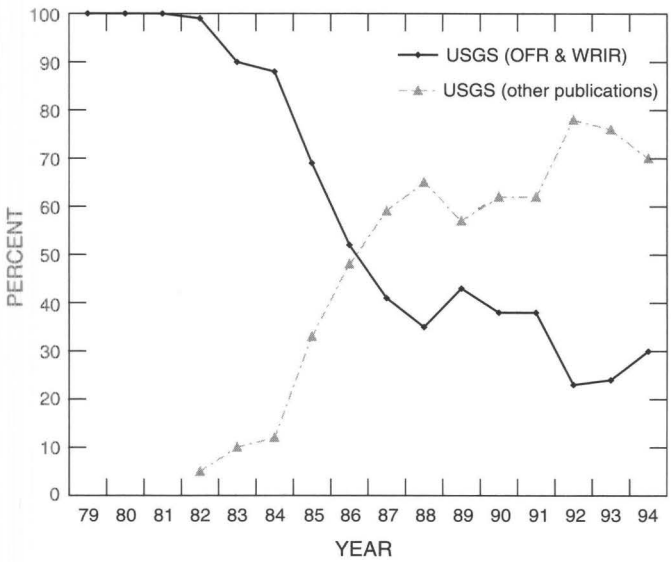
Angela K. Smith, Karyn L. Hill, Andra Parker, Melissa Hankoff, Jean Sullivan, Dorene E. MacCoy, Pete Jackson, Karyn Attelberry, Margaret Trasmundi, Melissa Carlozzi, Carolyn Ho, Patricia Terra, Victoria Hamlin, and Karen Kruen.

The District Publications Unit had a staff of 42 in 1980, but reorganization dispersed some members into project activities and, by change of duty stations, to other Survey divisions. In 1994, due to the aforementioned organizational changes and retirements, the District Publications Unit had only 28 staff members. Ironically, as the staff decreased in size, the workload increased and the nature of the publications changed. As shown on the graph of type of publications as a percentage of total, during the period 1979 through 1983 virtually 100 percent of the annual 25–30 reports were Water-Resources Investigations (WRIR) or Open-File Reports (OFR). At the urging of John Bredehoeft, Western Regional Hydrologist, and District Chief Tim Durbin, the ratio of Professional Papers, Water-Supply Papers, Circulars, Atlases, textbook chapters, Bulletins, and professional journal articles began to increase in comparison to the OFR's and WRIR's. Since the mid-1980's, OFR's and WRIR's have made up well under 50 percent of the average annual output of 60–70 papers. Nancy Ordazzo served as Supervisory Technical Editor and Publications Unit Manager from prior to 1979 until her retirement in 1994. Jerry Woodcox, Technical Publications Editor, was her principal assistant responsible for manuscripts coming from the southern California area. Supervisory Technical Editors were Gertrude Sysak (1978–82), Linda Rogers (1984–93), and Debra A. Grillo (1982–98). Technical Editors during the period were Joy Anderson, Gwen Breland, Myrna Debortoli, Judi DeVarnne, Carol Donovan Sanchez, Jean Lucas, Peter Morse, Randall Schluter, Glen Schwegmann, Virginia Wenslaff, and David Wilson. Editorial Assistants/Editors were James Baker, Susan Davis, and Mary Kay Witter. Editorial Assistants were Carol Griner, Carolyn Hardin, Arlyn Lee, Louise Lucas, Valerie Quinn, Brenda Redfield, Barbara Reese, Michelle Sneed, Marguerite Steven, Barbara Symonds, and Terri Morotto-Williams. Draftsmen/Illustrators were Anna Borlin, Rudolph Contreras, Yvonne Gobert, Beth Gold, Ron Rodgers, Miguel Roque, Monroe E. Royce, Frank Shelton, David Uyematsu, and George Yamamoto.

Although computers had been used in the California District since about 1968, District computer support was a limited operation, with Alfred E. Janssen the first appointed District Computer Specialist in 1974. Each Subdistrict had a computer technician who assisted primarily in automated processing of records and data. However, as the need for more analytical uses of computers demanded individual services and virtually a computer at each desk, a Computer Services Unit was established under the Office of District Chief in 1983, with Jonathan Diamond as the first Chief of the Unit. The Unit continued to grow from a staff of 3 in 1983 to a staff of 10 in 1988, when Daniel J. Gockel reorganized and upgraded the status from a Unit to the Computer Services Section. Gockel was succeeded by William J. Manos in 1992, and the entire Section was placed under the Assistant District Chief for Information Resources. Those who have been members of the staff, in chronological order, are Ann Elliott, M. Kathy Shay, Lois M. Griffin, Karen Poeschel, Erick W. Lorenz, Patricia D. McBride, David K. Yancey, Bryce P. Jacobs, Judith Ward, Daranee B. Lee, Scott I. McFarlane, Bernard J. McNamara, Jeff Puckett, Tom W. Cutter, Michael DeGrand, and Said H. Mirzad.

During the 1979–94 period, several major Federal programs were administered directly by the District Chief's staff. From 1979 through 1983, the Central Valley Aquifer Project (CVAP), one of the first three Regional Aquifer-System Analysis (RASA) studies, was conducted. CVAP staff were Bertoldi (Chief), Lindsay A. Swain, Ronald Fogelman, Durl E. Burkham, Ronald W. Page, Alex K. Williamson, Mark E. Schaal, Margaret Farmer, Larry Hull, Jonathan W. Diamond, Elizabeth Silver, Lori Larragueta, and Paul Nady.

In 1984, mutated waterfowl hatchlings were found in a Bureau of Reclamation (BOR) reservoir used to hold agricultural drain water from the westside farms in the Central Valley. The mutating agent was believed to be the abnormally elevated concentrations of selenium present naturally in the previously non-irrigated soils of the area. This ecological problem brought members of the District into a multiagency scientific advisory committee. The District Chief directly supervised the Survey component. In 1985, the breadth of technical work became so large that an entire new studies unit was established under the Office of the District Chief. Robert J. Gilliom was appointed Chief of the San Joaquin Valley Studies Unit and served in that capacity until 1991 when funding ended. In 1987, as a part of the selenium



monitoring program, Marvin Yates (USGS) was selected as a Survey employee to head the BOR selenium laboratory in Sacramento. Others who served in the study unit were Walter Swain, Steven J. Deverel, Roger Fujii, Neil M. Dubrovsky, Joseph L. Domagalski, John M. Neil, John L. Fio, Steven P. Phillips, Larry R. Shelton, Sherrill L. Beard, James E. Fairchild, Lenore A. Donovan, and Sylvia V. Stork. As an outgrowth of the selenium studies and the initiation and implementation of the National Water-Quality Assessment (NAWQA) Program, the nationwide NAWQA Synthesis Program was established and housed in the California District Office. Five members of the San Joaquin Study Unit moved into positions on this program, and Robert Gilliom was appointed its Chief.

Hydrologic Surveillance (Data) Section

Prior to 1982, there was no formally identified "Data Section" at District Headquarters. California, having some Subdistricts larger than many Districts, chose to vest quality control and technical support for data at the Subdistrict level. Final review of data records for the annual data report was done by senior hydrologists and the surface-water specialists stationed at the District Office. Responsibility for editorial quality control of the annual reports prior to 1984 was vested in a small group of support people headed by Adelaide L. Davis. This group was actually a part of the Sacramento Subdistrict, but did final copy and other editorial work on annual data reports for several smaller Districts. In addition to Davis, others who made up the group were Linda R. Zeitz, Debra Grillo, and Sally E. Walker.

By 1982, a need for more direct control over the quality of data field operations was perceived by the District Chief. To accomplish this, northern, southern, and coastal California hydrologic data sections were established. Organizationally, each data section was composed of a Supervisory Hydrologist and one or two technical support people plus all the Field Offices within the designated area. Chiefs of the hydrologic data sections for 1983–85 were Edward J. Jones (northern California), Robert J. Longfield (southern California), and Kenneth W. Lee (coastal California); others who served at the District level were Joe N. Robles, John R. Beck, Stuart H. Hoffard, Rick T. Iwatsubo, and Verrie F. Pearce. In 1985, the Hydrologic Data Section was again reorganized into one District Headquarters Unit with two small technical services units (Sacramento and San Diego), a Data Base Management Unit, and a Quality Assurance Unit. Members who served in these Units but were not previously acknowledged are Lisa Lindberg, Joel D. Johnson, Gail L. Keeter, Marilyn R. Manley, Ronald P. Fogelman, Charles E. Lamb, John S. Bader, Michael T. Butcher, Richard A. Hunrichs, James M. Knott, Robert W. Meyer, and Anne G. Wells.

Hydrologic Investigations (Studies/Projects) Section

During the 1979–94 period, 220 people worked at one time or another in what collectively were identified as Hydrologic Investigations Sections, located in three Subdistrict Offices. Section Chiefs were William F. Hardt, Peter W. Anttila, Stewart H. Hoffard, Jay Akers, Michael V. Shulters, Greg C. Lines, Gilbert L. Bertoldi, Kenneth J. Hollett, and Dennis A. Wentz. Other personnel who served in the Investigations Sections were Ann Elliott, Mark W. Busby, Lawrence A. Eccles, James J. French, Jack H. Koehler, Anthony Buono, Peter Martin, William R. Moyle, James G. Setmire, John R. Freckleton, Christopher E. McConaughy, Charles E. Berenbrock, Paul Lipinski, David Frewald, Linda R. Woolfenden, James C. Blodgett, Clark J. Londquist, Hugh T. Mitten, Richard N. Oltmann, Dallas Childers, Steven A. Rettig, Michael J. Pierce, Lowell Duell, Kathryn Kuivila, Stephen K. Sorenson, Richard Ireland, William E. Templin, Willie B. Kinsey, Durl E. Burkham, Ronald W. Page, Alex K. Williamson, Ronald P. Fogelman, Margaret H. Farmer,

Marguerite Steven, John A. Izbicki, Barbara Symonds, Glen W. Kapple, Michael J. Johnson, Marc A. Sylvester, Christopher D. Farrar, Scott N. Hamlin, Rick T. Iwatsubo, Patricia Cascos, Wesley R. Danskin, Roy L. Glass, Diane Van Schoten, Edith McQuivey, Maura A. Miller, Mary O. Regan, Patricia Showalter, Lari Lopp, Kennth S. Muir, Timothy G. Rowe, Benjamin Weston, Karen L. Johnson, Walter Rast, Michael K. Nolan, Donna Marron, Stewart Rojstaczer, Leslie M. Okamura, Theodore Hromadha, Lawrence Smith, Karen Poeschel, Robert J. Gilliom, Steven J. Deverel, Roger Fujii, Richard J. Mandle, John M. Neil, Peter E. Smith, Peter D. Dileanis, Joel R. Guay, Jerry G. Harmon, Thomas J. Suk, Eugene B. Yates, William F. McCaffery, John T. Thornton, Mary A. Chanasee, Naferah A. Mustafu, Brian T. Yost, Erick N. Coleman, Gary L. Guzman, Kenneth R. Belitz, Michael R. Welsch, Carolyn L. Walti, Stephen P. Millard, Julie Laudon, John L. Fio, Daphne G. Clifton, Larry R. Shelton, Steven K. Gallanthine, Lynn Miller, David M. Sparks, Suzanne M. Makita-Iwatsubo, Sherrill L. Beard, Eric D. Kieselback, Ellen McCreary, Mary C. Walker, Herbert F. Berton, Lenore A. Donovan, Roy A. Schroeder, Anne C. Steinemann, Daniel J. Bright, Julia A. Schulenburg, Frederick J. Heimes, James W. Borchers, Verne L. Gamble, Marcus J. Taylor, Diane M. Nash, Richard M. Adorador, Jean F. Lucas, Irene Yamashita, Petrina Plies, Dorothy Blackstock, Teresa E. Fong, Jennifer Thornburg, Lisa McCann, Tom C. Haltom, Lawrence H. Zenky, Christina L. Stamos, Joseph L. Domagalski, Francis A. Huber, Sylvia V. Stork, Barry R. Hill, Marti E. Ikehara, Christine A. Massey, Kathryn M. Von Koynenburg, Sharon Douglas, Diane L. Stagner, Dean T. Brightman, Steve J. Williams, Karite Ahklong, M.J. Umari, DeJuan Williams, David B. Nash, John R. Burau, Terry F. Rees, Ronald G. Fay, Kathryn L. Crepeau, Ann T. Dickson, Edmond M. Lucas, Dorene E. MacCoy, Diane L. Rewis, Teresa M. Templin, Eric Reichard, Daniel E. Cherry, Barton G. Presley, Victoria K. Hamlin, Kelli J. Noteman, Tracy Nishikawa, Anne T. Chalmers, Susan M. Bird, Barry D. Kerr, Gregory F. Hodson, Loren E. Metzger, Kelly P. McPherson, Jennifer L. Shelton, Yvonne Leung, Mark G. Brushkiewiecz, Dwight D. Copeland, Jessica L. Ollerton, Ruth M. Boynton, Larry R. Brown, Mark D. Weegar, Mike S. Majewski, Larry R. Shelton, Paul M. Barlow, Charles N. Alpers, Alan W. Stroppini, Bronwen Wang, Lawrence Freeman, Darnella M. Murphy, Michael Hunerlach, Dawn Anderson, Daria Labrie, Collette A. Mrozek, Barbara Oxnam, Teresa Rogers, John M. Donovan, D'An M. Thompson, Cathy Munday, Jim DeRose, Bryan Jennings, David Baston, Dina Kadhim, Karen Burow, Sandra Panshin, Barbara J. Dawson, Robert Anders, Qui K. Troung, Katherine Shipke, Catherine M. Koczot, Gregory Mendez, Brian Grasoux, and Dennis Clark.

Subdistricts and Field Headquarters

As the 1979–94 period began, the California District had Subdistrict Offices in Menlo Park, Sacramento, and Laguna Niguel, each being an administrative structural microcosm of the District. By 1983, the Subdistricts were restructured into a northern California operations office and a southern California operations office. Each office had a Hydrologic Investigations (Project) Section and a Data Section. Field Headquarters were answerable to the Chief of the Data Unit of the respective operations office having geographic coverage. After 1985, all Field Headquarters reported to the Chief of Data Operations in Sacramento. Throughout the 1979–94 period, Field Headquarters locations were infrequently changed so that most Field Headquarters remained in the same geographic site for the entire period. The exceptions will be noted in the individual histories below.

Menlo Park Subdistrict and Associated Field Headquarters

In 1979, the office was located at 855 Oak Grove Avenue in Menlo Park. The Subdistrict occupied a complex of privately owned professional buildings along with the District Office until 1982 when the office was disbanded and absorbed into the northern California operations office. Charles W. Boning served as Subdistrict Chief until 1981, at which time he was appointed District Chief of Texas. Stewart H. Hoffard succeeded Boning and remained Subdistrict Chief until the Subdistrict was reorganized and absorbed into the Northern District operations in 1982–83. Others who served in the Subdistrict Office were Carolyn J. Reeves, Jacqueline Hamilton, Katherine McLaughlin, Amy Mohler, DeAnn Jones, Kenneth W. Lee, Joe N. Robles, John Limerinos, Lucile Coleman, John R. Beck, Larry Trujillo, Michael J. Dai, Addie L. Seacer, Maxine F. Brody, and 17 others previously acknowledged in the discussion of the District Hydrologic Investigations Section.

Eureka Field Headquarters

Located at 1105 Sixth Street in Eureka. Technicians-in-Charge during the period were Gerald W. LaRue (1979–81), Malcolm W. Weston (1981–83), Steven W. Anderson (1983–88), and John R. Palmer (1988–94). The Eureka Field Headquarters was closed and its operational functions were absorbed into the Ukiah Field Headquarters at the end of 1994. Personnel who served in the Eureka Field Headquarters during the 1979–94 period were Patrick L. Dugle, Trudy L. Dorsey, Gregory F. Susich, Barry R. Hill, Larry F. Hudspeth, Michael McFadden, Lawrence A. Freeman, William J. Hardy, and George E. Zenk.

Santa Rosa Field Headquarters

Located at 3900 Finley Avenue in Santa Rosa. Technicians-in-Charge during the period were Eugene J. LaCorneu (1979–82) and Kenneth L. Markham (1982–92). The Santa Rosa Field Headquarters closed in 1992. Operations merged with the Eureka Field Headquarters and relocated to Ukiah. Personnel serving in the Santa Rosa Field Headquarters were Michael R. Simpson, Dorothy Narducci, Walter L. Kearns, Karl K. Lee, Michael D. Webster, James J. Gibbons, Linda Thurston, Jon C. McNulty, Christopher D. Farrar, Jennifer L. Elliott, Delores M. Fussy, David M. Sparks, and Kathleen L. St. Clair.

Salinas Field Headquarters

Located in the U.S. Department of Agriculture (USDA) complex at 1636 E. Alisal Street, Building 17A, Salinas. Technicians-in-Charge during the period were Vincent Piro (1979–86) and Larry F. Trujillo (1986–97). Personnel who served in the Salinas Field Headquarters were Carlyle T. Peck, Wendell Ayers, Gerald Rich, Carol F. Hawkins, Fred Hayden, Laura Devens, Peter D. Dileanis, William R. Brazelton, Traci A. Holden, Gayle A. Croley, Teresa Deuchweiler, David B. Dale, Glen M. Luscombe, Sharon F. Guieb, Charles E. Nahn, Orlynn Haakedahl, William G. Hardy, Ernest R. Houston, Jerry L. Sinclair, Kathleen L. Wells, and Eduardo Marquez. Prior to 1984, the District sediment laboratory was housed in the Sacramento District Office, where Leroy Gamble was Technician-in-Charge. Wayne Steuben and Teresa Templin assisted Gamble. In 1984, the laboratory was moved from District Headquarters in Sacramento to the USDA complex in Salinas and was placed under the administrative control of the Technician-in-Charge of the Salinas Field Headquarters. Those serving in the sediment laboratory in Salinas were Allan C. Mlodnosky, Cathy A. Figuli, Judith A. Segundo, Jeffery P. Ennis, Roberto S. Reterio, Faith L. Beattle, Robert Reyes, and Freddie Aldana.

Laguna Niguel Subdistrict and Associated Field Headquarters

Located in the Chet Holifield Federal Building, 2400 Avila Road in Laguna Niguel. It remained a Subdistrict Office until 1983 when it became a project office reporting to the Assistant District Chief for southern California operations. Darwin Knochenmus served as Subdistrict Chief from prior to 1979 until the 1983 reorganization, at which time he was appointed District Chief of Louisiana. Others who served in the Laguna Niguel Subdistrict were previously acknowledged in the discussion of the Hydrologic Investigations Units.

Santa Barbara Field Headquarters

Located at 126 West Figueroa Street in Santa Barbara until 1989, when it was closed and personnel were assigned to other offices. Technicians-in-Charge during the period were John A. Singer (1979–84) and Keith Polinoski (1984–89). Others who served in Santa Barbara were Jacob Sarkin, Floyd Lee, Thomas G. Kane, Suzanne G. Pompe, Gregg Ikehara, James Van Maanan, Colleen Kegg, Keith I. Kelson, Kellen L. Soifer, David W. Sheets, David K. Yancey, Mary L. King, Scott B. Vincent, Jefferey Tolhurst, Albert L. Pendleton, Julie A. Cerne, and Gregory W. James.

San Bernardino/Redlands Field Headquarters

Began operations in 1980 at 1350 South E Street in San Bernardino and remained there until 1988 when the operation moved to 10421 Corporate Drive in Redlands. In 1991, the Redlands Field Headquarters closed. James C. Bowers was the only Technician-in-Charge for the entire period. Others who served in the San Bernardino/Redlands office were John J. Hanneman, Frank A. Carson, Allan D. Flowers, Jeffrey Agajanian, Joel D. Lowe, James D. Lowe, Sue MacKimmie, W.H. Vandenbergh, Jerry T. Braden, Kay L. Spiegel, John McGreavy, Peter J. Armstrong, Michael Wulfeck, James Durkin, Joanna M. Combs, Bradley E. Mayo, Michael J. Degrand, Kenneth N. Nelson, and Phillip B. Scott.

Santee Field Headquarters

Established in 1982 at 10130 Mission Gorge Road in Santee. Technicians-in-Charge were Bryant G. Smith (1982–89), Randy J. Jensen (1989–90), Paul D. Hayes (1990–93), and Jeffrey Agajanian (1993–94). Others who served in the Santee Field Headquarters were John J. Janssen, Ronald G. Fay, Linda R. Woolfenden, Paula J. Smith, Larry A. Caldwell, Louis A. Caldwell, Gregory Schenework, Linda Thurston, Orlynn K. Perez, Robin D. Meeter, William A. Soucie, Clinton D. Nagel, Michael Smith, and Gary Maxwell.

Laguna Niguel Field Headquarters

Established in 1983, the Field Headquarters occupied the Chet Holifield Federal Building along with the office of southern California operations. Charles E. Lamb served as Technician-in-Charge until 1986 when he was succeeded by Christopher E. McConaughy. McConaughy served until 1988 when this office was closed. Others who served in the Laguna Niguel Field Office were Daniel J. Downing, Florence M. Glenn, Dorothy E. Maltby, Karen T. Downing, Patricia B. Sharake, and John D. Conners.

Bakersfield Field Headquarters

Established in 1989 and located at 3159 Pegasus Drive in Bakersfield. Technicians-in-Charge were Eugene B. Hoffmann (1989–93) and Paul D. Hayes (1993–99). Others who served in the Bakersfield office were Barbara L. Machado, Paul A. Buchanan, Harold J. McIntyre, Robert E. Dean, Alan D. Minear, Nicole A. Norkoski, Stuart A. Hill, F.F. Young, Robert Taylor, Ernest R. Houston, and Michael Kuster.

Sacramento Subdistrict and Associated Field Headquarters

Located in the Federal Building at 2800 Cottage Way in Sacramento. Subdistrict Chief at the beginning of the period was E.J. McClelland (1979–83). In 1983 the operational duties of the Subdistrict were combined with those of the Menlo Park Subdistrict and transferred to the northern California operations section of the District. During the 1979–83 period, the following served in various capacities in the Subdistrict: John Duensing, Verrie F. Pearce, Jay R. Foulk, Verne L. Gamble, Gordon F. Lokke, Richard N. Oltmann, Dallas A. Childers, Gary H. Rood, Byron Lawrence, Wayne Steuben, Donald E. Underwood, Ronald P. Fogelman, Jerry G. Harmon, William E. Faulkender, Robert L. Arens, Richard L. Peterson, Willie B. Kinsey, Randall Abbott, Richard M. Adorador, and 23 others previously acknowledged in the discussion of the office of District Chief.

Merced Field Headquarters

Located in a private office complex at 1547 Yosemite Parkway in Merced until it closed in 1991. Thomas C. Hunter was the Technician-in-Charge for the entire period. Others who served in the Merced Field Headquarters were Jon C. McNulty, Allan J. Asquith, Robert H. Taylor, Dolores Dare, Robert D. Harvey, Henry C. French, Geraldine Block, Gary Maxwell, Michael Dai, Sonya A. Petty, Ellen Busch, Jerry R. Smithson, Jeffrey B. West, Martin E. Genrich, Douglas N. Ufkes, Geraldine A. Martinez, Linda D. Miller, and Michael D. Lee.

Tahoe City Field Headquarters

Located at 605 Westlake Boulevard in Tahoe City until 1993, when it relocated to 5229 North Lake Boulevard, Carnelian Bay. James R. Mullen was the Office Chief until the 1993 relocation when Gerald R. Rockwell succeeded him. Those serving in the Tahoe/Carnelian Bay Field Headquarters were James L. VanMaanen, Barbara VanUmmersen, Lowell W. Duell, Diane Nork, Denis J. O'Halloran, James A. Howle, Robert E. Schumacher, Marcia S. Sands, Jack C. Sengbusch, Carol J. Simons, Dave Carlson, and Paul Honeywell.

Redding Field Headquarters

Located at 640 Twin View Road in Redding until 1988 when it relocated to 11075 Black Marble Way, also in Redding. Wallace F. Shelton was Technician-in-Charge until 1991 when he retired and was succeeded by Michael F. Friebel. Employees serving in the Redding Field Headquarters were Malcolm W. Weston, Gary W. Moeckli, Christine S. O'Neil, Lee A. Price, Wallace A. Wallgren, Nadine P. Hutton, George E. Zink, and Terry Gordon.

Sacramento Field Headquarters

The Sacramento Field Headquarters was housed in the Federal Building at 2800 Cottage Way, Sacramento, until 1994 when it moved to 3419–A Arden

Way. At various times, the Sacramento Field Headquarters was otherwise identified as the "Sacramento Data Section of the Sacramento Subdistrict" (1979–82), or the "Surface Water Unit of the Sacramento office of northern California operations" (1982–84). Regardless of its name, the field operations remained the same throughout the 1979–94 period. Hydrologists-in-Charge of the Sacramento Data Section/Field Headquarters were John Duensing (1979), Edward J. Jones (1980–83), Robert G. Simpson (1983–88), and Steven W. Anderson (1988–99). Others who served in the Sacramento Field Headquarters/Data Unit were Rod Lindberg, Timothy G. Rowe, Lisa Wulfert, Thomas Hankins, William E. Faulkender, Rob L. Johnson, Anne Wells, Wallace A. Wallgren, William J. Hardy, Mark H. Woloszyk, Laureen J. Fong-Frydendal, Jeffrey P. Ennis, Paul Buchanan, and Dave Sparks.

FUNDING AND COOPERATION

As shown in the table of funds, funding for the District increased from about $9.1 million in 1979 to nearly $20 million in 1994. With the exception of 3 years—1981, 1982, 1986—total funding mostly kept pace with inflation. The other Federal agencies (OFA) program increased substantially (about $2.5 million) in 1985 and ranged (except in 1986) from 32 to 44 percent of the total program from 1985 to 1991. The increase in OFA funding was supported primarily by money from the Bureau of Reclamation for studies of the effects of selenium-tainted agricultural drain water on the west side of the San Joaquin Valley. Other major OFA funding came from the U.S. Air Force for land subsidence and water use studies at Edwards Air Force Base and for toxic-cleanup oversight studies on six major military sites.

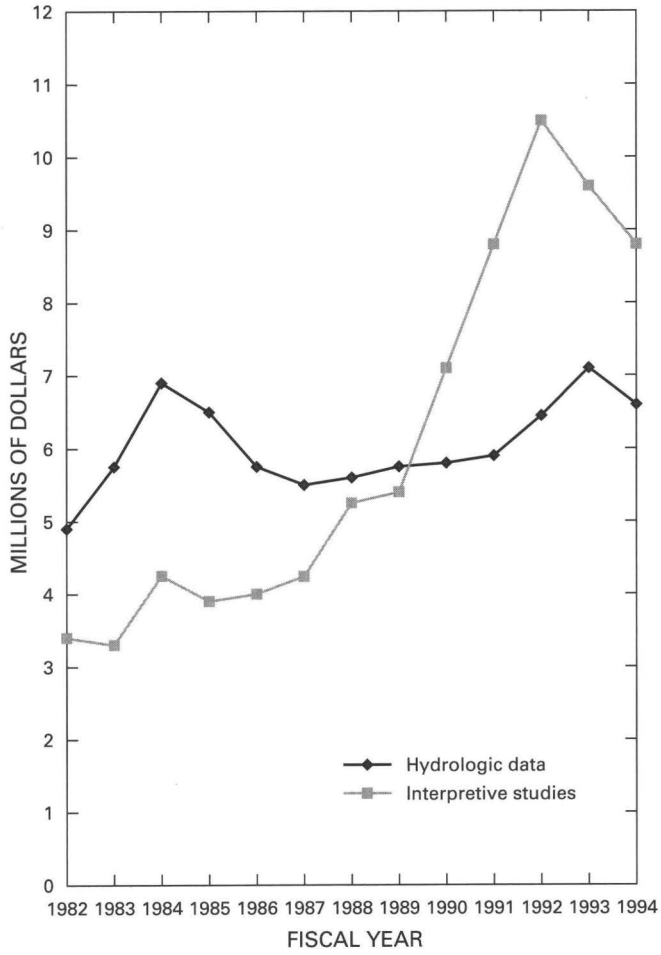
Funding in the Federal program remained fairly constant from 1979 to 1990, supported mostly by RASA studies, collection of basic records, and one National Water-Quality Assessment (NAWQA) study. In 1991, two new NAWQA studies caused a substantial upswing in Federal funding that continued to increase through 1994.

California District funds, fiscal years 1979–94
Source: District program documents for periods 1983–85; Administrative Information Systems records for 1979–82 and 1986–94

[OFA, other Federal agency; funds in thousands of dollars]

Fiscal year	Federal	OFA	State	Federal matching funds	Total
1979	1,549	1,663	3,051	2,865	9,128
1980	1,535	2,210	2,830	2,752	9,328
1981	1,162	1,773	2,952	2,823	8,711
1982	762	1,732	3,024	2,885	8,404
1983	853	2,396	2,995	2,860	9,103
1984	1,476	3,155	3,350	3,136	11,117
1985	997	5,693	3,239	2,972	12,901
1986	1,088	2,924	3,374	2,963	10,349
1987	1,022	4,324	3,746	3,281	12,373
1988	910	5,410	3,986	3,442	13,748
1989	988	5,314	4,321	3,386	14,009
1990	1,274	4,564	4,741	3,690	14,269
1991	2,933	3,498	4,865	3,800	15,097
1992	4,062	3,420	6,034	3,765	17,280
1993	4,023	4,765	5,890	3,891	18,569
1994	4,949	5,068	5,952	4,001	19,969

CALIFORNIA DISTRICT FUNDING BY PROGRAM ACTIVITY
Fiscal Years 1982 to 1994



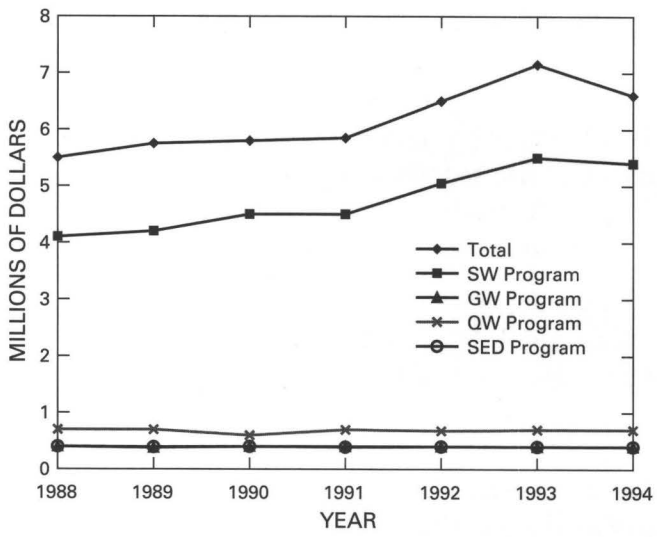
The Federal-State Cooperative (Coop) program in proportion to the total District program ranged from a high of 70 percent of total funding in 1982 to a low of 49 percent of total funding in 1994. Federal matching funds adjusted for inflation decreased by about $1.5 million during the 16-year period (1979–94). This decline could have been greater if the District had not been successful in the Division's merit competition that started in 1983 and ended in 1995. Adjusted cooperator matching funds, however, remained nearly constant. Long-term cooperative programs such as the San Francisco Bay Hydrodynamics, Subsidence in the San Joaquin–Sacramento Delta, and the Oxnard Salt Water Intrusion, were funded with the California Department of Water Resources (DWR), California State Water Resources Control Board, California Department of Transportation, California Department of Pesticide Regulation, two Indian tribes, and more than 50 local, county, or municipal water agencies.

SUMMARY OF PROGRAMS

Hydrologic Data Collection

If one divides scientific activities into two simple categories, "Hydrologic Data Collection" and "Interpretive Studies," and maintains that "never the twain shall meet," one can draw inference of the relative size and activity between these two categories. The graph of "California District funding by program activity" shows that, in terms of dollars, the hydrologic data activity demanded a major portion of the total District budget, as compared to interpretive studies, until about 1989. Since that time a reduction in surface-water data collection and a major demand for systematic analytical scientific reports has caused the "flip-flop" relation shown on the graph. A second graph, "California District funding distribution of data programs by funding source," shows the distribution of funds among the four data programs during the 1988–94 period. It is interesting to note the steady position of the ground-water (GW), sediment, and quality of water (QW) elements of the data program. In the period 1991–94, a rise in dollars expended for collection of data actually resulted from specialized data collection done during the course of interpretive studies rather than from planned data collection.

CALIFORNIA DISTRICT FUNDING DISTRIBUTION OF DATA PROGRAMS BY FUNDING SOURCE



Streamflow Stations

Since the completion of the construction of the physical facilities of the California Water Plan and the Central Valley Project in the late 1960's and early 1970's, the demand for streamflow data has declined. In 1966, there were about 900 continuous-recording streamflow-measuring stations in California. In 1979, that number had been reduced to about 700. This reduction was due in large part to a combination of factors, among them inflation, demand for data, and reduced State funds. The number of continuous-recording stations continued to decline until 1987 when there were approximately 460 statewide. However, following 1987, the number of stations increased. In 1994, there were about 580 stations.

During the period of decline in the number of continuous-recording stations, the number of records from streamflow-monitoring stations furnished by other agencies, such as Federal Energy Regulatory Commission (FERC), California DWR, and the BOR, was increasing. In 1994, approximately 200 furnished records were reviewed and published.

Beginning in 1984 under the leadership of E.J. McClelland (then Assistant District Chief), a program was developed to upgrade the full performance levels of Field Office Chiefs from GS–11 to GS–12; in order to do so, it was necessary to increase the duties and level of technical responsibility as defined in the Field Office Chief position. A major addition to the position description was the responsibility for the technical quality of surface-water records both in their area of responsibility and when required in other areas of the

State. Another increased responsibility was that the Field Office Chief became the point-of-contact and chief program negotiator with Field Office cooperators. Individual office chiefs were promoted (the first being Shelton in Redding) beginning in 1985 and continuing through 1994 until responsibility for the quality of surface-water records in the California District had been placed on the Field Headquarters Chief. All Field Headquarters were equipped with state-of-the-art computers and automated streamflow software.

Ground-Water Data

Historically (1966), more than 1,000 ground-water data sites were listed in the annual data report. At the beginning of the 1979–94 period, the annual report listed fewer than 500 sites. Although the number of observation wells in the statewide network declined to fewer than 500 sites, there was a continuous rise in numbers of water levels (both those furnished by other agencies and those monitored by the USGS) published until by 1985 about 1,000 water levels were reported in the annual data report of the District. From 1985 to 1994, the number of water levels reported remained fairly constant between 950 and 1,200 per year.

A shifting emphasis toward acceptance of "other agency" data and a reliance on digital models as a source of "synthesized" data contributed to a reduction of the statewide network of wells early in the 1970's. Ironically, in the latter part of the 1970's, ground-water modelers reported a woeful lack of data on ground-water pumpage. In 1977, a large cooperative program with the California Department of Water Resources launched the most comprehensive pumpage evaluation program ever undertaken in California. By 1984, the program (headed by Hugh T. Mitten) was evaluating about 2 million annual power-use records of nearly 100,000 water wells pumping between 9 million and 11 million acre-feet of water per year. These data were published in numerous individual Open-File Reports by ground-water basin. In addition to the observation-well network, invaluable ground-water information was collected and entered into the National Ground-Water Site Inventory (GWSI) system, as a part of interpretive studies done from 1979 to 1994.

Water-Quality Data

Water-quality data were published under three general headings in the District's annual data report: surface-water quality, ground-water quality, and sediment. The number of surface-water-quality stations remained relatively constant through the 1979–94 period (about 65); approximately one-half were daily stations and one-half were periodic. In addition, about 20 National Stream-Quality Accounting Network (NASQAN) stations (the number varies ±1 depending on the year) were sampled for chemical-quality components.

The number of ground-water-quality sites and published data remained relatively constant for the 1979–94 period at about 350–380 records per year. Non-network sites, those furnishing data from special projects or from the NAWQA Program, added an additional 75–100 records per year from 1990 to 1994. Topical water-quality data were collected in special projects; for example, selenium, carbon, and pesticide data were collected at the rate of 75–80 sites per year from 1984 to 1992. As with ground-water-quality data, the statewide sediment-data network remained stable during the 1979–94 period. Suspended sediment was measured at 15 ±1 daily stations and 21 ±1 periodic stations. In addition, 14 daily and 9 periodic site measurements were made at NASQAN and hydrologic benchmark stations.

Water-Use Data

California has the largest volume of offstream water use in the Nation. For the past 40 years, the State has consistently withdrawn more ground water and surface water than any other State. Long before the 1977 Congressional Act establishing the National Water-Use Information Program (NWUIP), the California District in cooperation with the California DWR had established a program that, at first, evaluated crop irrigation and pumpage information. The NWUIP now annually collects, categorizes, and stores water-use information in the following subject areas: agricultural nonirrigation, commercial, domestic, industrial, irrigation, mining, power generation, fossil fuel, geothermal, hydroelectric, nuclear, sewage treatment, and water supply.

Interpretive Studies

Cooperative Ground-Water Studies

Ground-water basins in California have been studied by the USGS for over 100 years, beginning with the first irrigation census completed between 1889 and 1904. In much of southern California and the Central Valley, the abundance of historical ground-water data has allowed investigators to build elaborate digital computer models for precise quantification of water availability, quality, and ultimate proper management of the resources. Continuing ground-water studies, from which digital flow models were built during the 1979–94 period, were done by Roy Schroeder (Indian Wells and China Lake Naval Weapons Station), John R. Freckleton (City of Santa Barbara), Dan Bright (Santa Ynez River Water Conservation District), Wesley Danskin (San Bernardino Valley Municipal Water District; Owens Valley), Linda Woolfenden (Rialto-Colton Basins), Greg Lines (Mojave River Basin), Clark Londquist (Madera County Ground-Water Flow Model), Gus Yates (Ground Water in the Salinas Valley), Hugh T. Mitten (Fresno County 3-D Flow Model), and Michael Johnson (Pajaro Valley Ground-Water Flow Model). In addition to flow models, Danskin produced an economic optimization model for the City of San Bernardino, Schroeder was able to complete a solute-transport model for the Indian Wells area, and Lines used digital techniques to examine interchange of surface water and ground water in the Mojave River Basin.

Other ground-water investigations were made by Peter Martin (U.S. Marine Corps Air-Ground Combat Center, Twenty-Nine Palms), John L. Fio (Menlo Park-Atherton area), Charles N. Alpers (Penn Mine), James Borchers (Wawona area of Yosemite National Park), Charles Kaehler (Wolf Valley, Pechanga Indian Reservation), Berenbrock (Vandenberg Air Force Base), Gregory C. Lines (Water Resources of Indian Reservations – statewide), Peter Anttila (Ground-Water Recharge in Fresno County), Charles Kaehler (Fractured-Rock Aquifer Study), Christopher Farrar (Ground-Water Resources of Mendocino County), Kenneth J. Hollett (Owens Valley), and K.D. Evenson (San Diego Wastewater Reuse).

Cooperative Surface-Water Studies

Changes in watershed runoff characteristics are continually recurring, especially in the desert alluvial basins and along the major rivers in the Central Valley. During the 1979–94 period, James C. Blodgett (Sacramento Riverbed-Scour Relationship; Antelope Valley Rainfall Runoff), Joel R. Guay (Changes in Runoff in Perris Valley, Riverside County), Jerry G. Harmon (Flood Hydrology of Butte Basin), and Alan Stroppini (California Military Bases Storm Runoff Project – statewide) provided valuable process information that has been used to develop civil engineering controls preventing damage in the studied areas. Other major surface-water studies were by Patricia Showalter (Characteristics of Selected Lakes and Reservoirs), James C. Blodgett (Characteristics of Flooding and Channel Changes of the Sacramento River; Hydrologic Hazard Assessment for Mount Shasta Area; Design Practices for Riprap Protection of Highway Crossings; Streamflow and Geomorphic Changes of Cottonwood Creek), Richard N. Oltmann (Computer Model for Computation of Tidal River Discharge), Donna C. Marron (Mudflow Hazards in the Vicinity of Lassen Peak), Lawrence H. Smith (Estimating Tidal and Residual Circulation in San Francisco Bay), Michael K. Nolan (Preliminary Assessment of Shoaling in San Leandro Bay; Erosional Processes in Lake Tahoe Basin; Erosion and Sediment Transport in the Drainage Basin of Permanente Creek), Michael Johnson (Hydrologic Impacts of Dams on Cottonwood Creek), and Thomas Hunter (Evaluation of an Electromagnetic Streamflow Gage).

Cooperative Water-Quality Studies

As water-quality data became more available in the late 1960's and through the mid-1980's, it became clear that major widespread chemical contamination of a large segment of the public water supply of California was occurring in ground-water aquifers and in surface water.

In the mid-1980's, the U.S. Department of Agriculture reported 1,2-dibromo-3-chloropropane (DBCP) contamination in most of the irrigation wells of the San Joaquin Valley. In 1984, elevated concentrations of selenium in irrigation drainage water caused genetic malformation of birds in the Kesterson Reservoir area of the west side of the San Joaquin Valley. Wildlife kills due to toxic contaminants became more frequent in the Salton Sea and the San Francisco

Bay–Delta areas. Although much was documented about chemically degraded waters, little was understood about the chemical and biochemical processes causing the attenuation, uptake, and transportation of the contaminants. Beginning in 1980 and continuing through 1994, some of the most significant scientific contributions made in the California District were those emanating from chemical and biological process studies. Studies of general effects of irrigation drainage on major wildlife refuges were made by Peter Dileanis in cooperation with the U.S. Fish and Wildlife Service (Klamath Basin), James Setmire in cooperation with the U.S. Fish and Wildlife Service (Salton Sea), and Kathryn Kuivila in cooperation with the California Water Resources Board (San Francisco Bay-Estuary Toxic Contaminants). Terry Rees studied distribution of nitrate concentrations in ground water and the densification, attenuation of organic compounds, and colloid transport related to use of reclaimed water.

Steven J. Deverel, Bronwen Wang, and Roger Fujii, in cooperation with the California Department of Water Resources, studied the effects of different irrigation techniques on aqueous and carbon fluxes and assessed biogeochemical pathways from carbon, hydrogen, and oxygen isotope composition. An understanding of these processes led not only to a better understanding of aqueous contamination and the effects on fish and wildlife, but also provided valuable insight into the physical phenomenon of land subsidence due to oxidation of peaty soils such as those found in the vast Sacramento–San Joaquin Delta.

A valuable study was made by Eric Reichard and Tracy Nishikawa in cooperation with the United Water Conservation District and Calleguas Municipal Water District in which a cross-sectional solute-transport model of seawater intrusion was made in the Oxnard Plain, Ventura County. Other water-quality studies of note were by Ronald Fogelman (Sacramento Valley Ground-Water Quality Assessment), Michael V. Shulters (Water Quality of National Park Service areas – statewide), Peter Martin (Salt Water Intrusion at Santa Barbara), Richard N. Oltmann (Rainfall and Runoff Quantity and Quality Characteristics of Urban Land Use in Fresno), Joel R. Guay (Effects of Urban Stormwater Drainage on the Quality of Water in the San Joaquin River), Stephen Sorenson (Effects of Non-Point Source Runoff from Alameda County on South San Francisco Bay; Giardia in the Sierra Nevada), Walter Rast (Stable Carbon Isotope and Primary Carbon Flux in Tracing the Food Chain of Striped Bass), Chris McConaughy (Sediment Transport in San Diego Creek Basin), and Roy Schroeder (Evaluation of a Gasoline Leak at Seal Beach Naval Weapons Station).

Regional Aquifer-System Analysis

During the 1979–94 period, two regional aquifer systems were studied. In 1978, CVAP was one of the first three RASA studies to begin (Bertoldi was the Project Chief). The aquifer system lies within one of the longest alluvial basins in the United States (about 20,000 square miles) and is pumped heavily (annually about 11,000,000 acre-feet in the period from 1960 to 1968). Half of the Nation's fruits, vegetables, and nuts are grown in the valley. The CVAP study was completed in 1984 and produced 24 reports.

The primary reports were Professional Papers in the 1401 series. Primary authors and subject matter were:

1401–A
Bertoldi—Summarizes the important geologic framework, regional ground-water flow, effects of development, and ground-water quality.

1401–B
Hull—Describes geochemistry and transport of dissolved chemical constituents in the aquifer system.

1401–C
Page—Describes the geologic framework of the aquifer with special emphasis on textural changes in the alluvial deposits that constitute the system.

1401–D
Williamson—Discusses ground-water hydraulics with special emphasis on an analysis of regional ground-water flow prior to and after extensive ground-water development.

Other reports and their senior authors were Jonathan Diamond (ground-water pumpage), Ronald Fogelman (maps of dissolved-solids concentrations), James French, Charles Berkstresser, and Ronald Page (series of eight data reports on exploratory drilling), Paul Nady (hydrologic atlas showing irrigation development, and average annual streamflow into the Central Valley), and Alex Williamson (description of hydraulic flow model).

A second RASA study was begun in 1990 and continued through and beyond 1994. Peter Martin was the Project Chief. This study was the southern California Regional Aquifer-System Analysis, which included 89 ground-water basins in a 75,000-square-mile area of coastal and desert areas of southern California. A large number of basins were categorized and grouped into one of two types— coastal or desert basins—according to common hydrologic character and relations. The Santa Clara Calleguas Basin was selected as a coastal type for intensive study and the Mojave Basin was chosen as a desert basin for intensive study. Transient-state flow models and cross-sectional solute-transport models were used to analyze these basins. As of 1994, a paper by Jill Densmore (Degradation of Ground Water in the Barstow Area) had been published. A Professional Paper describing the major problems and issues affecting the different types of aquifers in southern California was prepared for later publication.

Ground-Water Investigation in Owens Valley

From 1982 through 1988, Kenneth J. Hollett was the Chief of the Owens Valley ground-water investigations. This project was one of the few that were jointly funded by opposing litigants, each litigant recognizing the importance of both the Survey's reputation as a "neutral" scientific agency and its leadership in the field of hydrology.

In the 1970's, the area of Owens Valley floor covered by phreatophytes declined. These plants are important for ground cover, forage, and protection against widespread soil erosion. Increased ground-water pumpage and export of the pumped water to Los Angeles were thought to have a detrimental effect on the phreatophyte population. At the time (1982) the Survey was called upon to study the problem, no scientific studies had been done to evaluate the sensitivity of Owens Valley vegetation to changes in the water table. The project was done in four consecutive and overlapping phases: (1) intensive site investigations to develop a one-dimensional model of soil-moisture changes coupled with microclimate and phreatophyte water use, (2) a preliminary three-dimensional model and a two-dimensional, probabilistic-deterministic model to evaluate initial and boundary conditions; (3) detailed two-dimensional, cross-sectional models; and (4) valleywide, three-dimensional, predictive and optimization models that help develop pumping strategies with the minimum effect on valley vegetation.

Hydrodynamic Study of San Francisco Bay Delta Estuary, California

This large multiagency study began in 1984 in cooperation with the California Department of Water Resources, California Department of Fish and Game, State Water Resources Control Board, National Marine Fisheries Service, Bureau of Reclamation, U.S. Environmental Protection Agency, and U.S. Army Corps of Engineers. The goal of the study was to understand circulation and mixing in the estuary and how these processes are affected by the freshwater diversions and altered flows resulting from operations of California's two largest water projects—the State Water Project and the Federal Central Valley Project. The study employed state-of-the-art instruments to measure currents and salinity in the bay, including in-situ and vessel-mounted acoustic Doppler current profilers. Several two- and three-dimensional models were used to understand the effect of freshwater outflow from the Sacramento–San Joaquin Delta on tidal and residual circulation and salt distribution in the bay. In 1992, the study was expanded to develop large-scale hydrodynamic studies in Suisun Bay for the purpose of defining and charting changes in the null-entrapment zone. This project has been the most prolific project (in terms of published papers) in the 1979–94 period. A 1995 summary report by Peter E. Smith, Richard N. Oltmann, and Lawrence H. Smith (Technical Report 45) listed over 70 papers, 40 percent of which were by Survey authors.

National Water-Quality Assessment (NAWQA) Program

The San Joaquin–Tulare Basin NAWQA started in 1993 and continued through 1994 and beyond. Neil M. Dubrovsky was the Project Chief. Although the project was just beginning near the end of 1979–94 historical reporting period, a substantial amount of water-quality data was gathered during the period and a retrospective of tissue and bed-sediment samples was completed at 18 sampling sites to determine the occurrence of trace elements and hydrophobic organic contaminants. An intensive field study of seasonal variations in dissolved pesticides in Orestimba Creek, Salt Slough, the Merced River, and the San Joaquin River was started in January 1993 and continued through 1996. As of 1994, only two papers were

published: one by Dubrovsky and one by Joseph Domagalski (Pesticides Detected in the San Joaquin River).

Ground Water and Subsidence Studies in the Edwards Air Force Base Area

Edwards Air Force Base, located in Antelope Valley, has extensive test facilities for newly developed aircraft. In addition, the Space Shuttle lands on Rogers Lake (dry) lakebed runways when inclement weather conditions prevent landing at Cape Kennedy. By the late 1980's, declining ground-water levels in the valley had caused widespread land subsidence in the southwest part of the base, and an extensive system of fissures, cracks, and potholes had developed on the Rogers Lake lakebed. All of these phenomena negatively affect the mission of both the Air Force test program and NASA's shuttle missions. A project was started in 1989, and continues, to try to define the ground-water basin, quantify hydrologic properties of the aquifer, develop a long-term water-level monitoring program, and develop a compaction monitoring program and land-subsidence quantification program. As of 1994, several publications have been published that describe an extensive geophysical surveying part of this program (Londquist) and use of GPS in land-subsidence studies and results of drilling wells and establishing extensometer sites (Rewis).

HAWAII

By William Meyer *and reviewed by* Charles Ewart, Barry Hill, Valerie Ige, *and* Charles Hunt

GEOGRAPHIC EXTENT AND GENERAL ORGANIZATION OF THE DISTRICT

During 1979–94, the Hawaii District included the islands of the State of Hawaii, the Commonwealth of the Northern Mariana Islands (CNMI), the Territories of American Samoa and Guam, and the United Nations mandated Trust Territory of the Pacific Islands administered by the United States. The mandated Trust Territory of the Pacific Islands (TTPI) included the major island groups of the Caroline Islands (Palau, Yap, Chuuk, Pohnpei, and Kosrae) and the Marshall Islands. The TTPI were under the administration of the U.S. Department of the Interior.

The District conducted cooperative programs with State and county agencies in Hawaii and governmental agencies in Guam, Samoa, and the CNMI. Programs in the TTPI were initially conducted in cooperation with Office of the High Commissioner within the Department of the Interior. The United Nations-mandated Trust relationship with all of the islands except Palau ended in 1987. Two separate sovereign nations, the Federated States of Micronesia (FSM) and the Republic of the Marshall Islands (RMI), were created at this time.

The FSM consist of the main or high volcanic islands of Pohnpei, Yap, Chuuk, and Kosrae and numerous small or low-lying coral islands. Each main island and its associated low islands form an individual state within the FSM. The Republic of the Marshall Islands consists of 29 low-lying atolls and 5 small coral islands. Majuro Atoll is the seat of the RMI government. These nations maintain a "compact of free association" status with the United States that includes economic and defense provisions from the United States. Following their conversion to sovereign nations, the District continued to conduct programs throughout the area in cooperation with the new state governments of the FSM and the national government of the RMI. The District also conducted cooperative work with the local government of Palau, which remained a Trust Territory in 1994.

The District's main office was in Honolulu throughout this period. At the beginning of the period, Subdistrict Offices were located in Honolulu and on Guam. Field Offices were located in Hilo on Hawaii, Kahului on Maui, and Lihue on Kauai. In response to increasing pressure on water resources from a growing population, Field Offices were added on Saipan in 1990 and on Tinian in 1992.

District Personnel

District staff in 1979 consisted of 52 employees, 28 of whom retired before 1994. The number of employees varied as the programs within the District varied and in accordance with personnel ceilings imposed by national policies. From 1989 onward, however, the program became more stable, and total employment varied from 60 to 67 employees with the majority of newly opened permanent positions being filled with recent graduates from the University of Hawaii.

Office of the District Chief

Three District Chiefs served in Hawaii between 1979 and 1994. Benjamin Jones was District Chief from 1979 to 1983. Stanley Kapustka became District Chief in 1983 following Jones' promotion to Assistant Regional Hydrologist of the Western Region. William Meyer became District Chief in 1986 following Kapustka's retirement that same year.

Dan Davis was the Associate District Chief from 1979 until his retirement in 1990. Following Davis' retirement, Charles Ewart became the Associate District Chief.

From 1979 to 1994 the Hydrologic Investigations Section was headed by Charles Ewart (1979–82), Santos Valenciano (1983–85), Charles Huxel (1986–87), Kiyoshi Takaski (1988–89), Iwao Matsuoka (1990–91), James Eychaner (1992–93), and William Souza (1994).

The Hydrologic Data Section was headed by Reuben Lee (1979–87), Richard Nakahara (1988–90), and Iwao Matsuoka (1991–94).

The Water Quality Unit was headed by Johnson Yee from 1981 through 1991.

District Staff

District staff in 1979 consisted of 31 people in the Honolulu District Office, 6 in the Honolulu Subdistrict, 3 each at the Hilo, Maui, and Lihue Field Offices, and 6 in the Guam Subdistrict for a total of 52. The District also had employees located on Palau, Yap, Pohnpei, Kosrae, and American Samoa. These employees were actually employed by the governments of the respective islands they worked on, but their work was dedicated solely to USGS data collection, and their governments received direct credit for their salary and expenses from the USGS. The employees were trained and otherwise supported by the USGS. In all, there was one local employee on Palau, Yap, and Pohnpei and two local employees on American Samoa. The intent of the District was to train personnel within the individual islands so that their governments could eventually conduct the data-collection programs themselves. The Honolulu Subdistrict oversaw the two local employees in American Samoa. All other local employees were overseen by the Guam Subdistrict.

Besides the District Chief and Associate District Chief, the staff in the Honolulu District Office in 1979 consisted of Charles Ewart, Reuben Lee, Iwao Matsuoka, Richard Nakahara, Santos Valenciano, Johnson Yee, Ronald Soroos, Isao Yamashiro, Tamio Ishibashi, Rose Maruoka, Pearl Tam, Akiko Tanaka, Grace Tateishi, Amy Watanabe, Violet Ansai, Joan Hirai, Louise Kabasawa, and Kiyoshi Takasaki. Charles Hunt, Paul Eyre, Patricia Shade, and Lodie Celebrado were hired in 1979.

Personnel in the Honolulu Subdistrict Office consisted of Salwyn Chinn as Hydrologist-in-Charge, Harold Sexton, Frank Romualdo, George Dayag, Katherine Wong, and Benjamin Shimizu. The Field Office in Hilo consisted of Eugene Capellas as the Hydrologic Technician-in-Charge and Hideo Gushiken and Isami Ogi. George Gohara was the Hydrologic Technician-in-Charge at the Kahului Field Office. James Kanno and Norman Yoshioka worked in Maui also. The Kauai Field Office consisted of Noriaki Kojiri, who was the Hydrologic Technician-in-Charge, and Kenneth Konishi and Roy Taogoshi.

The Guam Subdistrict Office consisted of Otto van der Brug as Hydrologist-in-Charge, Charles Huxel, Jose Quinata, David Beck, and Rosalie Gibson. Gregg Ikehara joined the Guam office in 1979.

Some of the employees that worked in the Hawaii District between 1980 and 1994, and the year they came into the District, were Marti Ikehara, Valerie Ige, Cynthia Miyaji, and William Souza in 1980; Dale Nishimoto in 1981; Vaughn Kunishige in 1982; Stanley Kapustka and Leonora Fukuda in 1983; Stephen Anthony and Scott Hamlin in 1984; Terry Takara in 1985; William Meyer in 1986; Mark Underwood and Tomas Kane in 1987; John Hoffmann, Leanne Kitano, Darlene Lytle, Duane Nishimura, Steven Spengler, Gordon Tribble, and Don Arnold in 1988; Barry Hill, Scot Izuka, Michael Niederer, Leonard Thompson, Jill Torikai, Matt Wong, and Clayton Yoshida in 1989; Eric Decarlo (faculty appointment), Karen Fields-Poasa, Steve Gingerich, Donald Mackay, Lenore Nakama, Richard Obata, Todd Presley, Mark Reid, and Stephen Terracciano in 1990; James Eychaner, Twyla Thomas, Ronna Torgerson, and Daniel Yeatts in 1991; Holly Martinson, Michael Pavelko, James Rounds, and Fred Thibedeau in 1992; and Edward Bolke (rehired annuitant), Arthur Camacho, George Heick, and Delwyn Oki in 1993.

Hydrologic Investigations—Central and South Pacific

Hydrologic studies in the late 1970's and early 1980's in the Central Pacific were largely focused on reconnaissance-level surveys of water resources in the islands of Chuuk, Yap, Kosrae, Pohnpei, Palau, and Saipan by van der Brug and a study of stream sedimentation in southern Guam by Shade. van der Brug also documented the hydrologic effects of the 1983 drought in the western Pacific. Takasaki continued a study of the effects 1977–78 drought in Chuuk that was initiated in 1978.

In 1984, Hamlin and Takasaki conducted a water-quality reconnaissance of ground water in the inhabited outer atoll islands of Chuuk. Hamlin and Anthony completed a study of the ground-water resources of Laura Island in Majuro Atoll in 1987, and results of a study of the ground-water resources of the high volcanic islands of Chuuk by Takasaki were published in 1988. Shade, Anthony, and Takasaki conducted a ground-water reconnaissance of the Yap main islands in the late 1980's and results were published in 1992.

In 1988, the District began a cooperative program with Pohnpei State to study ground-water occurrence in selected atoll islands of Pohnpei. These studies, conducted from the late 1980's through the mid-1990's by Anthony, culminated in reports describing ground-water occurrence in Kahlap Island on Mwoakilloa Atoll, Ngatik Island on Sapwuahfik Atoll, Pingelap Island on Pingelap Atoll, and Lenger Island in Pohnpei State.

The District began a program of test drilling in the Kagman area of Saipan in 1988. The purpose of the program, which was in cooperation with the CNMI Division of Environmental Quality and the Natural Resources Conservation Service of the U.S. Department of Agriculture, was to describe the geology and occurrence of fresh ground water in the Kagman area. Hoffmann and Presley, graduate students at the University of Hawaii, were hired on student appointments to assist in this work. Eight test wells were drilled to obtain information on geology, ground-water levels, water quality, and the hydraulic properties of the rocks containing fresh ground water. The test holes were drilled to depths ranging from 10 to 36 feet below sea level after which aquifer tests were conducted. The holes were then deepened to about 50 feet below sea level for a second round of testing at this depth. A description of the results of this work, including projected well yields for the area, was published in 1998.

The results from this program encouraged the CNMI Commonwealth Utilities Corporation (CUC) to purchase drilling equipment and continue the program throughout the island. The District provided technical assistance for the purchase of drilling equipment and entered into a cooperative (Coop) program with the CUC to oversee the test-drilling program throughout Saipan. Hoffman was converted to permanent status and transferred to Saipan in 1990 to oversee this work.

Interest by the CUC in the possibility of using Talufofo Stream as a possible source of water led to an expansion of the Coop program in which Izuka and Ewart described the geologic setting, streamflow characteristics, and water chemistry of the stream basin in 1990.

Wong and Hill conducted a study of Lake Susupe on Saipan in 1990 in order to help the CUC assess the potential of the lake as a source of water. Their study provided information on the bathymetry of the lake and the quality of water in the lake on an areal, vertical, and seasonal basis.

Increasing population and development on the island of Tutuila, American Samoa, and the resulting increased demand on water supplies led to a cooperative program with the American Samoa Environmental Protection Agency to conduct an analysis of ground-water quality and another study of streamflow characteristics on the island. Between 1980 and 1990, the population of Tutuila increased from 30,000 to 45,000 and ground-water pumpage increased from 3 to 6 million gallons per day. Concern about the potential effect of land-use changes on the quality of ground water led to the study, which was conducted by Eyre and completed in 1989. The streamflow characteristics study by Wong updated information from an earlier study by Matsuoka in 1978 and was completed in 1994.

Programs with the U.S. Military in the Central Pacific and Indian Ocean

The District conducted a number of hydrologic studies for the U.S. Navy and the U.S. Army at some of their bases in the Pacific Ocean and at one location (Diego Garcia) in the Indian Ocean. The major studies conducted for the U.S. Navy were at Diego Garcia and

Guam. The major study conducted for the U.S. Army was at Kwajalein Atoll.

U.S. Navy—Diego Garcia, Indian Ocean

In 1978, at the request of the U.S. Navy, Davis visited the coral island of Diego Garcia in the Indian Ocean to investigate ground-water availability on the island. Diego Garcia is part of the British Indian Ocean Territory and serves as a major base for U.S. military operations in the region, including those in the Persian Gulf. Based on Davis's recommendations, the Navy installed a system of shallow wells and instituted a program for metering pumpage and monitoring chloride concentration in pumped water and in deep monitoring wells. The District oversaw construction of wells and entered into a long-term program of assisting the Navy in monitoring and managing the water supply. Davis, and later Davis and Hunt, visited the island on an annual basis as part of the District's program with the Navy, which extended beyond 1994. In later years, USGS analysis focused on climate-induced fluctuations in freshwater lens thickness, documenting the drought sensitivity of the hydrologic system, and comparing prior estimates of sustainable yield to the observed performance of the water supply under actual operating conditions.

A leaking pipeline on Diego Garcia introduced jet fuel to the aquifer along the airstrip. At the time, about 30 percent of freshwater used on the island was derived from this aquifer. Immediate responses by USGS included an onsite visit by Hunt and Gingerich to map the extent of contamination with shallow borings, and formulation of a hydraulic diversion program of pumping and injecting at existing water wells to create a water-table mound and inhibit fuel migration toward the wells. Navy concerns regarding long-term effects of the spill resulted in a study by the District in cooperation with the Navy to evaluate the hydrologic and geochemical aspects of the fuel spill to provide a conceptual basis for aquifer remediation. The study continued from 1991 to 1993 until it was taken over by the U.S. Air Force. Tribble, Hunt, and Torikai led different parts of the study.

U.S. Navy—Guam

At the request of the U.S. Navy in Guam, the District undertook a study in 1990 to determine the storage capacity of Fena Reservoir. This reservoir, constructed by the U.S. Navy in 1951, is the Navy's primary water source on Guam and also provides potable water to a significant portion of the local civilian population. The study, completed by Nakama, indicated that the reservoir had lost 13.5 percent of its original capacity due to sediment deposition.

Following this study, the U.S. Navy requested the District to conduct an investigation to determine the relationship between rainfall on the Fena Reservoir watershed and runoff into the reservoir. This study was completed by Nakama in 1993. The District then entered into a continuing program with the U.S. Navy to use a rainfall-runoff model to provide estimates of reservoir water levels 5 months into the future, assuming selected monthly rainfall values for these months. The Navy in turn used these estimates as part of the criteria for managing the water supply from the reservoir, particularly during the dry season.

U.S. Army—Kwajalein Atoll

The U.S. Army maintains extensive facilities on the islands of Kwajalein and Roi-Namur at Kwajalein Atoll. In preparation for expanding their facilities, the Army requested that the District conduct a study that would define the areal extent of fresh ground water underlying the two islands, assess the potential for contaminant migration from known sources, and reevaluate the amount of freshwater available. Hunt headed hydrologic studies at Kwajalein Island, and Gingerich headed studies at Roi-Namur. Field studies in 1990 and 1991 included construction of multidepth monitoring wells using a USGS drilling rig. Concurrent to the hydrologic studies, Tribble investigated chemical characteristics of ground water at Kwajalein Island, including general water chemistry, the types and extent of nonconservative chemical reactions in the aquifer, and factors that influence the fate of organic contaminants. Tribble and Hunt later applied hydrologic and geochemical findings from these studies to determine that nutrient fluxes from Kwajalein Island to nearshore marine waters and reefs are small in comparison to natural nutrient fluxes from seawater.

Hydrologic Investigations—Hawaiian Islands

Studies by Takasaki and John Mink (Honolulu Board of Water Supply) in the early 1980's described the water resources of southeastern Oahu and provided an evaluation of the release of water from storage in dike-impounded reservoirs above Waiahole ditch.

Shade described hydrologic conditions and sediment transport in Moanalua Valley and Richard Nakahara investigated the magnitude and frequency of floods on Oahu. A Regional Aquifer-System Analysis (RASA) with Charles Ewart as its head began in 1982. Other major contributors to the study were Dave Nichols, William Souza, Charles Hunt, Patricia Shade, and Paul Eyre. Cliff Voss from the National Research Program also provided technical input to the program.

The overall goal of the RASA program in Hawaii was to (1) provide a firm understanding of the complex hydrology and hydraulics of Oahu's ground-water system, and (2) provide a framework for future hydrologic studies and data-collection efforts on Oahu. This area was selected for study under the RASA program owing to the fact that Oahu supports approximately 80 percent of the State's population, including the city of Honolulu. Ground water is the major source of water on the island; as a result, the economy of Oahu and therefore most of the State is dependent on this resource for continued growth. Based on estimates made in the 1980's, the ground-water potential for Oahu was expected to be close to the maximum development possible by the year 2000.

The 1987–88 New Year's Eve flood and debris flows devastated a large area in southeastern Oahu. Concerns created by this event led to a Coop program between the District and the City and County of Honolulu Department of Public Works for the study of landslides and debris flows in the Honolulu District of Oahu. Stephen Ellen and Robert Fleming of the Geologic Division technically headed this study while the District provided administrative support and technical input on the water-related aspects of the study. The District hired Reid for the latter purpose. Spengler and Torikai, graduate students at the University of Hawaii, were hired on student appointments to assist in the study also. Rex Baum from the Geologic Division provided significant input to the study.

The effect of construction of H–3, a major highway across the Koolau Range, on streams was examined by Hill in a study of streamflow and suspended-sediment transport in streams along the route of construction. Data collection began in 1983 and was under the direction of Sexton until his retirement in 1988, at which time Hill transferred to the District to assume supervision of the project. Data were collected before, during, and after construction activities that continued past 1994. Wong continued a study begun by Sexton in 1983 that documented the rate of sediment accumulation in Waimaluhia Reservoir during construction of the H–3 Highway.

Hill also conducted a study of sediment sources and erosion processes in the North Halawa Valley on Oahu in conjunction with the ongoing H–3 project. The study, completed in 1991, quantified sediment contributions from channel erosion, landslides, and highway construction by using a combination of field measurements, regional regression relations, and comparison of tracers in sediment sources and fluvial sediments. Researchers from the University of Hawaii and the National Research Program collaborated in the study.

Izuka conducted a geohydrologic investigation of North Halawa Valley, Oahu, in response to concerns that runoff from Highway H–3 draining into the stream might seep into the ground and contaminate potable water pumped at a nearby skimming well. This study, completed in 1991, indicated that North Halawa Stream lost water from seepage through its streambed; therefore, there was a potential for seepage from the stream to reach the underlying aquifer.

Concerns about the continued availability of ground water in Hawaii (including its quality) caused the State Legislature to enact the Hawaii State Water Code in 1987. This code created a Commission on Water Resources Management (CWRM) and placed the administration of the State's water resources under the commission. The CWRM immediately replaced the Division of Land and Water within the State's Department of Land and Natural Resources as the District's major cooperator for collection of hydrologic data in the State. The CWRM was mandated by the Legislature to conduct comprehensive studies of the water resources. These studies were to include estimates of the sustainable yield of the State's aquifers.

The need to determine ground-water availability as a requirement for ground-water development resulted in the District entering into ground-water availability studies in the North Kohala area of the island of Hawaii, the Central Oahu area on Oahu, and the Lihue area on Kauai. It also led directly to a program of test drilling conducted by the District on the three islands.

The District, in cooperation with the Hawaii County Department of Water Supply (HCDWS), undertook a study in 1988 to determine the potential for developing 20 million gallons of water per day from the Hawi aquifer in North Kohala, Hawaii. Underwood, a graduate student at the University of

Hawaii, was assigned as Project Chief and Tribble was also hired by the District at this time to assist in the work. As part of this study, an exploratory test-drilling program with the Western Region drill rig was undertaken. The purpose was to obtain information on water levels, water quality, including depth to and thickness of the transition zone between fresh ground water and the underlying saltwater, and the hydraulic properties of the volcanic rocks that constitute the Hawi aquifer. These data were then used in conjunction with other geologic and hydrologic information to construct a ground-water model of the area.

Following completion of the North Kohala study, the Western Region drill rig was used to drill several test holes in the Kailua-Kona area on the island of Hawaii. This effort helped lead to the discovery of a major new source of water for the area, a high-level ground-water body located approximately 2 miles inland from the ocean. Prior to the discovery of the water body, the Kailua-Kona area did not have sufficient ground-water supplies to meet demands for further growth.

The test-drilling results for North Kohala and the Kailua-Kona areas proved so successful that in 1991 the District entered into a cooperative test-drilling program with the City and County of Honolulu Board of Water Supply (BWS), the HCDWS, and the Kauai County Department of Water (Kauai DOW). The three water departments provided funds for the District to purchase and run a drill rig capable of drilling 2,000 feet. The District in turn hired several experienced drill-rig operators to run and care for the equipment. Ewart was assigned the responsibility for overseeing the test-drilling program.

The test-drilling program had a stated life of 10 years, and the drill rig was to be used for a period of 6 months to a year on each of the islands in succession, beginning with Oahu. The purpose of the program was to explore for new sources of ground water and to support ground-water availability studies on the three islands. Test drilling began in 1993 in the Waialua and Kawailoa ground-water areas of northern Oahu. This drilling was in support of a cooperative study with the BWS of ground-water availability in northern Oahu. Oki, a graduate student at the University of Hawaii, was assigned as Project Chief. Test drilling was completed in 1994, and the drill rig was moved to Kauai to conduct test drilling in support of a cooperative study with the Kauai DOW to determine ground-water availability in the Lihue Basin. Izuka and Gingerich conducted the ground-water availability study. Shade computed water budgets for the North Kohala and Lihue Basin ground-water models.

By 1990 ground-water withdrawal from the Iao aquifer on Maui was approaching the State's estimate of the sustainable yield for the aquifer, and water demand on the island was steadily increasing. This aquifer is the principal source of domestic water for Maui. Nearly all the water withdrawn from the aquifer was from well fields operated by the County of Maui Department of Water Supply (MDWS), and concern for the long-term reliability of their pumpage led to a cooperative agreement between the MDWS and the District to monitor this aquifer. As part of the program, ground-water withdrawal, ground-water levels, the position of the transition zone between freshwater and saltwater, and measurement of rainfall were reported to the MDWS on a quarterly basis.

The CWRM was also mandated by the Legislature to conduct comprehensive studies of the surface-water resources of the State. In response to this mandate, the District undertook a cooperative study with the CWRM to estimate median streamflow for perennial streams. This study, completed in 1992, was conducted by Fontaine, Wong, and Matsuoka.

The data-collection program for ground water in Hawaii was evaluated by Anthony in 1992, and the data-collection program for surface-water quantity, surface-water quality, and rainfall in Hawaii was evaluated by Fontaine in 1994.

Hydrologic-Data-Collection Activities

The District's hydrologic-data-collection programs from 1979 through 1994 consisted of collecting information on surface-water quantity, surface-water quality, rainfall, ground-water levels, and ground-water quality including chloride concentration in selected observation wells. In general, the number of hydrologic stations where data were collected decreased throughout this time period, although the amount of hydrologic data collected for hydrologic studies increased. Federal funding for the data-collection programs in the Hawaii District was derived from the USGS Federal and Cooperative (Coop) Programs and the U.S. Army Corps of Engineers. Major cooperators included the Division of Land and Water (1979–86) and the Commission on Water Resources Management (1987–94), both housed within the State of Hawaii Department of Land and Natural Resources, the Hawaii Department of

Agriculture, the City and County of Honolulu Board of Water Supply, the City and County of Honolulu Department of Public Works, the Hawaii Department of Transportation, the Hawaii County Department of Water, and the Maui County Department of Water Supply. Cooperative funds were provided by the Territories of Guam and American Samoa, the TTPI (from 1979 through 1987), and after 1987 the island governments of Palau, Yap, Chuuk, Pohnpei, and Kosrae.

Data Collection—Hawaii

The ground-water data-collection program conducted by the District between 1979 and 1994 was based on a program established in 1972. The purpose of the program was to document temporal and spatial changes in ground-water levels and ground-water quality (temperature, specific conductance, and chloride concentration) at selected locations on each of the major islands. One hundred and seventy wells were initially selected for the program, but the distribution of wells and the type of data collected were occasionally adjusted to take advantage of newly constructed wells and to replace wells destroyed or lost. Data were collected from observation and pumping wells. By 1992 there were 188 wells in the program.

The surface-water collection activities from 1979 through 1994 can be classified into one of four principal categories: (1) continuous-record gages, (2) crest-stage gages, (3) low-flow partial-record gages, and (4) miscellaneous measurement sites. The number of continuous-record gages fell from 112 in 1979 to 89 in 1994, reflecting a decline that began after 1966 when the number of gages reached a maximum of 197, the largest number of gages ever operated by the District. The size of the crest-stage program remained constant from 1979 through 1994 with 107 gages in operation. The number of low-flow partial-record gages operated by the District varied between 1979 and 1994 from a low of 9 in 1986 to 24 in 1983.

Surface-water-quality data were collected at 136 sites between 1979 and 1994. Water-quality data collected included physical properties, sediment data, common ions, metals, general organic properties, biological properties, phytoplankton data, pesticides, specific conductance, suspended-sediment discharge, and water temperature. The collection of rainfall data by the USGS dates back to 1910 when five gages were installed on Kauai. One of these gages is the Mount Waialeale rain gage, which has recorded the highest annual rainfall in the world for most of its period of record. The District operated 42 rain gages between 1979 and 1994.

Data Collection—Central and South Pacific Islands

The hydrologic-data-collection program varied significantly from 1979 through 1994, and the number of stations where surface-water-quantity data were being collected declined over time. The number of continuous-record gaging stations fell from 41 in 1979 to 24 in 1990. By 1994 only 18 continuous stream-gaging stations were being operated on islands in this part of the Pacific Ocean. Two gages were on Saipan, 8 were on Guam, 4 on Palau, and 4 on Samoa. The number of low-flow partial-record stations fell from 33 to 11 between 1979 and 1990. There were no low-flow partial-record stations in 1994. The number of observation wells in the program rose from 13 in 1979 to 36 by 1988, but fell rapidly to only 7 (all on Guam) in 1990. Most of the reduction in the data program could be attributed to the conversion of the Trust Territories to sovereign governments and the loss of data programs in these islands. By 1994 hydrologic data in the former Trust Territories were being collected only on Palau and Pohnpei.

The loss of the data program in the Federated States of Micronesia was offset by an expanding program of ground-water exploration and monitoring in the Commonwealth of the Northern Mariana Islands that began in 1988. Rainfall also began to be monitored in 1990 with one gage on Saipan, four gages on Guam, one gage on Palau, and four gages on Samoa.

District Funding

Annual funding and sources of funding between 1979 and 1994 are shown below. As indicated in the table, funding varied from a low of $1,779,960 in 1979 to a high of $5,962,822 in 1991.

The District's total funding between 1979 and 1981 ranged from about 1.8 to 2.2 million dollars each year with about 41 to 43 percent of this funding derived from State and County cooperators. Total funding began to rise in 1982 largely in response to Federal funding of the RASA program. State and county funding dropped as a percentage of the District's total during these years, but the amount of annual funding from this program remained relatively constant between 1.8 and 2.2 million dollars each year. Total District funding and funding from State and county programs rose significantly in 1989 (4.28 million dollars and 2.24 million dollars, respectively)

Hawaii District funding, 1979–94

[Funding, in thousands of dollars]

Year	Federal	OFA	State/ County	Federal matching	Total
1979	163	97	768	752	1,780
1980	147	217	800	794	1,958
1981	197	109	960	903	2,168
1982	514	145	1,001	891	2,552
1983	1,040	102	1,061	911	3,113
1984	1,059	286	1,166	926	3,437
1985	627	148	1,039	883	2,697
1986	761	375	960	812	2,908
1987	704	434	1,002	798	2,938
1988	712	171	1,207	1,002	3,092
1989	210	268	2,239	1,565	4,282
1990	242	584	1,743	1,212	3,781
1991	292	571	3,813	1,286	5,963
1992	273	1,151	2,441	1,210	5,075
1993	1,075	463	2,484	1,277	5,299
1994	152	806	2,693	1,257	4,908

over previous years, largely in response to the District's test drilling program and in response to an increase in funding for the Highway H–3 project. From 1989 through 1994, State and county funding also represented a higher percentage of the District's annual budget, ranging from 46 to 64 percent of the total. The large increase in Federal funds in 1993 reflects funds obtained by the District to rebuild infrastructure impacted by Hurricane Iniki.

IDAHO

This report was prepared *by* Richard L. Whitehead, who retired as a Hydrologist from the Idaho District Office in 1993 after more than 41 years of service to the USGS, *and* Barbara N. Kemp, currently a Technical Publications Editor at the Idaho District Office, *with significant contributions from* Gerald F. Lindholm, Brennon R. Orr, *and* Nathan D. Jacobson *and valuable assistance and review by* Maree Rae Larsen, Linda K. Channel, *and* other members of the Idaho District staff.

ORGANIZATION AND PERSONNEL

As the period began, the Idaho District consisted of a District Office in Boise and Field Offices in Idaho Falls and Sandpoint. Personnel in the Boise Hydrologic Records Unit at the District Office collected data for the Boise area and, in 1990, became the Boise Field Office. In 1979, these offices were staffed by 57 full- and part-time employees. A Project Office at the Idaho National Engineering Laboratory (INEL) was staffed by three employees supervised by a hydrologist who reported to the Office of the Regional Research Hydrologist at Western Region in Menlo Park, Calif. In 1980, a fourth Field Office staffed by two employees was established in Twin Falls.

From October 1982 until August 1987, the Idaho and Nevada Districts were combined into a single Idaho-Nevada District. State Office Chiefs for Idaho and Nevada were supervised by a District Chief for both States.

In 1984, activities at the INEL Project Office were expanded, more employees were hired, and the office came under the administration of the Idaho State Office Chief.

During the period, the number of employees at the District Office fluctuated depending on staffing needs for federally funded regional-aquifer studies and the National Water-Quality Assessment (NAWQA) Program but remained relatively stable because, as these Federal programs grew, cooperative programs diminished. In contrast, the number of employees at the INEL increased fourfold and, at the Twin Falls Office, threefold. The number of employees in the District, including the INEL Project Office, ranged from 61 in 1979 to 103 in 1993.

District Headquarters, Boise

Office of the District Chief.—From 1966 until 1983, the District Office was in the Federal Building at 550 West Fort Street in Boise. Additional space for shop and storage was leased from the City of Boise at Gowen Field on the south side of the municipal airport, about 6 miles from the office. In February 1983, the Idaho District acquired 11 acres of property occupied by the Bureau of Land Management (BLM), Boise District, at 230 Collins Road, about five blocks east of the Federal Building. Of the 10 buildings acquired with the property, three were remodeled to provide office space for all employees, a computer center, and a water-quality laboratory. During 1992–93, another office building was constructed to house 12 employees who originally were part of the Upper Snake River Basin NAWQA Program.

As 1979 began, Ernest F. Hubbard, Jr., had been Idaho District Chief for about 6 months. When the

Idaho and Nevada Districts merged in 1982, he became the Idaho-Nevada District Chief and served in that position until the Districts were separated. During the Idaho-Nevada District years, Herman A. Ray served as Idaho State Office Chief from 1982 to 1984, when he retired. Jerry L. Hughes then transferred from Pueblo, Colo., to replace Ray. In 1987, Hubbard transferred to Reston, the Idaho-Nevada District was reorganized as two Districts again, and Hughes became Idaho District Chief, a position he held for the remainder of the period.

Ralph F. Norvitch, Associate District Chief since mid-1977, served in that position until 1982, when he retired. After the Idaho-Nevada District was separated, Robert E. Lewis, long-time resident of the Hydrologic Studies Section, became Assistant District Chief until 1992, when he transferred to Denver, Colo. Stephen W. Lipscomb became Assistant District Chief for Operations and Technical Support in 1993; Kimball E. Goddard became Assistant District Chief for Investigations and Research in 1994.

Discipline specialists during the period were as follows (in chronological order): Water-Quality Specialists—Walton H. Low, Ray J. Hoffman (Nevada State Office), Paul F. Woods, Timothy B. Spruill, Ivalou O'Dell, and Mark A. Hardy; Ground-Water Specialists—William D. Nichols (Nevada State Office), Larry J. Mann, and Daniel J. Ackerman; Surface-Water Specialists—Otto Moosburner (Nevada State Office), Luther C. Kjelstrom, and Stephen W. Lipscomb.

District secretaries during the period were (in chronological order) C. Jeanne Hopfenspirger, Judy M. Black, Marianne Rowe, and Maree Rae Larsen.

Administrative Services Section.—Glenda A. Blessing began her administrative work in the District Office in 1974. She was head of the Administrative Services Section, first as a Budget Analyst and then as Administrative Officer, until she transferred to the BLM in 1988. During her term, when the Idaho-Nevada District was in existence, the Administrative Services Section assumed duties in support of the Idaho-Nevada District Office. Deborah M. Treseder succeeded Blessing from 1988 to 1992, when she transferred to Denver, Colo. Rosemary A. Smith arrived in Boise from the U.S. Forest Service in Enumclaw, Wash., and began serving as Administrative Officer in 1993.

Others who served in the Administrative Services Section or as technical support for this Section for more than one year during the period were Lorraine R. Arden, Clifford E. Barney, Mary D. Francis, Barbara J. Garrett, Viola M. Hagman, Helen E. Hahn, Tina M. Hardie, Jo-Ann Jones, Judy A. Lansing, Sally D. Martin, Tomas Puga, Jr., Diana J. Robinson, A. Ilaine Tracy, Doris E. Winkler, Glenna A. Wilson, Kiera J. Wood, and Adrienne J. Woods.

Technical Support Section.—This Section evolved in about 1987 and comprised the Automated Data Processing (ADP) and Reports Units. In 1979, Chiefs of the ADP and Reports Units were William A. Harenberg and Linda K. Channel, respectively. In 1987, the ADP Unit became the Computer Services Unit under the supervision of Randall L. Fields. Robert E. Lewis, Assistant District Chief in 1987, supervised the newly formed Technical Support Section from 1987 until 1993. In that year, the Geographic Information System (GIS) Unit was established as part of the Section under the supervision of Joseph M. Spinazola. Steve P. Garcia moved from the Reports Unit to the GIS Unit in 1994 to assist Spinazola.

ADP/Computer Services Unit.—William A. Harenberg, Chief of the ADP Unit from its inception in 1979 until he moved to the Hydrologic Data Section in 1985, was instrumental in moving the District from data storage and management centralized in Reston, Va., to storage and management using more sophisticated equipment onsite. Before 1984, data were keypunched onto cards and submitted to the WATSTORE system on the mainframe computer in Reston, Va., over dial-up phone lines. This data system evolved through a stage of processing by using card-image data and then to the ADR Records System (precursor to ADAPS) when a minicomputer was installed at the District in 1986. A. Kay Lehmann and Theresa M. Frostrom were the computer operators before and during this transition.

Randall L. Fields came to the District as Computer Services Unit Chief in 1987. In 1989, the first personal computers were installed in the Reports Unit to replace the magnetic-card word processing machines then used for production of reports. In 1991, the Idaho District became the first District in the country to install new computer equipment from the Distributed Information Systems (DIS) contract on a large scale. By the end of the year, a large server, 31 workstations, and 15 X-terminals were in place to serve most employees at the District Office. The three

remote Field Offices were equipped with servers the following year.

Technicians, data transcribers, programmers, analysts, and computer specialists who served in the Computer Services Unit during the period were Linda L. Elder, Theresa M. Frostrom, Virginia Gates, Loren G. Kloft, A. Kay Lehmann, Michael Lim, Carol L. Mollner, Sheila E. Poole, Edwin W. Quillian, Brian L. Skeen, and Susan Starr.

Reports Unit.—The Reports Unit, under Linda K. Channel's supervision since 1979, had a monumental task of managing from rough draft through distribution the large number of reports generated by the Boise and INEL offices. With an average of four full-time people and one part-time person, the Unit produced as many as 35 reports per year. Albert S. (Steve) VanDenberg, Nevada State Office, served as Reports Specialist during 1982–87. He was succeeded by Robert E. Lewis after the State Offices were separated, until Lewis transferred from the District. For the remainder of the period, Channel served both as Reports Specialist and Reports Unit Chief. In addition to local and statewide reports, the Unit worked on many reports sponsored by several national programs: the Snake River Plain Regional Aquifer-System Analysis (RASA), the Upper Snake River Basin NAWQA Program, and the National Ground-Water Atlas (Segments 7, 8, and 13). Periodically, the Reports Unit edited or illustrated projects for the Nevada, Colorado, and Washington Districts. During 1979–94, the Unit continually modified its operating procedures to accommodate rapidly changing technology, from magnetic-card word-processing equipment and pen-and-ink illustrations to digitally prepared text and graphics. The Reports Unit also maintained the Idaho District library and provided printing, editing, and graphics services to other staff in the District.

During the period, the editors, illustrators, and assistants who served the Reports Unit were Launa H. Allen, Emily A. Bender, Linda G. Buckmaster, Linda L. Elder, Theresa M. Frostrom, Steve P. Garcia, Richard L. Helton, Marjorie L. Jacobs, Barbara N. Kemp, Ruth L. Murphy, Kirstin Runberg, Vera H. Schumaker, and Nancy L. Yearsley.

Hydrologic Data Section.— As the period began, Herman A. Ray served as Chief of the Section, and James R. Spofford served as Supervisory Hydrologist. When Spofford retired in 1980, Robert W. Harper first moved from the Boise Hydrologic Records Unit to become Supervisory Hydrologist of the Section; then, upon Ray's retirement in 1984, Harper became Chief of the Section until his own retirement in 1992. He was succeeded by Stephen W. Lipscomb, who transferred from the Hydrologic Studies Section.

William A. Harenberg, formerly Chief of the ADP Unit, served as Chief of the Surface-Water Unit after Harper retired. Harold G. Sisco was Chief of the Ground-Water Unit until his retirement in 1987, at which time Michael L. Jones became Chief. Walton H. Low was Chief of the Water-Quality Unit until 1980. When Low transferred to the newly established Snake River Plain RASA Section, Thomas K. Edwards became Water-Quality Unit Chief. In 1982, Ivalou O'Dell replaced Edwards and remained Chief of the Unit through the period.

Others assigned to the Hydrologic Data Section for more than one year during the period were Lorraine S. Aldan, Thomas S. Brennan, Sheldon C. Cordes, Janet K. Crockett, Johnna S. Emery, Carla M. Hansen, Luther C. Kjelstrom, A. Kay Lehmann, Michael Lim, Molly A. Maupin, Robert L. Moffatt, Susan E. Moore, Dennis K. O'Dell, Ivalou O'Dell, Becky M. Owens, Jennifer K. Parsons, Diane J. Pratt, Tomas Puga, Jr., Alvin A. Sablan, Matthew S. Sower, Annette M. Tungate, Douglas C. Werner, and Rhea P. Williams.

Hydrologic Studies Section.—Hydrologic studies during 1979–94 addressed a variety of hydrologic problems. In addition to quantifying surface- and ground-water supplies by using statistical and computer modeling methods, increased effort was directed toward water-quality concerns. Limnological studies were conducted to determine characteristics of major lakes and reservoirs.

Thirty-six people (23 hydrologists, 7 hydrologic technicians, and 6 hydrologic aids) served in the Section during the period. Section Chiefs were Ralph F. Norvitch, 1979–80, Robert E. Lewis, 1981–86, Gerald F. Lindholm, 1987–93, and Kimball E. Goddard, 1994.

Other hydrologists who served in the Studies Section were Michael A. Beckwith, Charles E. Berenbrock, Bruce B. Bigelow, Thomas K. Edwards, Steven A. Frenzel, Stephen P. Garabedian, Sally A. Goodell, Luther C. Kjelstrom, Walton H. Low, Garth D. Newton, Deborah J. Parliman, Harold R. Seitz, Joseph M. Spinazola, Timothy B. Spruill, Mary Anna J. Stone, Richard L. Whitehead, Rhea P. Williams, Paul F. Woods, and Harold W. (Bill) Young.

Hydrologic technicians who assisted with studies were Rick L. Backsen, Michael D. Bassick, David L. George, Anthony W. Grover, Michael L. Jones, Tamara L. Rogers, and James L. Schaefer. Six hydrologic aids served at various times during the period.

The Field Offices

By 1980, four Field Offices were responsible for collection of hydrologic data in Idaho and parts of Wyoming.

Boise Field Office.—During the period, an average of seven or eight employees in this Unit, known as the Boise Hydrologic Records Unit until 1990, were involved in hydrologic data collection and operation, maintenance, and construction of gaging stations in the southwestern part of the State and as far north as Lewiston, Idaho. Edward L. Young, who had transferred from Alaska in 1961, supervised this group of hydrologists and technicians from 1980 until he retired in 1990. During the period, Robert W. Luscombe served as Lead Technician until he retired in 1991. In 1990, Jack D. Doyle transferred to Idaho and served as supervisor of the group, which became the Boise Field Office.

Sheldon C. Cordes, Hydrologic Data Section technician and employee at the Idaho District since 1952, was the main supervisor for construction projects statewide until his retirement in 1988. For the entire period, Lois J. Douglas provided administrative support for this Field Office. When she retired in 1994, Theresa M. Frostrom was reassigned from the Reports Unit to assume the administrative tasks.

Other hydrologists and technicians who served in this Unit for more than one year during the period were Joseph T. Bunt, Russ H. Christensen, George W. Eisele, David L. George, Richard L. Jesser, David M. Knifong, David J. Langman, Andrew W. Records, Kyle D. Reed, Alvin A. Sablan, James L. Schaefer, Ralph A. Shelton, Gregory R. Trunkle, and Frank W. Youngkin.

Idaho Falls Field Office.—Employees at this Field Office, the oldest Field Office in Idaho, collect data from all of eastern Idaho and a few sites in western Wyoming. Monitoring water in the Snake River and its tributaries is of utmost importance in managing the large distribution of water for irrigation on the eastern Snake River Plain.

In 1979, this office was located at 591 Park Avenue in the old Federal Building. C. Michael Bennett was Supervisory Hydrologist. Other staff were Hydrologist Nathan D. Jacobson, Lead Hydrologic Technician Robert W. Erickson, and Hydrologic Technicians Dale H. Miller, Byrt Wammack, John H. Johnson, and Michael D. Campbell. Part-time technicians were Stanley G. Landon, Leo C. Shelley, Ron Bush, and Vern D. Cromwell, and the Administrative Clerk was Debra A. Berglund.

For the remainder of the period, staff changes—changes in tours of duty, promotions, new hires, transfers, and resignations—were the norm. Landon became a full-time employee. In 1981, Jacobson, after about a year as Acting Supervisory Hydrologist, officially was hired as Supervisory Hydrologist. Other Administrative Clerks who served during the period were, in chronological order, Marietta L. Pond, Ellyn M. Weber, Pat Staffen, and Deena F. Green. Other Hydrologic Technicians who served during the period were Jay E. Bateman, Kelly D. Bateman, Catherine S. Black, Bruce A. Benedick, Brandon Burnett, Donald G. Cole, Jonathan B. Evans, Joseph Gillis, Lynn O. Hellewell, Brian D. Higgs, Kevin F. Kirlin, Owen E. McLaughlin, Robert E. Taylor, D. Brad Vandekamp, Steven J. Wegner, and Rebecca S. Westover.

In 1986 the Federal Building was sold and the Field Office moved to 366 D Street.

Sandpoint Field Office.—Established in the early 1960's, this Field Office is the second oldest in the State. Hydrologists and technicians from this office collect data from the area north of Lewiston. Some of the data collected satisfy the international agreement with Canada concerning transboundary flows of the Kootenay (Kootenai) River. Three of Idaho's largest lakes also are monitored by this office: Coeur d'Alene Lake, Pend Oreille Lake, and Priest Lake. Emphasis on hydrologic data collection increased after metals from 100 years of upstream mining were discovered in the bottom sediments of Coeur d'Alene Lake.

Stewart A. Gutenberger supervised operations at this office until he retired in 1990. Rick L. Backsen then transferred from the Twin Falls Field Office to serve as supervisor, and Kevin Kirlin transferred from the Idaho Falls Field Office. Others who served in the Sandpoint Field Office for more than one year during the period were Donna M. Ashenmacher, Michael L. Childress, Eunice M. Cramer, John O. Gralow, Jeffrey T. Schelling, Jonathan G. Thatcher, Douglas N. Ufkes, and John R. Wagner.

Twin Falls Field Office.—The Twin Falls Field Office was established in October 1980 by Rick L. Backsen, Lead Hydrologic Technician, and Thomas S. Brennan, Hydrologic Technician. The office originally was located in the back of the State Agriculture Inspectors Office on Blue Lakes Boulevard in Twin Falls. The area of responsibility for this office is the south-central part of Idaho and northward to Salmon. The area includes the Thousand Springs, where large amounts of ground water issue from the Snake River Canyon wall. The water is used for fish rearing, electrical power generation, and irrigation.

Brennan transferred to Anchorage in 1983 and was replaced by Michael D. Campbell from the Idaho Falls Field Office. In 1985, when the area of operation and number of field sites were increased, Brennan returned from Anchorage and Keith L. Hein was hired to help with the increased responsibilities. In 1990, Backsen and Brennan transferred to other Idaho offices and Campbell became Lead Hydrologic Technician. Others who served in the Twin Falls Field Office for more than one year during the period were Kim M. Browne, Craig L. Bowers, Jeffrey B. Foster, Michael A. Nolevanko, Robert E. Reaves, and Claudia R. Zanone.

Project Office—Idaho National Engineering Laboratory

In 1979, the INEL Project Office was under the direction of the Office of the Western Regional Hydrologist and the Project Chief was Jack Barraclaugh. The Project Office staff at that time consisted of two hydrologists, one hydrologic technician, and one support person. In 1984, the Project Office was placed under the direction of the District Office, and Larry J. Mann became Project Chief. By the early 1990's, the USGS technical staff at the INEL had increased to eight hydrologists, seven hydrologic technicians and support staff, and several students.

Hydrologists assigned to the INEL Project Office during 1979–94 were Daniel J. Ackerman, Steven R. Anderson, Jack T. Barraclaugh, Roy C. Bartholomay, C. Michael Bennett, Renee L. Bunde, L. DeWayne Cecil, Linda C. Davis, Flora J. Goldstein, Charles H. Hemming, James D. Keith, LeRoy L. Knobel, Barney D. Lewis, Michael J. Liszewski, Larry J. Mann, Lynn B. Nelson, Brennon R. Orr, Michael F. Reed, Steven J. Wegner, Luke J. White, and Linda M. Williams. Hydrologic technicians were Jefferson C. Bagby, Leigh I. Beem, Donald L. Boyce, Kim M. Cannon, Jean M. Eagleton, Daniel D. Edwards, Patrick R. Fischer, Michael R. Greene, Steven R. Hannula, Allen J. Heakin, Brian D. Higgs, Rodger G. Jensen, Gary S. Lords, Larry L. Matson, Teddy J. Norton, Douglas S. Ott, John R. Pittman, Beverly Stephens, and Betty J. Tucker. Administrative staff were Paulette P. DeForest and Diane M. Roberts. Personnel assigned to the INEL Project Office during 1979–94 were based both at the Radiological and Environmental Sciences Labortory at the Central Facilities Area of the INEL and at the Idaho State University campus in Pocatello.

FUNDING AND COOPERATION

The funding table shows sources and annual amounts of funding for the Idaho District during 1979–94 (INEL funds are not included).

Although total funding during the period increased almost fourfold, several short-term fluctuations are noticeable. The initial increase during 1979–81 corresponded to the startup of the Federal Snake River Plain RASA study. Although RASA funding did not end until 1986, the table shows that total funding decreased significantly during 1981–84. Because this decrease was during the period of reorganization when the Idaho and Nevada Districts were

Funding for the Idaho District, 1979–94, in U.S. dollars

[Funding in thousands of dollars]

Fiscal year	Federal	Other Federal agencies	State	Federal matching	Total
1979	295	667	535	535	2,033
1980	871	709	619	619	2,818
1981	1,238	658	730	735	3,361
1982	1,017	700	567	582	2,866
1983	480	610	483	425	1,998
1984	364	560	546	441	1,911
1985	351	706	568	517	2,142
1986	501	913	820	798	3,032
1987	695	1,029	954	970	3,648
1988	607	1,377	1,090	1,073	4,147
1989	445	2,070	1,078	1,070	4,662
1990	356	2,976	1,036	1,024	5,392
1991	778	2,926	1,400	1,290	6,394
1992	1,239	2,769	1,512	1,210	6,731
1993	1,603	2,769	1,466	1,173	7,011
1994	1,867	3,360	1,637	1,152	8,015

combined, it could reflect exchange of funds between the two State offices rather than a true funding trend for the District.

During 1984–94, total funding steadily increased by an average of about 12 percent per year, owing to a wide range of new hydrologic studies and increasing demand for basic data.

Federal funding decreased significantly during the period 1982–91. Cooperative projects with State and other Federal agencies and sometimes with local and nongovernmental entities—always critical in achieving the Survey's goals—became even more critical during these years.

The U.S. Geological Survey (USGS) and agencies of the State of Idaho have had cooperative agreements for the systematic collection of streamflow data since 1909 and for interpretive ground-water studies and ground-water-data collection since 1946. During the years between 1979 and 1994, 27 State and local agencies participated in cooperative programs with the Idaho District. (Records for cooperators in fiscal years 1981 and 1985 were unavailable.) Those participating for 5 or more years during the period, in order from most to least years of participation, were Idaho Department of Water Resources (IDWR), Teton County Commissioners (Wyoming), College of Southern Idaho, Southwest Irrigation District, Idaho Department of Fish and Game, Idaho Department of Health and Welfare (IDHW), Shoshone Bannock Tribes—Fort Hall Indian Reservation, County of Shoshone, Water District 01, and Water District 32D. Other cooperators during the period were Bonner County Commissioners, Bonneville County Commissioners, Butte Soil Conservation District, City of Middleton, City of Nampa, City of Orofino, City of Twin Falls, Idaho Department of Parks and Recreation, Idaho Department of Transportation, Nez Perce Indian Tribe, Salmon River Canal Company, Sun Valley Water and Sewer District, University of Idaho, Utah Department of Natural Resources, Water District 31, Water District 65, and West Cassia Soil and Water Conservation District.

Throughout the period, the USGS maintained an agreement with the International Joint Commission, Department of State, concerning transboundary flows of the Kootenay (Kootenai) River between Canada and the United States.

Eighteen Federal agencies participated in cooperative programs with the Idaho District. Those participating for 4 or more years during the period, in order from most to least years of participation, were Department of Energy (DOE), U.S. Army Corps of Engineers, Bureau of Reclamation, Bonneville Power Administration, Bureau of Land Management, Federal Energy Regulatory Commission (FERC), U.S. Forest Service, National Park Service (NPS), Mountain Home Air Force Base (MHAFB), and the U.S. Environmental Protection Agency (USEPA). Other Federal cooperators during the period were Bureau of Indian Affairs (BIA), Department of Agriculture, Department of Housing and Urban Development, Department of the Interior (DOI)—Office of the Secretary, Federal Emergency Management Agency (FEMA), U.S. Fish and Wildlife Service (FWS), and Soil Conservation Service (now the Natural Resources Conservation Service).

SIGNIFICANT EVENTS

Significant natural events during this period of the Water Resources Division history had a variety of effects on Idaho's hydrologic and geologic resources.

In May 1980, the eruption of Mount St. Helens in Washington deposited volcanic ash over a large part of northern Idaho. Steven A. Frenzel was Chief of a study to determine the extent and thickness of the Idaho ash deposits. There were no apparent long-lasting detrimental effects from the ash deposits in Idaho.

In October 1983, the Borah Peak earthquake, magnitude of 7.3, affected the hydrologic regimen in the central part of Idaho and parts of western Montana. A fault scarp several miles long formed in the Big Lost River Valley near Mackay, Idaho. It is believed that the mountain range on the east side of the valley rose about 5 feet and that the valley floor dropped a similar amount. Hydrologic effects were widespread in the area. Numerous sand boils developed; some springs stopped or decreased in flow, whereas others increased. Flows of most streams in a large area increased following the earthquake. Ground-water levels in much of the area rose about 5 feet. Streamflows and ground-water levels were monitored for more than a year following the earthquake, and some hydrologic effects were still apparent in 1994. Richard L. Whitehead, Robert W. Harper, and Harold G. Sisco were leaders in this monitoring effort. Results were published in a journal article and a book chapter.

A drought began in Idaho in 1987 and continued until 1993. Precipitation in 1987 and 1988 was the

lowest for period of record. As a result, ground-water levels declined in much of the State. After about 7 years of below-normal precipitation, a period of above-normal precipitation began.

The U.S. Army Corps of Engineers experimentally drew down Lower Granite Reservoir on the Snake River in 1992 to help evaluate alternative methods of managing the reservoir to aid salmon migration. The Survey measured and monitored reservoir velocity changes, time of travel, sediment load, and various water-quality parameters throughout the experiment. State-of-the-art use of an acoustic Doppler current profiler provided a way to quickly and accurately measure velocity profiles in reservoirs at various pool elevations. Robert W. Harper and Stephen W. Lipscomb led the Survey's efforts. Open-File Report 94–109 was published as a result of these activities.

Designation of the Bruneau Hot Springs snail as an endangered species under the Endangered Species Act became effective in January 1993. This adversely affected ground-water users in the Bruneau Valley and adjacent areas. Charles E. Berenbrock was Chief of a study and author of a report (WRIR 93–4001) to define the hydrologic system and effects of water use on snail habitat.

In July 1993, a massive landslide (about 100 acres) near Bliss, Idaho, formed a temporary earthen dam across the Snake River and caused river stage to rise about 10 feet before the dam was breached.

A landslide in April 1987 near the town of Hagerman, Idaho, caused an estimated $1.5 million in damages to the southernmost of two irrigation pumping stations and an undetermined amount of damage to fossil beds at the Hagerman Fauna Site National Landmark on adjacent BLM lands.

SUMMARY OF PROGRAMS

Hydrologic Data Collection

The number of wells monitored for water levels during the period was between 297 (1985) and 487 (1993), 20 to 36 of which were equipped with automatic recording gages. The number of surface-water stations remained at about 200 until the mid-1980's. After that time, the average number of stations increased to about 260 as a result of the initiation of the Swan Falls Project, an effort to quantify Snake River water resources upstream from the Swan Falls Dam.

The number of surface-water-quality sites was between 67 (1994) and 128 (1980). The number of ground-water-quality sites was between 97 (1990) and 196 (1980). Ground-water-quality samples were collected at about 400 different sites each year from 1991 to 1994. The total of 1,600 sites served as the basis for a network designed to be sampled on a rotating basis.

Hydrologic Studies

Federally Funded Studies.—Effects of water use, primarily for irrigation, and water-quality concerns were the major focuses of hydrologic studies in Idaho during the period. Federally funded regional aquifer studies and a regional water-quality assessment addressed these issues. The District also participated in National Ground-Water Atlas studies and in the largest Natural Resource Damage Assessment study in the Nation's history.

Regional aquifer studies. The Snake River Plain RASA study began in 1979 and was completed in 1986. Gerald F. Lindholm transferred from the Minnesota District to be Project Chief. The study generated 35 reports on the geology and hydrology of the eastern and western parts of the plain. Primary reports were a Professional Paper series (PP 1408 A–G) written by staff hydrologists. Richard L. Whitehead defined the geohydrologic framework of the Snake River Plain (PP 1408B); Luther C. Kjelstrom described streamflow gains and losses and ground-water budgets (PP 1408C); Warren W. Wood and Walton H. Low defined solute geochemistry (PP 1408D); Sally A. Goodell documented water use (PP 1408E); Stephen P. Garabedian described the hydrogeology and digitally simulated the eastern plain (PP 1408F); and Garth D. Newton did the same for the western plain (PP 1408G). Lindholm summarized the Snake River Plain RASA study (PP 1408A). Results of specific phases of study were presented in one Water-Supply Paper, six Hydrologic Investigations Atlases, five Miscellaneous Investigations Maps, six Open-File Reports, and 10 other reports.

The Intermontane Basins RASA study began in 1990 to describe parts of Montana and Idaho. David W. Clark, Montana District, was Project Chief. Primary reports were Hydrologic Investigations Atlases HA–738A, B, and C, which included geologic

history, ground-water levels, and quality of ground and surface water in the Intermontane Basins. Idaho investigators were Deborah J. Parliman, Mary Anna J. Stone, and James L. Schaefer.

National Water-Quality Assessment Studies. The Upper Snake River Basin NAWQA study began in 1991 to describe water-quality conditions and long-term trends and to identify major factors that affect water quality in the Snake River Basin upstream from King Hill, Idaho. Walton H. Low served as Project Chief until he transferred to Reston, Va., in 1997. Numerous publications were published as a result of this study.

National Ground-Water Atlas Studies. A National Ground-Water Atlas program was initiated in the 1980's to unify the description of aquifers in all States, Puerto Rico, and the U.S. Virgin Islands. During 1987–90, Richard L. Whitehead compiled and presented information on nine States in Chapters H (Idaho, Oregon, and Washington), I (Montana, North Dakota, South Dakota, and Wyoming), and N (Alaska, Hawaii, Puerto Rico, and the Virgin Islands). James A. Miller, Georgia District, was overall supervisor of the Ground-Water Atlas program.

Natural Resource Damage Assessment Studies. A Natural Resource Damage Assessment (NRDA) of the Coeur d'Alene River drainage basin was conducted by the Federal Government; the Idaho District conducted four studies as part of this NRDA. The USGS studies, coordinated by Paul F. Woods, investigated effects of sediment transport and deposition on natural resources within the Coeur d'Alene River drainage basin. This assessment, the largest NRDA in the Nation's history (and ongoing as of 2001), included numerous environmental studies leading to litigation for recovery of natural resource damages.

Cooperative Studies.—In addition to the federally funded regional studies, a variety of local studies were done in cooperation with State and local agencies and nongovernment entities. Descriptions of some of these studies follow.

Ground-Water Studies. In the early 1980's, Harold W. (Bill) Young supervised a study done in cooperation with the Southwest Irrigation District to define the geohydrology of the Oakley Fan area. Another aspect of the study was to consider the feasibility of artificially recharging aquifers in the area, in which four Critical Ground-Water Areas had been established. Recharge efforts were guided by a digital ground-water flow model of the area developed by Garth D. Newton. The study generated two reports, WRIR 83–4245 and WRIR 88–4065.

Also in the early 1980's, Steven A. Frenzel developed techniques to estimate ground-water pumpage. WRIR 83–4277 was published as a result of this study.

Increased use of ground water for irrigation in the Mud Lake area prompted a cooperative study with the IDWR that began in 1989. Project Chief, Joseph M. Spinazola, developed a numerical ground-water flow model to evaluate the effects of water-use changes on ground-water levels and on losses from and gains to streams and lakes in the study area. Data-collection results were published in Open-File Report 92–133. Geohydrology of the study area and the numerical model were described in companion reports by Spinazola (WRIR 93–4227 and WRIR 93–4228).

Depth to water in the Snake River Plain and several tributary valleys was mapped by Molly A. Maupin in 1990 and 1991 (WRIR 90–4193 and WRIR 91–4020). Depth to water in the Rathdrum Prairie, Idaho, Moscow-Lewiston-Grangeville area, Idaho, selected intermontane valleys in east-central Idaho, and the Spokane River Valley in Washington was mapped by Charles E. Berenbrock and others (WRIR 94–4087). These depth-to-water data and data from several other agencies were used by the IDHW, Division of Environmental Quality (DEQ) to assess the vulnerability of ground water in Idaho to contamination.

Limnological Studies. Paul F. Woods transferred from the Alaska District in 1986 to initiate limnological studies in Idaho. After the acquisition and renovation of a 27-foot research vessel, the Pend Oreille Lake study began in 1989. That was followed by studies of Coeur d'Alene Lake in 1991 and Payette Lake in 1994. Results of the Coeur d'Alene Lake study created widespread concern because of the abundance of metal-bearing sediments present on the lake bottom and their potential for creating environmental problems. The source of the metals in the lake was the Coeur d'Alene drainage basin upstream from the lake, a 21-square-mile part of which was designated by the USEPA in 1983 as the Bunker Hill Superfund Site. Woods was assisted in his studies by Steven A. Frenzel, Michael A. Beckwith, and Sabrina N. (Nichols) Conti. Numerous reports were generated from these lake studies.

Surface-Water Studies. Collection of data for a study of sediment transport in the Snake and Clearwater Rivers near Lewiston, Idaho, was completed in 1979. Michael L. Jones and Harold R. Seitz, in cooperation with the Corps of Engineers, directed the study and published OFR 80–690 in 1980 to present results.

In 1980, William A. Harenberg and Luther C. Kjelstrom published results of a study to determine whether channel-geometry measurements could be used to estimate flood-flow characteristics at ungaged sites in Idaho (WRIR 80–83). In the early 1980's, Harenberg also directed mapping of flood plains in several basins for FEMA.

In 1983, Seitz and Jones collected and published data (OFR 82–102), in cooperation with the IDHW, to describe changes in water-quality and cross-sectional properties of the Spokane River from Coeur d'Alene Lake to Post Falls Dam.

In 1988, Kjelstrom began developing profiles of the Snake River downstream from Swan Falls Dam to estimate river stages during the irrigation season and how changes in stage could affect waterfowl nesting habitat. The study was done in cooperation with the FWS and FERC as part of the Swan Falls settlement. WRIR 91–4198 was published to present results of this study.

In 1988, Kjelstrom, in cooperation with the IDWR, estimated high-lift irrigation pumpage from the Snake River using impeller and ultrasonic flow meters and other methods. An article presenting results was published in the Journal of Irrigation and Drainage Engineering.

Stephen W. Lipscomb did a statistical study of the upper Salmon and Clearwater River Basins using basin characteristics. The study, which started in 1989, was done in cooperation with the BIA to help define areas critical to anadromous fish recovery efforts. USGS Professional Paper 1604 was published as a result of this study.

Water-Quality Studies. In 1979, Deborah J. Parliman and Richard L. Whitehead proposed a ground-water-quality monitoring network for Idaho (OFR 79–1477) to keep water managers informed of water quality in the State and to serve as a warning system for undesirable changes in water quality. A revised network was developed in cooperation with the DEQ. Timothy B. Spruill was the USGS representative in the planning process. As implemented, the USGS, under the leadership of Ivalou O'Dell, periodically collects samples that are then analyzed and reported by DEQ.

During the period, Parliman collected and analyzed ground-water-quality data for numerous areas and sites in Idaho, including the eastern and western Snake River Basins, Payette River Basin, North Idaho, east-central Idaho valleys, several counties, MHAFB, and the Boise, Blackfoot, and Fort Hall areas. Parliman also collected samples from selected sites in Grand Teton National Park, Wyo., and compiled data collected from 1921 to 1991 on thermal water wells and springs in Idaho. These studies were done in cooperation with the IDHW—DEQ, IDWR, Shoshone-Bannock Tribes, Fort Hall Indian Reservation, MHAFB, and the NPS. Numerous reports, including Fact Sheets, Open-File Reports, and Water-Resources Investigations Reports, were published as a result of these studies.

In 1988, Walton H. Low and William H. Mullins began a reconnaissance investigation to determine the quality of irrigation return flow in the American Falls Reservoir area in Idaho. This study was part of a program initiated in 1985 by the DOI to identify the nature and extent of irrigation-induced water-quality problems that might exist in the Western States. The American Falls Reservoir area was one of 19 locations in 13 States that were selected for investigation.

In 1993, Kjelstrom, in cooperation with several State and local agencies and Boise State University, began a study to determine the quality and volume of stormwater runoff to the Boise River in Boise and Garden City, Idaho. Results of the study were published in WRIR 95–4228.

Geothermal Studies. Geothermal water has been used to heat about 200 homes, several businesses, and several State office buildings in Boise for the past 100 years. Water temperature has remained stable at about 170 degrees Fahrenheit; however, increased use has caused pressure to decrease. During the period, Robert E. Lewis, Deborah J. Parliman, and Harold W. (Bill) Young led USGS monitoring and research efforts in Boise and other parts of the State. Robert H. Mariner, Western Region, was instrumental in using isotopes to determine reservoir temperatures and source of water.

Idaho National Engineering Laboratory

The INEL Project Office has conducted hydrologic investigations since 1949 at the DOE–INEL in southeastern Idaho. The objective of these investigations has been to assess the effects of radioactive- and chemical-waste disposal from INEL facilities on ground water.

During 1979–94, hydrologic data were being collected from a growing network of wells to monitor the movement of INEL-related contaminants in the Snake River Plain aquifer. In addition, large-scale reconnaissance sampling studies were conducted to develop "snapshots" of a broad range of radiochemical, inorganic-chemical, and trace-element constituents. During this time, improved analytical methods indicated that radiochemical, inorganic-chemical, and organic-chemical contaminants had migrated to the Snake River Plain aquifer.

In 1984, in response to the improved analytical results, the USGS program was expanded to better evaluate the extent of contamination and the capability of the aquifer to assimilate contaminants. The expanded program was designed to define the amount, timing, and location of recharge to the flow system, the geologic framework of the aquifer, hydraulic characteristics of the basalts, and geochemical reactions that could affect contaminant mobility. Numerical simulations were planned to evaluate the conceptual model of flow and the understanding of contaminant fate and transport in the aquifer.

By 1994, the initial phases of the expanded USGS program were near completion. A study was completed that documented channel losses on the Big Lost River, the principal source of recharge to the Snake River Plain aquifer at the INEL. A detailed stratigraphic data base had been assembled from geophysical logs and other data collected from more than 300 boreholes at and near the INEL. Aquifer-test analyses had been completed for 94 wells completed in the aquifer and for 22 wells completed in perched-water zones at specific INEL facilities. More than 60 wells had been sampled for a comprehensive suite of analytes to characterize aquifer geochemical reactions.

During the period, the INEL Project Office provided to the USGS, the DOE, and INEL contractors support personnel and licensing for operation of two vans equipped with borehole geophysical and video logging equipment. In November 1990, the Project Office opened the INEL Core Library to preserve core and cuttings samples from many of the boreholes drilled on and near the INEL since 1949. By 1994, the Core Library had archived more than 45,000 feet of core. In 1990, the Central Region Research Drilling Group transferred two drill rigs, ancillary equipment, and a driller to the INEL Project Office. The drilling unit was used to construct several deep geotechnical holes in areas where hydrologic and geologic data were needed.

More than 80 reports describing the distribution of INEL-related contaminants in the subsurface and characterizing geohydrologic conditions in the Snake River Plain aquifer at the INEL were published during 1979–94. These reports included 26 Water-Resources Investigations Reports (WRIR's), 37 Open-File Reports (OFR's), 1 Bulletin, 1 Water-Supply Paper, 1 Hydrologic Atlas, and more than 14 journal articles, proceedings, and other peer-reviewed papers.

NEVADA

By A.S. VanDenburgh, Jon O. Nowlin, *and* Patrick A. Glancy

INTRODUCTION

Nevada's population growth rate led the Nation for more than four decades as of 2000. This surge has centered in Clark County (the Las Vegas area), in southeast Nevada, and in the Reno/Sparks/Carson City area, in northwest Nevada. Except for the Colorado and Truckee Rivers as sources of supply to the Las Vegas and Reno–Sparks metropolitan areas, respectively, most communities in the State have depended on ground water or local perennial streams for water supply. Statewide, however, agricultural irrigation remains the principal water use. For both public-supply and irrigation needs, the issues of location, sustainability, and water quality were key factors in Nevada that in turn enhanced the importance of USGS water-resources activities during 1979–94.

WRD "highlights" in the Silver State included program growth, merger with a neighboring District, demerger, and more program growth. Overall, the program expanded from about $2 million in fiscal year 1979 to almost $11 million in 1994; meanwhile, the full-time-equivalent staff count rose from 32 to 136. Likewise, the publication count increased, from 5 releases in calendar year 1979 to 52 in 1994. Most of the major interpretive projects during that period were federally funded, but the District also did considerable interesting science as a result of cooperative funding agreements. All told, 1979–94 was a good-news/bad-news period for the Nevada District; fortunately, the former seems to have outweighed the latter.

HYDROLOGIC CONDITIONS DURING 1979–94

Nevada generally is considered the Nation's driest State, with long-term precipitation averaging only 9 inches per year. Short-term (less than 10-year) rates can be double or half the average annual rate over large areas. WRD efforts in the State are, in part, an outgrowth of these climatic traits.

Nevada streamflow can vary considerably from year to year, and the trends during 1979–94 were no exception, as shown by the data in figure 1 for three index stream-gaging stations. In northern Nevada (East Fork Carson River and Humboldt River), the first half of the 16-year period was largely wetter to much wetter than average, whereas the second half (1987–94) was mostly drier to considerably drier. In the southern part of the State (Virgin River), the generally dry period began in 1986 and was interrupted by much wetter than average conditions in 1993.

North of mid-State, streamflow was abundant during an unusually strong and prolonged El Niño climate episode in 1982–84. In 1982 and 1983, heavy spring and early summer snowmelt runoff in the Truckee, Carson, and Walker River drainages of western Nevada caused localized flooding. On Slide Mountain, between Reno and Carson City, rapid melting of the 200-percent-of-average snowpack during a heat wave in late May 1983 caused a landslide that expelled the contents of a small mountain lake, generating a damaging debris flow. This unusual event is the subject of USGS Professional Paper 1617.

In the Humboldt River Basin to the northeast, 1983 was a very wet year. But those flows were dwarfed by the 1984 runoff, which was of record-setting Pleistocene proportions. The annual total at the Palisade index station (fig. 1) that year was almost 500 percent of average, relative to the 87-year period of record there through 1994. Widespread flooding ensued during both years.

In February 1986, a warm and unusually intense storm arrived from the vicinity of Hawaii. Most of the snowpack above 6,000 ft in the Sierra Nevada was retained, but heavy rain below that altitude caused severe flooding of the Truckee, Carson, and Walker Rivers east of the Sierra front.

In southern Nevada, numerous convective storms of tropical and monsoonal origin produced flash floods during many summers of 1979–94. In mid-August 1981, a large convective storm caused major, widespread flash flooding east of Las Vegas. Sparse population in the affected areas limited

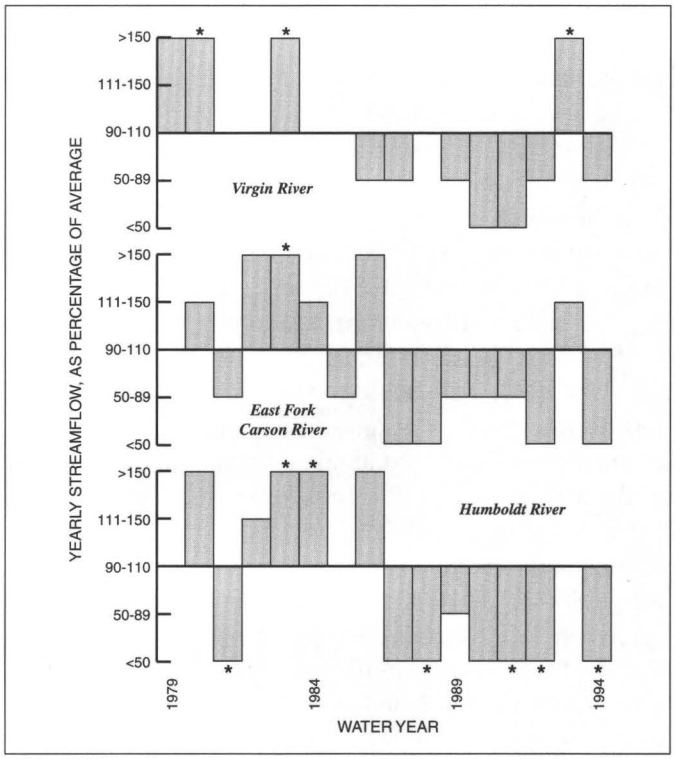


Figure 1. Year-to-year fluctuations in flow at index stream-gaging stations during water years 1979–94, relative to average flow for longest period of concurrent record (1961–94). Asterisk indicates annual flow greater than 200 percent or less than 35 percent of average. Index stations: Virgin River at Littlefield, Ariz., about 10 miles upstream from Nevada; may reflect generalized year-to-year trends in **southern** part of State. East Fork Carson River near Markleeville, Calif., almost 10 miles upstream from Nevada; depicts fluctuations in far **western** part. Humboldt River at Palisade, Nev.; exemplifies **northeastern** part. Flows were largely unaffected by upstream impoundments. Agricultural diversions exist in Virgin and Humboldt basins upstream from index station; no substantive agriculture above Markleeville gage.

damage, but the proximity to the rapidly growing metropolis provided a grim warning of the potential for future disaster there.

Monsoonal storm activity was particularly severe and repetitively intense during the summer of 1984. For example, eight flash floods badly damaged Las Vegas Valley and claimed half a dozen lives during a 6-week period. These storms affected most of southern Nevada, with occasional incursions as far north as the Reno–Carson City area.

In addition to times of overabundance, streams in the Silver State also were subject to drought conditions, as exemplified by data from the three index gaging stations (fig. 1). The statewide drought during most of 1987–94 was especially pronounced in northeastern Nevada, where flow at the Humboldt River

index station was less than 35 percent of average during 4 of those 8 water years; in 1992, it was less than 20 percent of average.

Las Vegas Wash in southern Nevada is truly a desert anomaly. Because the formerly ephemeral stream is now fed mostly by sewage effluent from the expanding Las Vegas metropolitan area, it has hosted a steadily increasing flow destined for Lake Mead on the Colorado River. In water year 1979, the average discharge was 94 ft^3/s; by 1994, it was almost 180 ft^3/s. Major channel downcutting has resulted in the lower wash.

Ground water is a precious, vulnerable commodity in Nevada. In some places, it is the sole source of supply; in other places, it augments the unpredictable surface-water resource, especially in drought years. Agriculture and domestic/public supplies are the principal uses.

During 1979–94, water-level declines continued in places such as Diamond Valley near Eureka (northeastern Nevada; pumpage for irrigation), Hawthorne (west-central Nevada; largely an indirect result of upstream irrigation in the neighboring Walker River Basin), and Las Vegas (southern Nevada; public supplies). In other places, water levels that declined early in the 16-year period, mostly due to pumping, seemed to have stabilized at least locally during 1985–94 (parts of Carson City in western Nevada and Pahrump Valley in the south; public-supply withdrawals).

ORGANIZATION AND MANAGEMENT

During 1979–94, a succession of five District Chiefs oversaw most WRD-Nevada operations, but only four were headquartered in the State. This apparent inconsistency was the result of a management experiment during 1982–87 (discussed herein). As 1979 dawned, Frank T. Hidaka presided over the Nevada District, but he retired a year later in January 1980. Hidaka's place was taken by his assistant, Timothy J. Durbin. When Durbin moved on to head the much larger California District in January 1982, his assistant, Terrance L. Katzer, served as Acting District Chief.

At about this time, Western Regional Hydrologist John D. Bredehoeft conceptualized a locally controversial "paired-District" management scheme; Nevada and its neighbor to the north, Idaho, were selected as the first experimental merger partners, in August 1982. Ernest F. (Ernie) Hubbard of Boise was placed in charge of the new Idaho-Nevada District, and Katzer became the first of three Nevada Office Chiefs. In March 1985, Katzer relinquished command to Otto Moosburner, who served as Acting Chief until appointee William J. Carswell arrived in January 1986. In August 1987, the "oranges and apples" merger was terminated (much to the relief of many participants) by Regional Hydrologist T. John Conomos, who had been appointed to that position in mid-1985. As a result, Bill Carswell became Chief of the Nevada District and Jon O. Nowlin was Associate Chief.

In early 1991, an "area management structure" was initiated nationwide by WRD Senior Staff, and in March, Carswell was appointed Great Basin Area Hydrologist (overseeing operations of the Nevada, Arizona, and Utah Districts). Nowlin was selected to succeed Carswell as Nevada District Chief and continued until Nowlin's retirement more than 9 years later; only the first Nevada Chief, George F. Worts, had a longer tenure (1962–74). The Nevada District is proud that Worts was the first WRD District Chief in the Nation (Joe Cragwall became Chief of the Tennessee District shortly thereafter). In June 1992, Richard D. Hayes was named Associate Chief.

Throughout 1979–94, the in-State headquarters for most WRD operations was Carson City—the capital—about 30 miles south of Reno in northwestern Nevada. In 1979, statewide data collection was facilitated by small Field Offices in Elko and Las Vegas (northeastern and southern Nevada, respectively). By 1988, program growth in the south earned Subdistrict status for the Las Vegas office (Elko remained a small but important field operation).

PERSONNEL

In Nevada, the period 1979–94 was one of uninterrupted population growth. The statewide total increased by almost 100 percent, from about 767,000 in 1979 to 1,491,000 in 1994. In early 1979, the Nevada District was a relatively small operation, with a staff of only 40 that included 26 full-time, 8 part-time, and 6 when-actually-employed (WAE) members. Fifteen years later, the contrast was startling: in March 1994, the District staff totaled 154. Included were 129 full-time, 10 part-time, 12 temporary, and 3 student employees. Throughout 1979–94, Clark County, which includes metropolitan Las Vegas in southern Nevada, dominated statewide population totals with almost 58 percent in 1979 and just over 65 percent in

1994. During that time interval, the District's Las Vegas contingent grew from 1 person to 36!

In 1979, District staff consisted of 52 percent scientists/engineers, 20 percent technicians, and 28 percent operational support personnel. By 1994, the scientists/engineers had decreased to 44 percent while technicians increased to 31 percent; support staff remained almost the same at 25 percent of the total workforce.

The honor of "first woman scientist/engineer" in the Nevada District went to Rita L. Carman, in 1980; she also was the District's first female technician, in 1979. By 1994, the Nevada District boasted 13 female scientists and six technicians. Carol J. Boughton was the District's first female hydrologic-studies supervisor, beginning in 1991.

Table 1 provides a year-by-year tally of organizational units within the District, their supervisors, and the number of staff members (see footnote 1 therein).

Formal designation of Nevada Office discipline specialists began in about 1981. Appointees to these technical advisory/mentor positions during 1984–94 are listed:

Nevada District office discipline specialists[1]
Surface water
Otto Moosburner, 1984–93
Rhea P. Williams, 1994+
Ground water[2]
William D. (Dave) Nichols, 1984–85
Michael D. Dettinger, 1988–89
James R. Harrill, 1990–94
Quality of water
Ray J. Hoffman, 1984–94+
Reports
Albert S. (Steve) VanDenburgh, 1984–94+

[1]See footnote 1, table 1, regarding sources of information. Specialists were not acknowledged in WRD directories until 1984. During 1983–87, Moosburner, Hoffman, and VanDenburgh were specialists for entire Idaho-Nevada District as well as for Nevada Office; Nichols was "dual specialist" until late 1985.

[2]From late 1985 until 1987, James R. Harrill and David E. Prudic shared duties informally as co-acting specialists for Nevada Office. When Harrill retired in mid-1994, Prudic became acting Nevada District specialist.

Additional WRD personnel worked in Nevada during 1979–94, but most of them were headquartered out of State and were not formally affiliated with the Nevada District. Included were members of the Nevada Test Site program, the Yucca Mountain Project, and the National Research Program.

FUNDING

Continuing efforts begun in 1974 to diversify District scientific programs, the mix of projects and cooperators expanded significantly during 1979–94. Figure 2 and table 2 summarize the trends and growth in funding for this period. The increase in total funds was almost fivefold (real growth was 250 percent, expressed in 1979 dollars to compensate for inflation). Total full-time equivalent staff (FTE) grew from 32 to 136 (table 2), a 325-percent increase.

Most program growth was in interpretive studies and research, which increased from 35 percent of the total in 1979 to 81 percent by 1994. A long-term goal of the District since 1975 was to develop roughly equal funding in the Cooperative (Coop), Federal, and other Federal agency (OFA) programs. In 1975 the Coop program constituted 75 percent of the District funding, with 14 percent in Federal and 12 percent in OFA programs. By 1992–94, program balance was about 38 percent Coop, 28 percent Federal, and 34 percent OFA.

PRINCIPAL PROGRAMS

Hydrologic Data Collection

Data-collection activities for water years 1979–94 are summarized in table 3 on the basis of totals from annual water-resources data reports for Nevada. Not all of the published surface-water data were collected by Nevada District personnel: some were provided by other agencies and by neighboring WRD Districts. The tabulation below gives examples for water years 1979 and 1994.

Type of published surface-water data	Data sources and number of sites					
	Other Federal agencies		Neighboring WRD Districts		Nevada District	
	79	94	79	94	79	94
Gaging stations						
Discharge: streams, canals, and drains	2	1	19	23	110	163
Stage and contents: lakes and reservoirs	9	5	2	3	9	14
Total	11	6	21	26	119	177
Water-quality sites						
Streams, canals, and drains	0	0	8	12	88	165
Lakes and reservoirs	3	0	4	1	1	0
Total	3	0	12	13	89	165

Table 1. Nevada District organization and personnel, 1979–94 (including the period of the Idaho–Nevada District merger, 1982–87)

[Abbreviations: NAWQA, National Water-Quality Assessment Program; RASA, Regional Aquifer-System Analysis Program]

Organizational units and supervisors	Number of staff members in organizational unit, by calendar year[1]															
	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
Office of Nevada District Chief[2]	5	4	4	3	5	6	3	4	4	4	7	8	6	8	7	7
Data Section[3]																
Leo A. Bohner	11															
Otto Moosburner	--	13	17	19	19	21	13	12	19	29						
Richard D. Hayes	--	--	--	--	--	--	--	--	--	--	19	18	24	22		
Kerry T. Garcia (acting)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	
Stephen E. Hammond	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	28
Studies Section[3]																
Timothy J. Durbin	16	16														
Terrance L. Katzer	--	--	9	12												
William D. Nichols	--	--	--	--	16	13										
Jon O. Nowlin	--	--	--	--	--	--	24	[4]21	15	10						
Hugh E. Bevans	--	--	--	--	--	--	--	--	--	--	9	16				
Carol J. Boughton	--	--	--	--	--	--	--	--	--	--	--	--	17	17	19	24
Truckee–Carson River Quality Assessment																
Jon O. Nowlin	--	8	7	3												
Great Basin RASA Section																
James R. Harrill	--	--	6	9	9	11	9									
Nevada Test Site Project (Las Vegas)[5]																
William D. Nichols	--	--	--	--	---	--	2									
Charles O. Morgan	--	--	--	--	--	--	--	4								
William B. Scott	--	--	--	--	--	--	--	--	5	7						
Carbonate Aquifer Program Section[6]																
James R. Harrill	--	--	--	--	--	--	--	13	12	9	7					
Special Projects Section (1988–90) and research group (1989–93)																
Jon O. Nowlin	--	--	--	--	--	--	--	--	--	10	18	15	6	6	7	
NAWQA Section /Project																
Hugh E. Bevans	--	--	--	--	--	--	--	--	--	--	--	--	8	12	12	11
Digital Methods Development Section[7]																
Timothy D. Liebermann	--	--	--	--	--	--	--	--	--	--	--	--	6	5	8	7
Truckee-Carson Program																
Otto Moosburner (acting)	--	--	--	--	--	--	--	--	--	--	--	--	--	3		
Larry R. Bohman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5	7
Administrative Section[3]																
Deborah L. Arnett	[8]5	2	4	4												
(vacant)	--	--	--	--	5	--	3									
Richard L. Wheelhouse	--	--	--	--	--	5										
W. James Kratz	--	--	--	--	--	--	--	3	4	7	7	7	8	8	11	12

Table 1. Nevada District organization and personnel, 1979–94 (including the period of the Idaho–Nevada District merger, 1982–87)—Continued

[Abbreviations: NAWQA, National Water-Quality Assessment Program; RASA, Regional Aquifer-System Analysis Program]

Organizational units and supervisors	Number of staff members in organizational unit, by calendar year[1]															
	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
Computer Section[3]																
Sandra D. Tebeau	3	--	--	--	--	--	--	4	4	3						
Walter L. Rennick	--	4	3	6	5	6										
William D. Nichols	--	--	--	--	--	--	5									
Sharon A. Watkins	--	--	--	--	--	--	--	--	--	--	5	4	6			
J. James Lanson	--	--	--	--	--	--	--	--	--	--	--	--	--	6		
Kenn D. Cartier (acting)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	
Margaret C. Bunch															--	4
Publications Section[9]																
Albert S. VanDenburgh	--	3	4	5	5	5	7	7	5	8	7					
Elinor H. Handman	--	--	--	--	--	--	--	--	--	--	--	9	12	15	16	17
LAS VEGAS SUBDISTRICT																
Office of Subdistrict Chief[10]																
William B. Scott	--	--	--	--	--	--	--	--	--	--	5	4	5			
(vacant)	--	--	--	--	--	--	--	--	--	--	--	--	--	6		
Terence W. Danielson	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	7
Data Section[11]																
Daniel E. Hitch	--	--	--	--	--	--	--	--	--	--	6	7	--	6	8	
David A. Beck	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--	16
Studies Section[12]																
(vacant)	--	--	--	--	--	--	--	--	--	--	9					
Kenneth J. Covay	--	--	--	--	--	--	--	--	--	--	--	12	7			
Douglas A. Trudeau	--	--	--	--	--	--	--	--	--	--	--	--	--	10	14	14
Yucca Mountain Project																
David A. Beck	--	--	--	--	--	--	--	--	--	--	--	--	--	12	10	
District totals	40	50	54	61	64	67	66	68	68	87	99	100	116	136	158	154

[1]Data for 1979–91 are from annual WRD directories (which are dated "January" through 1986 edition; no month is given thereafter). Data for 1992–94 are from District Program Review documents (produced in February or March of indicated year). Staff tallies are not adjusted to full-time equivalents.

[2]State Office Chief was senior Nevada manager during Idaho-Nevada merger (August 1982–August 1987).

[3]"Generic" organizational title. Actual titles commonly were changed often during 1979–94. An extreme example: data operation was known simply as "Hydrologic Data Section" in 1979–80 and again in 1994; during 13 intervening years, five other titles, most of which were cumbersome (such as "Hydrologic Data Collection and Analysis Section" during 1983–86) identified data group. Note: Staff-member counts for District data section include Elko Field Office personnel throughout 1979–94 and Las Vegas/Boulder City personnel until that office attained Subdistrict status in 1988.

[4]Includes staff of short-lived Environmental Quality Section.

[5]Renamed NTS Weapons Testing Hydrology Program in 1987; became part of Subdistrict operations in 1988.

[6]Renamed Great Basin Aquifer Studies Section in 1987.

[7]Renamed Methods Development Section (1992–93) and Spatial Data Section (1994).

[8]Included four members of soon-disbanded General Services Unit.

[9]Generic title; in early 1979, report typing and related services were provided by two members of General Services Unit (footnote 8).

[10]Includes Las Vegas administrative and computer personnel.

[11]Generic title; included Yucca Mountain projects (mostly data collection) in 1994.

[12]Generic title; consisted entirely of weapons-testing projects (at Nevada Test Site) in 1992 and 1993.

Table 2. Nevada District funds (in thousands of dollars) and full-time equivalent (FTE) staff, fiscal years 1979–94

[Abbreviations: **FY**, fiscal year; **Fed**, Federal; **OFA**, other Federal agency; **Coop**, Cooperative (non-Fed); **CC**, Carson City (includes Elko Field Office); **LV**, Las Vegas]

FY	Program category				1979 equiv-alent total	Program area		FTE
	Fed	OFA	Coop	Total		CC	LV	
79	1,043	322	824	2,188	2,188	2,174	15	32
80	983	385	1,000	2,367	2,171	2,352	16	44
81	1,510	321	1,039	2,869	2,410	2,853	16	45
Period of merged Idaho-Nevada District (August 1982–August 1987)								
82	1,670	176	1,376	3,222	2,513	3,165	57	56
83	1,257	259	1,718	3,234	2,426	3,109	126	55
84	1,242	395	1,616	3,253	2,342	3,020	233	57
85	961	1,016	1,730	3,707	2,558	3,100	607	66
86	921	1,052	2,047	4,020	2,733	3,219	801	67
87	1,299	1,198	2,122	4,619	3,048	3,675	944	71
88	1,201	1,357	2,773	5,331	3,359	4,598	733	84
89	1,478	1,763	2,661	5,902	3,600	5,175	727	94
90	1,405	2,274	2,897	6,576	3,814	4,817	1,759	93
91	1,860	2,111	3,935	7,906	4,428	6,346	1,561	107
92	3,439	2,825	3,851	10,114	5,462	7,611	2,503	123
93	3,539	3,078	3,944	10,561	5,597	7,617	2,943	136
94	3,458	3,049	4,281	10,788	5,610	7,972	2,816	136

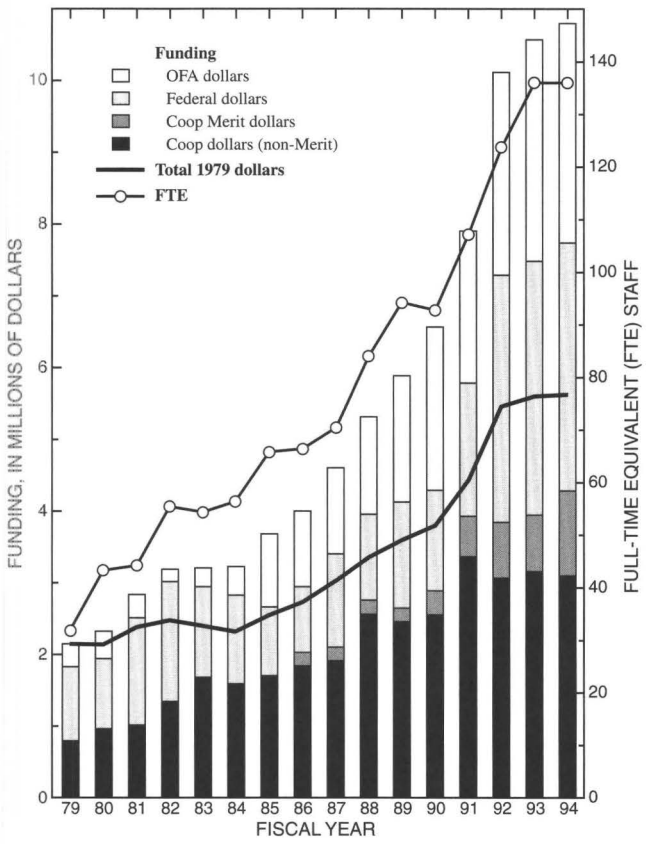


Figure 2. Nevada District trends in funding and staff.

Over time, the Nevada District's share of data published for gaging stations and water-quality sites increased somewhat, from 82 percent of the total site count (255) in 1979 to 88 percent (for 387 aggregate sites) in 1994. Almost 93 percent of the surface-water quality sites were operated by the District during 1994 compared to less than 86 percent in 1979.

The Nevada District collected surface-water quality data for three national networks during 1979–94. The numbers of sites for selected water years indicate that Federal network activity in Nevada diminished over time:

Network	1979	1986	1994
Hydrologic benchmark	2	2	2
National Stream-Quality Accounting	9	7	5
Pesticide	3	0	0

Data collection by the District involved financial cooperation with other Federal, State, and local agencies. The number of cooperators in each of those cate-

Table 3. Types of hydrologic data and number of sites for which records are listed in Nevada District annual data reports, water years 1979–94[1]

Type of data published	Number of sites for water year[2]			
	1979	1982	1987	1994
Discharge data:				
Gaging stations on streams, canals, and drains	131	120	86	187
Peak-flow, low-flow, and miscellaneous sites	94	94	144	160
Springs	0	42	35	66
Stage and contents for gaging stations on lakes and reservoirs	20	21	14	22
	208	229	304	758
Water levels in wells	0	0	12	60
Precipitation quantities				
Water-quality data:	96	93	29	177
Streams, canals, and drains	8	13	0	1
Lakes and reservoirs	8	2	5	154
Wells	0	0	0	5
Precipitation				

[1]Some site totals listed herein differ from those compiled in annual data-report introductions, as a result of selected re-counts. Includes some adjacent-State sites in basins that are tributary to or downstream from Nevada. Beginning with report for 1988, data from Nevada projects also are included.

[2]Data are listed for first and last years of period and for years of Idaho–Nevada District merger and demerger.

gories remained relatively unchanged during 1979–94. Ranges for that period were as follows: Federal, 6 to 8 cooperators; State, 4 to 6; and local, 13 to 18 (the total number ranged from 23 to 29). Throughout the period the principal cooperators remained the Nevada Division of Water Resources, the Nevada Department of Transportation, and the Bureau of Reclamation (BOR).

Interpretive Studies

Federal Programs—Federal program investigations in Nevada during 1979–94 (fig. 2) were diverse in scope. Studies of processes and controls on migration of low-level radioactive wastes in the unsaturated zone near Beatty began in fiscal year 1977 (FY77). This research developed and applied innovative technology for documenting fluid and gas migration in deep and extremely dry unsaturated sediments. Substantial expansion of the District's scientific program in the water-quality disciplines began with the Federal Truckee–Carson River Quality Assessment (RQA) in FY79. Hydraulic data and biochemical reaction coefficients developed from intensive field studies for the RQA nutrient/dissolved-oxygen model of the Truckee River provided sound data benchmarks still considered state-of-the-art for that river.

Research studies on the geochemistry of arsenic in Carson Desert ground water beneath the Fallon area, funded during FY85–87 by the Toxics Program, developed an understanding of how alternate wetting and drying of unsaturated sediments in irrigated areas can mobilize arsenic and other natural contaminants. This information was subsequently important to the National Water-Quality Assessment (NAWQA) and Irrigation Water Quality Program studies. NAWQA studies in Nevada began in FY85 with the pilot Carson Basin Ground-Water NAWQA project, followed in FY92 by the Nevada Basin and Range (NVBR) NAWQA. The Carson Basin NAWQA disclosed widespread distribution of natural radioactive isotopes in ground water of alluvial basins receiving sediments derived from the dominantly granitic eastern Sierra Nevada. The NVBR study compared factors and processes affecting water quality in the Carson and Truckee River Basins in northwestern Nevada with those of Las Vegas Valley in southeastern Nevada. This unique bimodal NAWQA was designed to cover a gradient of land development, from Carson Valley (just starting to develop after decades of stable irrigation) to the Truckee Meadows (Reno-Sparks urban area) to Las Vegas (the fastest-growing urban area in the Nation for more than two decades). Major results of the NVBR project included the unanticipated presence of methyl *tert*-butyl ether (MTBE) and other volatile organic compounds in ground and surface water, including Lake Mead, and the detailed river biosurvey transects that are benchmarks for future monitoring by local, State, and Federal agencies.

Previous work in the District's statewide Coop reconnaissance program (1960–74) formed the foundation for the major Great Basin Regional Aquifer-System Analysis (RASA) studies (FY's 79–88, 91–92). Comprehensive data bases and concepts of regional ground-water flow developed in the Great Basin RASA subsequently led to major Coop projects in eastern and southern Nevada basins.

In southern Nevada, studies and data-collection networks for the Federal Yucca Mountain Program began in FY82 with assessments of flood hazards at Yucca Mountain and Fortymile Wash, including support for paleoflood studies. In the development of precipitation-runoff models of the American and Carson River Basins (California-Nevada) for the Federal Climate-Change Program beginning in FY93, the District pioneered concepts in dynamic linkage of Geographic Information Systems (GIS) with watershed models to expedite model calibration.

Decades of Federal-State, interstate, and intrastate litigation over water management in the Truckee and Carson River Basins resulted in congressional passage in 1990 of Public Law PL 101–618, the Truckee–Carson–Pyramid Lake Settlement Act. In support of implementation of PL 101–618 by the Department of the Interior (DOI), USGS initiated the Federal Truckee-Carson Program in FY92. This program provided technical support to DOI and cooperating agencies and developed complex streamflow and river/reservoir operation models for the two rivers. That work contributed significant upgrades to the U.S. Environmental Protection Agency (USEPA) "HSPF" hydrologic modeling systems.

OFA Programs—Program diversification efforts included the goal to increase investigations funded by other Federal agencies (OFA) in Nevada (fig. 2). The largest of these efforts included partnerships with the BOR in the Carbonate Aquifer Program and with the Department of Energy (DOE) in support of both the Department of Defense (DOD) at the Nevada Test Site (NTS) and the DOE Yucca Mountain Program.

The District supported the Bureau of Land Management (BLM) through geothermal studies in FY75–83, operation of gaging stations, and an initial assessment in FY93–94 of the potential effects of large-scale, open-pit gold mining in the Humboldt River Basin. This reconnaissance led to the establishment in FY94 of the major cooperative Humboldt River Basin Assessment.

Support of the National Park Service (NPS) in Nevada included a series of flood studies on tributaries to Lake Mead (FY's 77–81), monitoring of water levels in Devils Hole, a unique endangered-species habitat in the carbonate-rock aquifer of southern Nevada, and NVBR NAWQA spin-off surveys of the distribution of volatile organics in Lake Mead. For the U.S. Forest Service (USFS), stream gages were operated and ground-water availability was assessed in the Kyle/Lee Canyon watersheds of the Spring Mountains, west of Las Vegas. District GIS expertise was provided in support of DOD's International Hydrology Program and the USEPA's Environmental Monitoring Systems Laboratory in Las Vegas.

The BOR became a major partner to the District in both northern and southern Nevada. Extensive post-RASA studies on regional ground-water flow systems were done by the Carbonate Aquifer Program, a joint BOR–USGS–Nevada Legislature effort that began in FY84 to assess potential long-term ground-water supplies for Las Vegas. The District also provided technical support to the BOR in studies of salt loading to Lake Mead from Las Vegas Wash and other tributary basins. During FY's 92–93, the BOR funded the monitoring and mapping of ground-water levels in the Newlands Irrigation Project surrounding Fallon to support the implementation of PL 101–618.

The DOI National Irrigation Water Quality Program, which began in FY86, included USGS studies of agricultural drainage in the Fernley, Carson Lake, Stillwater, and Humboldt wildlife areas in northwestern Nevada.

Much of the significant increase in OFA programs during FY85–94 was in southern Nevada, principally to provide hydrologic support for DOD operations and environmental assessments at the NTS and for DOE assessment of the proposed nuclear-waste repository at Yucca Mountain. These programs included development of large regional hydrologic monitoring networks, GIS-based hydrologic data systems, and scientific studies of processes affecting ground-water recharge, discharge by evapotranspiration (ET), and regional ground-water flow systems in the carbonate-rock aquifers of southern Nevada.

An earlier partnership with the DOD involved work at the Hawthorne Army Ammunition Plant in arid west-central Nevada. These multidisciplinary studies, which were completed in 1980, delineated the migration and unexpectedly effective natural depletion of dissolved, nitrogen-bearing explosives wastes in the shallow ground-water aquifer between Hawthorne and closed-basin Walker Lake.

Cooperative Programs—The Federal-State Coop Program grew steadily during 1979–94, except for a brief decline in 1983–85 during the experimental Idaho-Nevada District merger (fig. 2). Recruitment of diversely talented scientific staff during FY's 76–79 facilitated expansion of the science and funding sources for cooperative studies. The Western Region competitive Scientific Merit Program for redistribution of Federal matching funds (FY's 86–98) provided both a stimulus for development of more diversified cooperative investigations and research and a source of new Federal matching funds to support cooperative science in the District. By 1994, winning merit projects had resulted in over $1 million of new funding for the District's Coop Program (fig. 2).

The cooperative statewide reconnaissance program of 1960–74 provided the impetus for several more detailed Coop investigations of ground-water availability during 1979–94, including ground-water models for Las Vegas, Eagle, Carson, Big Smoky, Honey Lake, and Desert Valleys. The Great Basin RASA led to increased understanding of the interconnections between ground-water basins in Nevada. It also posed additional questions about regional ground-water flow systems, prompting new Coop studies; the first was in the White Pine area of eastern Nevada. Then, the combined OFA/Coop Carbonate Aquifer Program assessed regional ground-water-flow systems extending from recharge areas in eastern Nevada to discharge areas in the Death Valley, Colorado River, and Great Salt Lake Basins along the Nevada borders with California, Arizona, and Utah.

The need to better understand ground-water recharge and discharge processes prompted "merit" Coop studies with research components, including early applications of geophysics (gravity) to estimate changes in ground-water storage and several systematic studies to quantify, and then regionalize, rates of ground-water ET by native plants. Coop matching funds obtained through the merit competition also

supported research that supplemented the immediate water-management needs of cooperators. An excellent example is the series of Eagle Valley recharge studies that met both the needs of local cooperators for sound information on water budgets and the District goal to increase scientific understanding of recharge processes in the Great Basin.

Diversification of science in District Coop projects included studies of ground-water contamination (by septic-tank effluent at Topaz Lake and Spanish Springs Valley and by mining wastes), stream erosion and sedimentation (the Carson River sediment model, erosion in Lake Tahoe tributaries, Virgin River geomorphology, and bridge scour), nutrient transport in streams (the Truckee River model, Lake Tahoe tributary monitoring, and Carson River loads), dendrochronology indices of long-term drought, and recharge/discharge studies using chloride-balance techniques and onsite measurements of ET.

Early recognition of the power of information technology resulted in Coop (and Federal) projects to develop, support, and apply tools of remote sensing, GIS, and advanced data bases to hydrologic studies. Coop projects included a series of applications of GIS and remote sensing to assist State agencies in quantifying water use, the cooperative Tahoe Environmental GIS (TEGIS), and cooperative statewide data bases to manage water-use, water permit, and well-drilling information. In turn, the resultant data bases developed by USGS and maintained by State agencies provide invaluable information for future USGS hydrologic studies.

Publication Productivity

Report production is an important measure of District operational success. Annual publication counts for the 16 calendar years 1979–94 show a favorable, generally ascending, sawtooth pattern, in which the tally for every even year exceeds those for neighboring odd years. The cumulative publication total for 1979–94 was about 400 items, of which approximately two-thirds were released subsequent to the 1987 demerger.

Table 4 shows several publication-related trends in the Nevada District for four key years during 1979–94. Included in addition to publication tallies are indices of author and publication-section productivity in the District and of Publication Section support for District report writers (most of whom were scientists/engineers).

Table 4. Publication-related trends, Nevada District, 1979–94

Index of publication productivity	Calendar year			
	79	82	87	94
Publications per year	5	9	22	52
Publications per scientist, per year	0.3	0.3	0.6	0.8
Scientists per staff member	6.4	6.1	7.6	3.9
Publications per staff member, per year	1.7	1.8	4.4	3.1

[1]Publication tallies include formal USGS- and State-series reports; USGS water-resources investigations, open-file, and annual data reports; journal articles; and symposium/conference/meeting papers and stand-alone abstracts. To be included, publication must have been authored or coauthored by at least one Nevada District staff member. "Scientist" refers to all scientists and engineers; "staff member" refers to Publications Section staff. Annual personnel totals in both categories are approximate full-time equivalents (FTE's).

[2]Data are listed for first and last years of period and for years of Idaho–Nevada District merger and demerger.

From 1979 to 1994, the number of publications per scientist/engineer (table 4) almost tripled—an admirable trend. Because the Publication Section staff increased markedly during 1990–94 (table 1), the number of scientists/engineers per Section staff member decreased by almost 50 percent between 1987 and 1994 (theoretically a helpful trend). However, the number of publications per Section staff member also decreased during the same period, by 30 percent. One reason for the latter trend may have been an increased emphasis on posters, slides, and larger transparencies (which are not, herein, considered published products) for technical presentations during 1990–94.

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OREGON

By Gary L. Gallino, Lawrence E. Hubbard, William D. McFarland, and Karen W. Miller

INTRODUCTION

The Oregon District experienced a wide variety of significant organizational and hydrologic occurrences during the 1980's and early 1990's. Several offices were relocated or closed, the subregional reorganization expanded interaction among scientists throughout the Western Region, and the scientific focus of the Oregon office continued to evolve. This reorganization merged pairs of Districts under one District Chief with a State Office Chief in each of the two former Districts. Although the merger of Oregon and Washington worked reasonably well, other mergers did not, and eventually Oregon along with Washington, Idaho, and Nevada became Districts again with their own District Chiefs. Another regional reorganization in 1991 established an area structure that subdivided regions into several areas, each headed by an Area Hydrologist. The Oregon District was assigned to the Pacific Northwest Area, which included Alaska, Idaho, Oregon, and Washington.

Hydrologically, the period included events ranging from statistically significant floods to record-breaking drought. Almost all areas of the State were affected in some way. Ground-water resources started being investigated as an alternative to surface supplies, which were mostly appropriated. Quality of ground water and surface water continued to increase in importance as population growth stressed the availability of water to meet demand. The eruption of Mount Saint Helens had only a minor effect on the District's program, but the establishment of the Cascades Volcano Observatory in Vancouver, Wash., provided an opportunity to include researchers interested in the hydrologic aftermath of eruptions in the District programming process.

A major change in the State property tax structure (Measure 5) in 1992 reduced available funds from the budgets of several State and local cooperators. This funding shortfall greatly reduced the surface-water Cooperative (Coop) program with these agencies. The Oregon Water Resources Department (OWRD), once the major cooperator for the hydrologic data-collection program, experienced limited funds almost overnight, causing the District to scramble to find other funding sources and to change the focus of the District surface-water program. The 1980's and early 1990's started a new era for the District's ground-water and quality of water programs. Investigative projects involved a higher level of complexity and analysis using hydrologic models. Key projects such as the Portland Basin Ground Water study included multiple cooperators like OWRD and the City of Portland who pooled their financial resources to fund large, complex studies.

ORGANIZATION AND PERSONNEL

In 1979 the Oregon District consisted of District and Subdistrict Offices in Portland, Field Offices in Medford, Eugene, and La Grande, and an OWRD liaison office in Salem. The Pacific Northwest Data Center, which provided near real-time processed streamflow data to Federal and State agencies throughout the Northwest, was housed with the Oregon District Office in Portland. Some Regional research programs also operated from the District Office and, for a short period, from the Eugene Field Office because of its proximity to the University of Oregon. Reorganization of Pacific Northwest Districts and new office management resulted in the closure of the La Grande Field Office in 1985 and the Eugene Field Office in 1990. The Salem liaison office was closed in 1992 after the program with OWRD was substantially reduced as a result of the passage of Measure 5. Lack of funding support and changing real-time data technology limited the viability of the Northwest Data Center, which was closed in 1988.

In 1979, the Oregon District was organized along the traditional lines used by most Districts. The management staff included the District Chief, an Associate District Chief, a Budget Analyst, and Assistant District Chiefs for the Hydrologic Data and Hydrologic Studies sections. During the 1980's and early 1990's the District went through some major changes and growing pains. The staff grew from about 60 to more than 100 employees. This growth was mostly due to the start of the National Water-Quality Assessment (NAWQA) Program and significant growth in the Hydrologic Studies and Environmental Quality Studies sections. The management structure changed to be less hierarchical and tended to be more lateral in nature, resulting in the Section Chiefs having a higher level of management responsibility. The management structure evolved to include the District Chief, Assistant District Chief (who also served as the

General Hydrologic Studies Chief), Environmental Quality Section Chief, Willamette NAWQA Section Chief, Reports Section Chief, Computer Support Section Chief, Data Program Chief, and the Administrative Officer.

DISTRICT HEADQUARTERS

In 1979 the District Office was located at 830 NE Holladay Street adjacent to the Bonneville Power Administration (BPA) headquarters along with all other Department of the Interior (DOI) agencies in the Portland metropolitan area. In 1984, the office relocated to the Nationwide Insurance Building at 847 NE 19th Street. Relocation was in part a result of BPA becoming a Department of Energy agency, which resulted in decentralization of DOI agencies. The office relocated again in 1989 to its present location at 10615 S.E. Cherry Blossom Drive as a result of District growing pains and the need to reactivate the District water chemistry laboratory.

Stanley Kapustka was the District Chief in 1979 and Garald Parker, Jr., was the Associate District Chief. Parker transferred to become District Chief of the Mississippi District in 1981. He returned to the Northwest in 1986 as Chief of the Washington State Office and later as Chief of the Pacific Northwest Area. Parker was replaced in Oregon by Edward Bolke who transferred in from the Washington District. Bolke became interim District Chief when Kapustka transferred to become District Chief of the Hawaii District in 1983.

The subregional reorganization brought Marvin Fretwell from his position as Western Region Water Quality Specialist to Oregon as State Office Chief in 1984. Bolke returned to his previous duties as head of the Ground-Water Studies Section and was selected for the newly established position of Assistant State Office Chief. He retired in 1991. William McFarland replaced Bolke as General Hydrologic Studies Section Chief and Assistant State Office Chief.

The office returned to District status in 1993. Fretwell was named representative for the northern half of the Western Region and Dennis D. Lynch was selected as District Chief. Lynch transferred from the Virginia State Office to become Chief of the Environmental Quality Section and to run the Tualatin River Basin water-quality study in 1990.

Camilla Alexander was the Administrative Officer at the start of this period in the history of the Oregon District. Alexander transferred to the Alaska District in 1979. Lois Barnes, who transferred from the Arizona District, became the Supervisory Budget Analyst and later the Administrative Officer. Barnes retired in 1989 and Karen Miller transferred from the U.S. Forest Service to become the new Administrative Officer.

In 1979 David Harris was the Assistant District Chief for Hydrologic Studies and Larry L. Hubbard was Assistant District Chief for Hydrologic Data. The reorganization eliminated the Assistant Chief positions in favor of a single Assistant Chief, Section Chiefs, Project Chiefs, and Area Discipline Specialists. Harris retired in 1984 and Hubbard retired in 1990. Gary Gallino was head of the Portland Subdistrict Office, which included the La Grande Field Office. The Field Office Chiefs in Medford, Eugene, and La Grande were Richard Kraus, William Higbee, and Wilmer Eicher, respectively. Gallino transferred to the Cascades Volcano Observatory in 1981 and was replaced by Carl Kroll, who was Gallino's assistant in the Portland Subdistrict. Kroll stepped down when the Subdistrict was reduced to Field Office status and was replaced by Thomas Herrett, who transferred from the Maryland District. Both Higbee and Eicher retired when the Eugene and La Grande Field Offices were closed in 1986. Responsibility for the data-collection activities of these offices was redistributed to the Medford, Portland, Pasco, Washington, and Boise, Idaho, Field Offices.

FUNDING AND COOPERATION

The budget of the Oregon District grew throughout this period in its history. Funding for cooperative hydrologic studies grew significantly because of large multidiscipline studies like the Portland Basin Ground Water Study and the Tualatin Basin Water Quality Study. The Federal Program grew significantly with the start of the Puget Sound Trough Regional Aquifer-System Analysis Study (RASA) in the early 1980's. In 1986 the budget received a real boost after the District was chosen to conduct one of the pilot National Water-Quality Assessment (NAWQA) studies in the Yakima Basin in central Washington State. Funding from Federal sources became predominant after the passage of Measure 5 limited available funds from State and local agencies dependent on property tax dollars to support hydrologic work.

Oregon District funds, fiscal years, 1980–94

[Coop; Cooperative program; FMF, Federal matching funds; OFA, other Federal agency; funds, in thousands of dollars]

Fund source	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Coop	767.4	832.2	694.5	464.7	589.6	710.7	904.3	1,063.2	1,183.3	1,137.7	1,262.8	1,431.2	1,340.9	1,377.1	1,346.6
FMF	733.4	796.1	633.4	449.5	384.2	484.4	861.0	985.3	1,099.5	1,070.2	1,120.9	1,424.8	1,256.3	1,301.2	1,280.1
OFA	765.1	735.0	841.9	540.7	491.9	543.8	1,171.7	1,083.3	1,262.6	1,385.6	1,382.7	1,277.4	1,528.1	1,726.8	1,711.8
Federal	317.5	471.0	325.5	313.5	231.4	375.4	523.6	543.4	448.8	391.5	562.5	1,466.7	2,009.5	2,184.0	2,258.9
Total	2,583.4	2,825.3	2,495.3	1,768.4	1,697.1	2,114.3	3,460.6	3,675.2	3,994.2	3,985.0	4,328.9	5,600.1	6,134.8	6,589.1	6,597.4

The Oregon and Washington State Office cost centers were combined from fiscal year (FY) 1990 to FY 1992. The Oregon State Office was returned to District status in 1993 with its own cost center.

The funding table illustrates the predominance of Federal funds that made up the District budget during this period. The substantial increase in Federal funds in 1986 was a result of the NAQWA pilot study in the Yakima River Basin. Federal thrust dollars for similar studies in the Willamette River Basin in 1991–92 continued to increase the Oregon District budget.

SUPPORT SERVICES

At the start of the period Alex Gonsalves was head of the Reports Section. He transferred to the Department of the Navy in about 1981 and was replaced by David Curtiss. The regional reorganization allowed the Oregon and Washington State Offices to utilize the expertise in reports preparation and computer support in a more efficient manner. Curtiss managed the Reports Unit in Oregon and provided management oversight and technical consultation in distributing the work of both State Offices. Richard Hollway was the lead person in the management and reorganization of the computer support teams in both States, and he also served as a representative on national committees responsible for computer support redesign.

HYDROLOGIC SURVEILLANCE

The hydrologic surveillance program accounted for a large part of the District budget in 1979. Approximately one-half the District staff was dedicated to the collection, analysis, and publication of hydrologic data. Streamflow was the predominant parameter, but the District also was active in the collection of stream-chemistry, sediment-transport, and ground-water-level data. The hydrologic surveillance staff also supported data-collection activities for interpretive and research projects and contributed to the development of acoustic-velocity metering systems and satellite data telemetry. Tony Laenen and Gary Gallino received technical and operational support from Field Office staff members as they tested acoustic and telemetry systems, respectively.

The traditional leadership of this program by an Assistant District Chief was eliminated by the sub-regional reorganization. The Field Office Chiefs became active in the development and maintenance of programs in their respective areas. Review and publication of hydrologic data for the Oregon and Washington Districts were centralized in the Oregon District

Hydrologic data network sites, 1979–94

Water year	Continuous streamflow	Stage only	Stage and contents	Crest stage	Continuous water quality	Precipitation
1979	278	10	43	95	85	---
1980	287	10	41	49	98	6
1981	270	12	44	50	90	8
1982	253	8	837	33	81	---
1983	254	6	27	33	81	4
1984	259	8	39	13	96	3
1985	259	10	37	5	82	3
1986	269	10	39	5	78	3
1987	264	8	39	5	69	3
1988	250	7	39	5	44	3
1989	251	7	39	5	43	3
1990	246	10	37	5	47	3
1991	236	7	36	5	48	3
1992	190	5	33	1	51	3
1993	199	5	31	1	53	2
1994	201	---	32	1	47	2

under the leadership of Lawrence E. (Ed) Hubbard. This centralization was so successful that it was retained when the regional organization reverted back to District-level operation. The redistribution of field work was also a success and was retained with the Pasco, Wash., Field Office running data sites in northeastern Oregon and the Boise, Idaho, Field Office collecting data for Snake River Basin streams in southeastern Oregon.

In 1992, the reduction in funds to OWRD and other State and local agencies resulted in the loss of 60 streamflow-data sites, including most of the natural streamflow sites operated in Oregon. Many of the remaining sites in the network were mandated by regulatory agencies. As a result, funding for many of these sites was shared by multiple agencies. The following table shows the number of sites in the data network.

The data program did expand to include continuous water-quality monitoring for the Corps of Engineers as part of the Lost Creek Reservoir Water Quality Program. Several 5-parameter water-quality monitors were installed and operated by the Medford Field Office. The City of Portland also expanded its hydrologic data-collection program in the Bull Run watershed, which provides water to Portland and several other cities in the metropolitan area. Periodic sediment pump samplers were installed at all existing streamflow data sites, and two additional sites were established to monitor sediment transport into the system's two reservoirs.

Another major effect on the hydrologic data program resulted from a major overhaul of data processing, the advent of distributed data bases at the District level, and technology advances in data collection and processing. The Oregon District was at the forefront in testing and implementing satellite-data telemetry, electronic data loggers, acoustic-velocity metering systems, and acoustic doppler streamflow-measuring techniques, and in equipping field personnel with laptop computers. The District became very active in providing real-time data through the Internet, a move that was widely popular with water managers and the public.

Several significant hydrologic events occurred during this period in the Oregon District's history. In 1983 the closed lakes basin in southeast Oregon and Utah experienced record high lake levels. Malheur and Harney Lakes rose to levels that inundated roads and rail lines for an extended period. The Oregon District monitored these rising lake levels and published a flood inundation report authored by Larry Hubbard. Some unique data-collection methodology had to be used to monitor multidirectional flow between Malheur and Harney Lakes. The Rogue River Basin experienced major flooding in 1984 and was plagued by severe drought conditions from 1985 to 1992. Many streamflow sites in the region recorded record minimum flow during this period. The drought extended statewide but was most severe in the southern part of the State.

HYDROLOGIC INVESTIGATIONS

The Oregon District was active with hydrologic investigations in all disciplines during the period 1979–94. A complete listing of reports published and studies in progress for this period in the Oregon District's history is in USGS Open-File Report 93–493, "Summary of Water Resources Activities in Oregon: Fiscal Year 1993." The staff evolved to include scientists and project leaders capable of advancing the understanding of the hydrology of the State and hydrologic science in general. Several new hydrologists with advanced degrees in geology, chemistry, mathematics, hydrology, and environmental science were added to the District staff. The District interpretive studies program changed from a largely quantitative resource-assessment focus to studies that were very qualitative involving state-of-the-art computer modeling. The District cooperated with over 25 Federal, State, and local agencies to conduct studies to improve knowledge of hydrologic systems in Oregon and the Pacific Northwest. One of the successes of the subregional reorganization was the interaction between scientific staff members in area States in designing and implementing sophisticated studies that would not have been possible with the expertise available to a single District.

SURFACE WATER

Surface-water studies included the traditional statistical analyses, flood profiles, and compilation reports as well as some more complex areas of hydrologic study. Studies incorporating modeling, urban hydrology, instrument development, and prediction and risk assessment were included in the District program.

Instrumentation development included the continuation of testing and system design for acoustic

systems. Tony Laenen and Winchell Smith, of the Regional staff, continued their work on acoustic-velocity metering systems and the analysis of data generated by these instruments (Water-Supply Paper 2213). Laenen was also at the forefront of developing techniques for the use of acoustic doppler streamflow-measuring systems. Both of these techniques are now common in streams affected by flow reversals, backwater, and slow velocities.

The Portland Subdistrict was involved very early in satellite-data telemetry. Gallino and the staff of the Portland Subdistrict Office tested several Landsat data-collection platforms in the City of Portland's Bull Run Watershed. This method of real-time data transmission, which has improved greatly with geostationary satellites, is now the norm in data telemetry nationwide.

Milo Crumrine started developing a data-collection system designed to continuously monitor scour around bridge piers during major flood events (WRIR 90–4199). When perfected, this instrumentation will be another tool available to improve public safety. This work was done in cooperation with the Oregon Department of Transportation (ODOT).

The 1980 eruption of Mount Saint Helens and the subsequent debris flows created a demand for risk analysis associated with these events. The proximity of researchers at the Cascades Volcano Observatory (CVO) in Vancouver, Wash., provided collegial opportunities to develop these studies. Lahar simulations by Laenen, Leonard L. Orzol, and Peter Hansen for a breakout of Spirit Lake on the flanks of Mount Saint Helens is an example of this cooperation. John Friday led a study to assess risk of debris flows in the Oregon Caves National Monument in southwestern Oregon, and Gallino and Pierson, of the CVO staff, studied the cause and effect of a debris flow on Mount Hood that took one life and caused tens of millions of dollars damage to roads and bridges.

Planners and managers in the Portland metropolitan area became very interested in urban hydrology as it applied to storm runoff quantity, quality, and areal and time distribution. Laenen was project leader for studies of urban basins in the Portland metropolitan area (including Vancouver, Wash.) and in Salem, Oreg.

David Harris and Ed Hubbard completed compilation reports on magnitude and frequency of flood events in eastern Oregon. Larry Hubbard investigated the hydrology and flooding of the closed lakes basin in southeastern Oregon, which includes Malheur and Harney Lakes, and Larry Hubbard was also the lead investigator for historical drought conditions in southern Oregon.

Laenen and John Risley were project leaders of studies using the application of rainfall-runoff models to simulate the effects of forest management practices in coastal basins in western Oregon.

GROUND WATER

The scope of ground-water studies escalated from county and basinwide assessment to studies of regional aquifer systems. Most studies became multidisciplinary, incorporating elements of water chemistry and the influence of base flow to streams. Digital models and Geographic Information System (GIS) interfaces to ground-water models became common tools in the understanding of natural and human-induced stress response of aquifers. Studies designed to increase understanding of the State's geothermal areas were initiated at both the State and Regional level. Oregon's Indian Reservation lands became the focus of several hydrologic-assessment projects.

Aquifer assessments at the quadrangle scale were conducted by F.J. Frank, J.H. Robison and C.A. Collins. Countywide studies were completed for Jackson County (L.L. Orzol) and for Clark County, Wash. (D.T. Snyder).

The Portland Basin was the focus of several studies as the city looked to the ground-water reservoir as a supplement to the surface supply from the Bull Run watershed. Before 1979, the District had limited experience with ground-water models. James Luzier transferred in from the New Jersey District to increase expertise in this area; he initiated a modeling program with the City of Portland to improve quantitative understanding of aquifers in the Portland well field. This modeling effort by Luzier, David Morgan, and William McFarland was the beginning of qualitative ground-water modeling in the Oregon District. The study was expanded in the late 1980's and early 1990's to a regional ground-water study of the Portland Basin. Several reports were published from these studies, including W.D. McFarland and Susan Hartford (WRIR 88–4110); R.D. Swanson, W.D. McFarland, J.B. Gonthier, and J.M. Wilkinson (WRIR 90–4196); W.D. McFarland and D.S. Morgan (WRIR 92–4041, 4089); and K.A. McCarthy and D.B. Anderson (OFR 90–126). Ground-water models were the primary tool

in analyzing ground-water systems in several studies conducted by Morgan, Bolke, Snyder, Orzol, and McFarland. These studies were instrumental in developing the ability to interface ground-water-flow models with GIS files.

The Coos Bay–North Bend area of the southern Oregon coast was also an area of intense study as this growing region looked for a way to increase the available supply of water. Early work in this area was done by Luzier and Collins. After Luzier retired in 1984, a team of hydrologists from the Washington State office began looking at the geochemistry of water from an aquifer under the sand dunes.

John J. Vaccaro, of the Washington State office, started a regional ground-water study of the Puget-Willamette Lowlands in 1988. This study included a description of principal aquifers and regional flow-system performance. Marshall W. Gannett was in charge of much of the RASA work in the Willamette River Valley with assistance from Collins, the District water-use coordinator.

Assessment of hydrothermal areas of the State were conducted by Morgan (southern Oregon and northern California) and by E.A. Sammel of the Western Regional Staff (central Oregon).

Several geohydrologists on the Oregon District staff were involved in hydrologic assessment of Indian Reservation lands. Robison and Laenen studied ground- and surface-water resources of the Warm Springs Reservation. Bolke and Gonthier worked on the Umatilla Indian Reservation to summarize water availability.

This is only a small sampling of the work that was accomplished in the ground-water discipline during this period in the Oregon District's history. The diversity of the staff and of the projects they developed elevated the District's technical image with cooperators throughout Federal and State hydrologic communities.

WATER QUALITY

During this period in the Oregon District's history a water-quality component became the driving force in many hydrologic investigations. The continuation of work on the Willamette River and Portland Harbor produced several report products and provided local managers with the tools necessary to plan the cleanup of the lower river. The Oregon office conducted one of the first pilot National Water-Quality Assessment (NAWQA) projects in the Yakima River Basin in central Washington.

Water-quality investigations evolved from assessments of surface- and ground-water chemistry to investigations of point-source and nonpoint-source pollution, studies of aquatic organisms as an indicator of stream health, and basinwide assessments aimed at identifying water-quality problems and solutions.

Although Rickert and Walter Hines left the District in 1976, much of their work and many report products from their study in the lower Willamette River and Portland Harbor continued into the early 1980's. The team included Stuart McKenzie, Joseph Rinella, Frank Rinella, and Timothy Miller and was supplemented by researchers from throughout the USGS. They published numerous Circulars on the health of the lower river (Circulars 715A–M). This major study provided a stepping stone to spin-off several studies looking at bed sediments as a storehouse for trace metals (G.J. Fuhrer and A.J. Horowitz, WRIR 88–4099; G.J. Fuhrer, WRIR 86–4088). Elutriate tests were also conducted on bed materials to assess the effects of dredging in the Portland Harbor and lower Columbia River (G.J. Fuhrer, WRIR 89–4005, 89–4051).

Long-term studies designed to evaluate the health of the water resource of large geographical areas became common. Federal thrust programs like NAWQA provided the impetus to expand from smaller, localized assessments to a basinwide cataloging of elements affecting surface- and ground-water health. Tim Miller from the Oregon District was named Chief of the NAWQA national thrust program after transferring to Reston in 1991.

During this period in the Oregon District's history, a major water-quality study was started in the Tualatin River Basin to evaluate phosphorus loads because of total maximum daily load restrictions established by the Oregon Department of Environmental Quality. These standards, set largely without scientific input, were of great concern to the United Sewerage Agency (USA) responsible for regional water treatment. In 1990, Dennis Lynch transferred to the District from the Virginia District to be Chief of this project and to accept managerial responsibility as Chief of the Environmental Studies Section. This study was largely responsible for advancing the District's ability in water-quality modeling. Stewart Rounds took over responsibility for this project when Lynch was named District Chief in 1993. Rounds worked with Tamara M. Wood and John Risley to

increase Oregon's expertise and ability in water-quality modeling.

Also during the period, two major NAWQA studies were conducted by the Oregon District. The Yakima Basin Pilot study in central Washington was headed up by Stuart McKenzie. His staff included Joseph Rinella, Frank Rinella, and G.J. Fuhrer. The Yakima study was one of the first series of NAWQA studies. The Yakima team developed several innovative study methods and had a major influence on future NAWQA studies.

In 1991, the Willamette NAWQA was initiated as one of the first set of NAWQA projects. Dennis Wentz transferred from the Wisconsin District to become Chief of the Willamette NAWQA. Early results from this study and the Willamette pesticides study conducted by Chauncey Anderson and Tammy Wood indicated that farming practices were affecting water resources in the Willamette Valley.

All of the larger studies included public forums and interaction between scientists from multiple agencies. The data generated by these studies provide an opportunity to develop models capable of predicting response to human activities, natural events, and remediation efforts.

EPILOGUE

During this period of the Oregon District's history, the changes in focus and the ability to perform large multidiscipline studies were notable. The District was a leader in promoting technical advances in analytical processes and instrumentation. District programs evolved from a water-quantity-based program dominated by surface-water-related projects and data collection to a program with more balance within the disciplines. Members of the District continued to be leaders in the hydrologic community of the State and served on numerous local, State, and national committees aimed at improving the hydrologic science and at providing the best possible support to agencies charged with water management.

UTAH

By Joseph S. Gates *and reviewed by* Ted Arnow, H. Lee Case, *and* Dale E. Wilberg, *with additional comments by* James L. Mason, Lawrence E. Spangler, David V. Allen, Carole B. Burden, *and* Julane N. Mulder

INTRODUCTION

The 1979–94 period was a time of great change in the Utah District. The District office moved to the Administration Building at 1700 South Street and Redwood Road in November 1979. It remained there throughout the period, although in the early 1990's, attempts were made to find new quarters because the Administration Building was about 50 years old, showing its age, and the General Services Administration stated it was scheduled to be decommissioned. Long-time District management changed, and the oversight of the District changed in fiscal year (FY) 1991 from the Central Region in Denver to the Western Region in Menlo Park.

Significant changes also took place in the District program. At the beginning of the period, the program was fairly stable from year to year and the cooperative (Coop) program, its largest component, was dominated by work done in cooperation with the Utah Division of Water Rights, and to a lesser extent the Division of Water Resources, agencies primarily interested in water supply and management. Only moderate effort to seek out new cooperators and programs was necessary. During the latter half of the 1979–94 period, balancing District expenses and funding was more difficult, partly because funding for energy-related studies and national interpretive programs declined, and it was necessary to expend more effort with current and potential cooperators to develop new programs.

The type of data collection and interpretive studies changed considerably—those related to water quality and contamination increased markedly to meet the growing need for this kind of information. In contrast, energy-related data collection and interpretive studies, which made up an important part of the program in the latter half of the 1966–79 period,

became a much smaller part of the program after 1984. National interpretive programs were important during 1979–94. The Regional Aquifer-System Analysis (RASA) program provided significant funding to the District during 1981–86, and the National Water-Quality Assessment (NAWQA) Program began in the District in 1994.

ORGANIZATION AND MANAGEMENT

District management, which had been stable during 1966–79, changed considerably during 1979–94. Ted Arnow, District Chief since 1966, retired in 1986 and was replaced by H. Lee Case who transferred from the New Mexico District in February 1987. James C. Mundorff, Chief of the Hydrologic Surveillance Section since 1966, retired in 1979 and was replaced by Russell W. Cruff, the Assistant District Chief, who continued to fill both positions until he retired in 1986. After 1986, the position of Assistant District Chief was not filled. Kenneth L. Lindskov, a project chief in the Investigations Section, who had also been serving as Publications Section Chief, replaced Cruff as Hydrologic Surveillance (HS) Section Chief and continued until he transferred to the North Dakota District in 1988. Darrell D. Carlson transferred into the District to take the position of HS Section Chief in 1988 and continued until he transferred in 1991 to become Surface-Water Specialist in the Southeast Region. James R. Kolva transferred into the District in 1992 to the position of HS Section Chief. Joseph S. Gates, Chief of the Investigations Section since 1977, continued during the 1979–94 period and retired in 1994.

The Publications Section was supervised by Don Price until he retired in 1987, by Kenneth L. Lindskov until 1988, and by Gail E. Cordy, who had been a project chief in the Investigations Section, until she transferred to the Arizona District in 1993. Geoffrey W. Freethey, a project chief in the Investigations Section, succeeded Cordy. David L. Hansen was the District Administrative Officer and head of the Administrative Services Section until he retired in 1984. He was succeeded by Kay R. Powell who served the remainder of the period. The District set up an Automatic Data Processing (ADP) Unit in 1981, supervised by Kidd M. Waddell, a project chief in the Investigations Section. The ADP Unit was designated the Computer Section in 1989. A Data Management Section was set up in 1992, supervised by David V. Allen.

In 1979, the District included Subdistricts in Salt Lake City, supervised by George E. Pyper; in Cedar City, supervised by George W. Sandberg; in Logan, supervised by Wallace N. Jibson; and in Vernal, supervised by Glenn C. Anderson. A Field Headquarters in Moab was supervised by George A. Birdwell. The District also had a small water-quality laboratory in Salt Lake City that was disbanded about 1982. After Pyper's transfer to the Investigations Section in 1980, the Salt Lake City Subdistrict was led by Ezra T. Hookano, Jr., during 1981–85. In 1986, the Salt Lake City Subdistrict was designated a Field Headquarters and was supervised by Michael D. ReMillard through 1994. Sandberg continued to lead the Cedar City Subdistrict until he retired in 1990. The Cedar City Subdistrict was designated a Field Headquarters in 1990, and Terry Lockner transferred into the District in 1990 to supervise it. Wallace Jibson retired in 1979, and the Logan Subdistrict was designated a Field Headquarters in 1981, supervised by Richard B. Garrett. The Logan office was closed in about 1985, and the personnel transferred to Salt Lake City. Glenn Anderson retired in 1985, and the Vernal Subdistrict was closed and personnel transferred to Salt Lake City. The Moab Field Headquarters was supervised by Birdwell throughout the 1979–94 period.

PERSONNEL

In 1979, the District staff was 80 persons: 53 full time, 19 part time, and 8 temporary. In 1993 (1994 information was not available), the District staff was 76: 67 full time, 8 part time and intermittent, and 1 temporary. In 1979, the staff included 29 hydrologists and computer programmers, 36 technicians (including computer and cartographic technicians), and 15 administrative personnel and editorial assistants. In 1993 the staff comprised 31 hydrologists, computer programmers, physical scientists, and editors, 39 technicians (including computer technicians), visual information specialists, and writer-editors, and 6 administrative personnel. The smaller number of administrative personnel was mainly a result of closing Field Offices and reducing clerical help in the District sections. In 1979, 35 people worked primarily in data collection and processing, 31 primarily in investigations, and 14 in support functions. In 1993, 29 people worked primarily in data collection and

processing, 33 people primarily in investigations, and 14 in support functions.

Key, long-term personnel in the District not mentioned elsewhere include, in the Administrative Services Section: Cathy Ralph, Shonna L. Dennison, and Shauna L. Meyer; in the HS Section, Carole B. Burden and Melanie Smith Elizondo; in the Salt Lake City Field Headquarters, Donald M. Batty (also was in the Vernal Field Headquarters), Lambert V. Jensen, James D. Sory, Dixie D. Canny (later in the ADP Section), Donald A. Bischoff (also in the Logan Field Headquarters), James P. Eads (later in the ADP Section), Gregory J. Smith, John A. Yarbrough, W. James Thomas, Michael R. Greene, Mark R. Danner, Paul Downhour, and Steven J. Gerner; in the ADP section, Patsy D. Fikstad and Julane N. Mulder (later of the Data Management Section); in the Publications Section, Doris A. Vandruff, Kenneth M. Merrill, Vickie H. McEwen (also was in the District Water-Quality Laboratory), Stefanie L. Dragos (also was in the District Chief's office), Joseph F. Gardner, Charles E. Turner, Ellen E. Hardy, and Constance J. Allen; in the Cedar City Field Headquarters, Deloy C. Emett, Rolaine G. King, Robert L. Swenson, Bradley A. Slaugh, Howard K. Christiansen, Bradley Sether (also was in the Vernal Field Headquarters), and James H. Howells; and in the Moab Field Headquarters, Jerry C. McNeely, James R. Tibbetts, and Michael G. Hawkins.

FUNDING

Table 1 presents data for funding sources for FY 1979–94. Total District funding was about the same in 1987 as it was in 1979, about $3 million, although it was as much as 2 percent higher in the years between. The Coop program increased about 42 percent during 1979–87, but the Federal program and funding from other Federal agencies decreased, mostly due to reductions in energy-related studies such as oil-shale hydrology. The slightly higher Federal funding during 1980–85 was largely a result of funding for the RASA program, which began in the District in 1981, peaked in 1983–84, and was at a low level by 1987.

From 1987 to 1994, District funding grew substantially, by about 66 percent, to a peak of more than $5 million in 1992 (table 1). The Coop program grew about 28 percent from 1987 to 1994, but the Federal program doubled, and funding from other Federal agencies more than tripled. Much of this funding was for studies of water contamination, and significant amounts came from the Department of Defense and other Department of the Interior agencies. Despite the increases in funding during 1987–94, in most years much creativity and effort were necessary to balance the budget.

Funding for data collection and processing increased about 64 percent from 1979 to 1994, but a large part of that was in funding for water-quality data, which almost quadrupled, from about $181,000 in 1981 to about $702,000 in 1994. In contrast, funding for surface- and ground-water data increased by only about 58 percent during the same period.

In terms of interpretive studies, funding for energy-related studies (hydrology and hydrologic problems related to actual or potential oil-shale, coal, petroleum, and tar-sands production), which was an

Table 1. Utah District funds by source, fiscal years 1979–94 (in thousands of dollars)

Fund source	1979	1980	1981	1982	1983	1984	1985	1986
Cooperative program	1,589.8	1,941.1	1,863.5	1,958.0	1,839.2	1,808.7	2,046.7	1,997.9
Federal program	707.7	799.7	926.9	749.4	821.9	755.9	702.7	516.9
Other Federal agencies	713.7	575.4	898.4	662.2	970.0	788.8	472.7	579.5
Total	3,011.2	3,316.1	3,688.7	3,369.6	3,631.1	3,353.4	3,222.1	3,094.4
Fund source	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
Cooperative program	2,253.4	2,395.7	2,496.3	2,389.8	2,673.1	2,484.3	2,592.6	2,874.1
Federal program	358.6	255.9	321.2	333.0	533.0	514.1	547.3	776.2
Other Federal agencies	396.2	843.6	1,059.6	1,419.3	1,220.0	2,289.9	1,758.8	1,333.7
Total	3,008.1	3,495.2	3,877.2	4,142.1	4,426.0	5,287.2	4,898.6	4,984.0

important part of the District program during 1975–79, continued to be a significant source of funding until 1987, after which it was less important. Funding for energy-related studies peaked in 1981 at about $970,000; at this point, most of the work was in coal-resource areas. Studies of water-quality contamination were significant sources of funding after 1987. Funding increased from about $175,000 in 1987 to $1.3 million in 1992, then decreased to about $570,000 in 1994. Much of this was to study contamination of ground water by organic chemicals at Hill Air Force Base near Ogden, Utah, and contamination of surface water and ground water by selenium derived from irrigation drainage in the middle Green River Basin.

CHANGES IN TECHNOLOGY

The rapid changes in technology that occurred during 1966–79, as noted in "A History of the Water Resources Division, volume VII," continued during 1979–94. Collection, processing, and analysis of data by computer became more routine. Surface-water data were transmitted by satellite, and real-time data were more readily available. The District's first data-collection platform was installed on the Duchesne River near Randlett in 1988. Collection and analysis of water samples to obtain quality data became much more sophisticated as accuracy of data became increasingly important. Quality-assurance programs were implemented to ensure reliability of water-quality data. The days of using a soda-pop bottle as an emergency container for a sample were long past. Geochemical data were collected and routinely used to interpret hydrology, and the use of biological data to assess water quality increased. Quality-assurance programs also were developed for surface- and ground-water data collection. Simulation of hydrologic systems (especially ground-water systems) using computer programs became common, and the complexity and sophistication of the programs increased.

The preparation, processing, and publication of reports also underwent substantial technological change. Reports were prepared on computers which could produce camera-ready copy. The process of preparing illustrations for reports changed during 1979–94 from traditional drafting techniques to use of computer graphics; after about 1990, these methods were used exclusively.

PROGRAMS

The Coop program continued to be the main part of District activity. In 1979, it was about 53 percent of the District's budget and in 1994 about 58 percent. In between, it varied from a low of 47 percent in 1992, the year the total budget was highest, to a high of 75 percent in 1987, the year the total budget was lowest. In 1992, Federal and other Federal agency funding was very high and in 1987 was very low. The Coop program funding actually changed relatively little, which illustrates that the Coop program was the most stable part of the District's activity and that these highs and lows mostly reflected changes in the Federal and other Federal agency programs. In the early part of the 1979–94 period, the part of the program in cooperation with the State's water-supply and management agencies, the Utah Divisions of Water Rights and Water Resources, was a larger proportion of District funding than at the end of the period. In 1982, when the Coop program was about 58 percent of the total District program, the program with the Divisions of Water Rights and Water Resources was 79 percent of the Coop program and 46 percent of the total District program. In 1994, when the Coop program was also 58 percent of the total, this part of the program was 71 percent of the Coop program and 41 percent of the total District program.

Hydrologic Surveillance

Collection, processing, and publication of hydrologic data generally made up about 50 percent of District activities during 1979–94 and was the most stable part of the program. The data program made up about 57 percent of the District budget in 1979 and about 51 percent in 1994. It varied from a low of 39 percent in 1981 to the high of 57 percent in 1979. In general, it tended to be lower when the total budget was high, and higher when the total budget was low. This illustrates that the Hydrologic Surveillance program was more stable than the Hydrologic Investigations program and that highs and lows in funding for hydrologic investigations were the major factor in variations in the total budget.

The District's long-term study to document and annually report changes in ground-water conditions in Utah (water-level changes, withdrawals of ground water, and construction of wells) began in 1964. It continued as a separate project until 1982 under the overall direction of the Investigations Section, with

Table 2. Data-collection sites in the Utah District, fiscal years (FY) 1979, 1986, and 1994

Type of site	FY1979	FY1986	FY1994
Surface-water data			
Streamflow stations	248	195	180
Streamflow stations (partial record)	–	–	7
Reservoirs	18	15	17
Lake-stage stations	3	2	3
Ground-water data			
Water-level observations			
Annual measurements	1,030	1,000	1,000
Semiannual measurements[1]	720	600	–
Monthly measurements[1]	–	–	2
Continuous data by recorder[1]	33	31	27
Springs—continuous stage/discharge data by recorder	4	–	–
Discharge from wells	330	300	280
Quality-of-water data			
Surface-water sites			
Water-quality analyses			
Periodic measurements	25	16	35
Daily measurements	7	8	–
Specific-conductance measurements[2]			
Periodic	140	157	?
Daily or continuous by recorder	—	—	8
Sediment-size analyses			
Periodic	21	21	8
Daily or continuous by recorder	11	5	2
Temperature			
Monthly	140	157	—
Daily	18	9	8
Ground-water sites			
Water-quality observation wells	315	190	210
Springs	3	–	–

[1] Generally included in the number of wells measured annually.
[2] Generally include temperature measurements.

Dashes indicate a lack of information on data collection at specific types of sites—for some types of sites, this probably reflects that no data were collected, at others it is unknown.

Source: "Water Resources Studies in Utah"—annual summaries of progress by the U.S. Geological Survey.

much of the data collection done by the HS Section. After 1982, this work was done under the ground-water data-collection program of the Hydrologic Surveillance Section, with participation by members of the Investigations Section.

Table 2 shows the data-collection sites in the District for 1979, 1986, and 1994. Although the total funding for data collection increased by about 64 percent during 1979–94, the numbers of sites generally decreased, although the surface-water-quality collection sites (except for sediment-data sites) increased slightly. The number of surface-water gaging stations (which accounted for about one-half of the funding for data collection in 1994 and probably more than that in 1979) decreased about 27 percent from 248 in 1979 to 180 in 1994. Although the funding for water-quality data collection increased by almost four times between 1981 and 1994, the number of data-collection sites for water quality increased only slightly. This reflects the increased costs for water-quality data collection (as we got more understanding of the potential for contamination of a sample as it is collected, we realized we needed better sampling methods and increased quality control), as well as special short-term data-collection programs for individual agencies at sites that are not included in table 2.

Hydrologic Investigations

During 1979–94, the District program of hydrologic investigations included most of the major elements from earlier periods. These were (1) detailed studies of basins in western Utah from which large amounts of ground water commonly were withdrawn from unconsolidated deposits for irrigation and public supply; (2) studies of Great Salt Lake and the Bonneville Salt Flats; (3) studies which interpreted surface-water data to characterize runoff, describe flooding, or do special analyses; (4) studies of water quality in river basins, surface reservoirs, and ground-water reservoirs; (5) studies of ground water in consolidated-rock aquifers (mainly the Navajo Sandstone and related formations) of eastern and southern Utah; and (6) studies of the hydrology of energy-resource areas (coal, oil shale, petroleum, and tar sands). In addition, during 1979–94 the District began (7) comprehensive studies of contamination of both surface and ground water—these studies made up a significant part of the District program beginning in 1988. The District also participated (8) in several national, regional, and local interpretive and data-collection studies.

Studies of ground water in western Utah basins: Studies of ground-water basins in western Utah, most of which are extensively developed, continued to be an important part of the District program. Many of these basins had been studied previously and were restudied because increased ground-water development provided additional data and increased need for assessment. In addition, new technology made more comprehensive analyses possible;

since 1975, studies generally have included construction of digital models of ground-water flow.

During 1979–94, ground-water basin studies included the Sevier Desert (the District's second study of the area) by Walter F. Holmes, Michael Enright, and Dale E. Wilberg; northern Utah Valley (the District's third study) by David W. Clark and Cynthia L. Appel; the Salt Lake Valley (the fourth study of this important area by the District, and a study which included much water-quality work) by Kidd M. Waddell, Ralph L. Seiler, D.K. Solomon, and Melissa Santini; the East Shore area (between the Great Salt Lake's east shore and the Wasatch Range—the fourth study in the area by the District) by Clark, Patrick M. Lambert, Gerald G. Plantz, and Robert L. Puryear; Ogden Valley (a valley just east of the Wasatch Range and thus just outside "western" Utah, and the District's second study) by Charles Avery; Pahvant Valley (District's third study) by Holmes and Susan A. Thiros; the central Sevier River valley (second study) by Lambert, James L. Mason, and Richard W. Puchta; Sanpete Valley (second study) by Wilberg and Victor M. Heilweil; the upper Sevier River Basin/ Panguitch Valley (second study) by Thiros and William C. Brothers; Heber and Round Valleys (second study) by D. Michael Roark, Holmes, and Heidi K. Shlosar (Hadley); southern Utah and Goshen Valleys (second study) by Lynette E. Brooks and Bernard J. Stolp; Cache Valley (second study) by Kim A. Kariya, Roark, and Karen M. Hanson; the District's fifth study of the Salt Lake Valley, focused on digital modeling and solute transport, by Lambert, Thiros, and Geoffrey W. Freethey; and Juab Valley (1992–95, second study) by Thiros, Stolp, Heidi K. Hadley, and Judy I. Steiger.

In addition, several ground-water basin studies did not include models of ground-water flow—a study of the Park City area (another valley just east of the Wasatch Range and the District's second study in the area) by Holmes, Kendall R. Thompson, and Enright; the southeastern part of Tooele Valley by Stolp; Beaver Dam Wash (including parts of the area in Arizona and Nevada) by Holmes, George E. Pyper, Joseph S. Gates, Donald H. Schaefer (of the Nevada District), and Waddell; and a third study of the Park City area (1993–97, which included digital-model simulation of snowmelt) by Brooks, Mason, and David D. Susong. A special study of recharge by irrigation was also done in the Milford area (which included model simulation of vertical unsaturated flow) by Susong.

Although a series of reconnaissances to study the hydrology (mostly ground water) of largely undeveloped basins in western Utah was completed in 1980, the District did a few more after that. These included the Sevier Lake area by Wilberg; a reconnaissance of springs in Juab, Millard, and Utah Counties by Wilberg and Stolp; and a reconnaissance of the several parts of the Paiute Indian Reservation in southwestern Utah by Don Price, Doyle W. Stephens, and Loretta S. Conroy.

Studies of Great Salt Lake and the Bonneville Salt Flats: Studies of Great Salt Lake, the Bonneville Salt Flats, and related projects included a study of water levels, water quality, and hydrologic characteristics of Great Salt Lake by Ted Arnow and Doyle W. Stephens; a project to update a digital model of the Great Salt Lake by Steven R. Wold, Blakemore E. Thomas, and Kidd M. Waddell; a study of the salt budget of West Pond, created when water was pumped out of Great Salt Lake during the high-water years of the mid-1980's, by Wold and Waddell; and a study of the Bonneville Salt Flats (District's second study—included a model) by James L. Mason, Kenneth L. Kipp, Jr. (of Central Region Research), William C. Brothers, Linda J. Gerner, and Pamela S. Muir.

Surface-water studies: Surface-water studies included flood-plain mapping and preparing profiles of theoretical floods, mainly in coal-lease areas in central and eastern Utah, by Kenneth L. Lindskov and Blakemore E. Thomas; regionalization of streamflow characteristics in the Colorado River Basin by Rulon C. Christensen and E. Blaine Johnson; and flood characteristics of urban watersheds along the western side of the Wasatch Range by Lindskov and Kendall R. Thompson.

The District's series of studies of seepage gains and losses to canals continued with canals in the Sevier Desert plus the Sevier River by Larry R. Herbert, Russell W. Cruff, and Walter F. Holmes; and canals in the Salt Lake Valley by Herbert, Cruff, and Kidd M. Waddell. Although this series ended as a separate set of studies in 1984, seepage studies of canals and streams continued as a part of several ground-water basin studies in order to obtain information on ground-water recharge and discharge. Canal or stream gain/loss studies were done for the Weber River and canals in the East Shore area and Ogden Valley by Herbert, Cruff, David W. Clark, and Charles Avery; of the Central Utah Canal in Pahvant Valley by Michael Enright; of canals in the central Sevier River valley by

Herbert and Gregory J. Smith; of the Sevier and San Pitch Rivers and canals in the central and upper Sevier River basin by George W. Sandberg and Cynthia J. Smith; of canals in Heber Valley by Herbert, Carole B. Burden, and Brian K. Thomas; and of the Bear River and Cutler Reservoir in Cache Valley by Herbert and Thomas.

Water-quality studies: Studies of water quality in river basins, surface reservoirs, and ground-water reservoirs included a continuation of the District program of reconnaissances of water quality and sediment in major river basins of the State (this series of studies ended in 1983) and a special study. Reconnaissances of water quality and sediment in river basins included those of the Weber River Basin by Kendall R. Thompson, and the upper Virgin River Basin by George W. Sandberg and LaVerne G. Sultz. The special water-quality study was of the effects of thermal, saline springs on the water quality of Utah Lake by Robert L. Baskin, Lawrence E. Spangler, and Walter F. Holmes.

Studies of ground water in consolidated-rock aquifers: Studies of ground water in consolidated-rock aquifers of southern and southeastern Utah included those of the northern San Rafael Swell by James W. Hood and Dennis J. Patterson; the Kaiparowits Plateau by Paul J. Blanchard; eastern San Juan County by Charles Avery; the Lake Powell area by Blanchard; Grand County/Spanish Valley by Blanchard; and the southwestern corner of Utah and adjacent northwestern Arizona (this study included a digital model) by Victor M. Heilweil and Geoffrey W. Freethey.

The hydrology of energy-resource areas: Studies of energy-resource areas included the hydrology of oil-shale, coal, petroleum, and tar-sands areas. The oil-shale hydrology study in the Uinta Basin began in 1975, had a large cut in funding in 1979, continued at a lower level of effort until 1981, and then went to mostly a monitoring effort through 1983. This study was conducted until 1981 by Kenneth L. Lindskov, Walter F. Holmes, Briant A. Kimball, John E. Tooley, Scott D. Waltemeyer, Ronald L. Naten, Loretta S. Conroy, and Ralph L. Seiler.

Studies of coal-resource areas included monitoring in coal areas of central and southern Utah through 1984 by Gerald G. Plantz; the Huntington and Cottonwood Creeks areas by Terence W. Danielson, Michael D. ReMillard, and Richard H. Fuller; the Ferron Sandstone in Castle Valley, Emery County by Gregory C. Lines and Daniel J. Morrissey (included a digital model of ground-water flow); the southern Wasatch Plateau by Danielson, Dean A. Sylla, Tooley, and Michael J. Graham; the Price River basin by Kidd M. Waddell and Jeanette E. Dodge; the Kaiparowits, Alton, and Kolob coal fields by Plantz and Judy I. Steiger; the Trail Mountain area by Lines; areas 56 (mainly the Wasatch Plateau) and 57 (mainly the Kaiparowits, Alton, and Kolob coal fields) of the Rocky Mountain Coal Province by Lines and Don Price; the Pleasant Valley coal area and effects of mining on Scofield Reservoir (this study could also be classified as a water-quality/contamination study) by Doyle W. Stephens, Kendall R. Thompson, and James B. Wangsgard; the Castle Valley Ridge and Alkali Creek coal-lease areas by Seiler and Robert L. Baskin; the Quitchupah, Pines, and L.C. Holding coal-lease areas by Gail E. Cordy, Susan A. Thiros, Ralph L. Seiler, and Bernard J. Stolp; the Alton coal field by Geoffrey W. Freethey; and hydrologic effects of land subsidence caused by coal mining in the Miller Creek drainage, Carbon County, by Cecil B. Slaughter, Freethey, and Lawrence E. Spangler.

Studies of petroleum and tar-sands areas included depth to the base of moderately saline ground water in the petroleum-resource area of the Uinta Basin by Lewis W. Howells and Mark S. Longson; depth to the base of moderately saline ground water in the petroleum-resource area of San Juan County by Howells; hydrologic effects of brine injection, Uinta Basin by Freethey; ground-water salinity in the Aneth area, San Juan County by Spangler; geochemical studies of ground-water salinity in the Aneth area by David L. Naftz and Spangler; and tar-sand areas of eastern Utah by Lindskov, Howard R. McCormack, George E. Pyper, Stolp, and Willis Dorman-Ligh.

Studies of contamination of ground and surface water: During 1979–94, the District became involved in several series of studies related to water quality and contamination of surface and ground water—surface-water quality in Salt Lake County, contamination of ground water related to military operations at Hill Air Force Base, contamination of ground and surface water related to mining and ore processing in the Park City area, surface-water quality and contamination by irrigation drainage in the Green River Basin of northeastern Utah, studies of recharge areas and their relation to potential ground-water contamination, and a study of contamination of streams by mining waste.

The study of surface-water quality in Salt Lake County included the main study, which was focused on the quality and contamination of urban runoff in Salt Lake County, by Rulon C. Christensen, Doyle W. Stephens, George E. Pyper, Howard W. McCormack, Jay F. Weigel, and Loretta S. Conroy; and substudies of the quality, toxic substances, turbidity and suspended sediment, and dissolved oxygen of the Jordan River by Stephens, Kendall R. Thompson, and Weigel. In addition, a study of atmospheric input to quality of urban runoff was conducted by Stephens; and a study of effects of urban runoff on Decker Lake in Salt Lake County was done by Stephens and Thompson.

The study of contamination of ground water at Hill Air Force Base began with USGS-funded research of contamination by trichloroethene at chemical disposal pit no. 3 by Kidd M. Waddell and Stephens—this study was discontinued because the Air Force planned to proceed with remediation before the study could have been completed. Subsequently, the District became involved in an Air Force-funded study of contamination at landfills 1 and 2 at Hill Air Force Base by Waddell, Kim A. Kariya, Ralph E. Seiler, Linda J. Gerner, Peter L. Haraden, and Conroy. This study was the largest in the District for several years and also involved work by Cecil B. Slaughter, James L. Mason, Thomas J. Burbey (of the Nevada District), Dale E. Wilberg, Steven R. Wold, Victor M. Heilweil, Walter F. Holmes, D. Michael Roark, Thompson, and Richard W. Puchta. A spin-off study of the geochemical aspects of the contamination at landfills 1 and 2 was conducted by Waddell, Wilberg, and Briant A. Kimball; and a study of the hydrology of landfill areas at the Utah Test and Training Range west of Great Salt Lake, a satellite area of Hill Air Force Base, was done by Michael Enright, Holmes, Slaughter, Gerner, and Wilberg.

The studies of ground- and surface-water contamination related to mining and ore processing in the Park City area were done by Mason, Holmes, and Thompson and included one study focused on the effects of the Silver Creek tailings in and downstream from Prospector Square and a companion study focused on ground water in Prospector Square.

The studies of surface-water quality and contamination related to irrigation drainage in the Green River Basin of northeastern Utah began with a study of the effects of irrigation drainage on Stewart Lake Waterfowl Management Area in the Uinta Basin by Stephens, Weigel, Thompson, Bruce H. Waddell, Jr. (of the U.S. Fish and Wildlife Service), and Jerry B. Miller (of the Bureau of Reclamation). This was followed by an expanded study of the effects of irrigation drainage in other wildlife areas and wetlands of the middle Green River Basin by Stephens and Lorri A. Peltz-Lewis; a study of selenium contamination of lower Ashley Creek, Uintah County, and monitoring during remedial action along Ashley Creek and near the Stewart Lake Waterfowl Management Area, Ouray National Wildlife Refuge, and the Green River by Stephens; and a study of contamination by irrigation drainage in the Scofield area of Carbon County and the Desert Lake Waterfowl Management Area of Emery County by Stephens.

Studies of recharge areas for selected ground-water basins and their relation to potential ground-water contamination began with a study of recharge areas and contamination potential in Salt Lake Valley by Robert L. Baskin and Kidd Waddell. This was followed by studies of recharge areas, contamination potential, and classification of ground water based on chemical quality in the East Shore area, Cache Valley, the lower Bear River Valley, and Utah Valley by Thompson, Wold, Paul B. Anderson (consultant), David D. Susong, Heilweil, Baskin, and Tito J. Darden. These studies were followed by one of recharge areas, physical extent of aquifers, and classification of ground water in terms of quality in western Kane County by Lawrence E. Spangler, and a similar study of the Navajo Sandstone in Washington County by Geoffrey W. Freethey. A related study in Salt Lake County was conducted to develop methods of determining the effective areas around wells that should be protected from sources of ground-water contamination (wellhead-protection areas). This study was done by Freethey and Spangler.

In 1990, Briant A. Kimball transferred from the Colorado District, bringing his research project on the chemical processes in streams and stream sediment related to metal-mining wastes in the Leadville, Colo., area. This study continued through 1994.

National, regional, and local interpretive and data-collection studies: In addition to the above categories of studies, the Utah District participated in several national, regional, and local interpretive and data-collection studies, including RASA, NAWQA, the water-use program, the National Irrigation Water-Quality Program of the Department of the Interior, a study of geology and hydrology related to the potential

for isolation of high-level radioactive waste in the Basin and Range Province of the Western United States, and a review of the Bureau of Reclamation's Central Utah Project.

The District participated with the Nevada (lead) District in the Great Basin RASA, and the Utah part of the study was conducted by James L. Mason, James R. Stark, Joseph S. Gates, John W. Atwood, and Patricia L. Buettner. As a part of the Great Basin RASA, Mason constructed a digital model of the Milford area. The Great Basin RASA staff also participated in and provided information to the study, mentioned in the preceding paragraph, of the Basin and Range Province related to isolation of high-level radioactive waste, which was coordinated from the Central Region. The District participated with the Colorado (lead) and Wyoming Districts in the Upper Colorado River Basin RASA. The Utah part of the study, which focused on sandstone aquifers of Mesozoic age, was conducted by James W. Hood, succeeded by Geoffrey W. Freethey, Gail E. Cordy, Blakemore E. Thomas, Jay R. Weigel, and Dale E. Wilberg. Thomas constructed digital models of the Navajo Sandstone in the Lake Powell area and the Four Corners area, and Emanuel Weiss of the Colorado District constructed a digital model of the Navajo Sandstone around and south of the San Rafael Swell of east-central Utah.

The District's NAWQA study was of the drainage basin of the Great Salt Lake, and included small parts of Idaho and Wyoming. The study began in FY 1994, with an initial staff of Kidd M. Waddell and Robert L. Baskin.

The water-use program, which began in FY 1978, continued with half of the work done by the Utah Division of Water Rights and half by the District under a cooperative funding agreement in which no exchange of funds was made between agencies. During 1979–94, the funding remained almost constant, without increases for the cost of inflation, so it was not possible to increase the scope of the study. The District's part of the work was conducted by Russell W. Cruff from 1979 to 1984, with assistance some years from Larry R. Herbert; by George E. Pyper from 1985 to 1990, with assistance some years from Robert L. Baskin and Heidi K. Shlosar; and by Heidi K. (Shlosar) Hadley and Katina K. Wilson from 1991 to 1994, with assistance most years by Pyper.

The District participated (1993–95) in the National Irrigation Water-Quality Program of the Interior Department—a study of the effects of irrigation on water quality. David L. Naftz contributed data analysis to this effort. The District also undertook, at the request of the Utah Congressional Delegation, a review of water-demand and utilization studies of the Bureau of Reclamation's Central Utah Project, including an analysis of the potential effects of seepage from the proposed Jordanelle Reservoir on the metal mines of the Park City area. This study was an intensive effort, including preparation of a report, over a period of about one year, and was conducted by Kidd M. Waddell, Freethey, David D. Susong, Pyper, and E. Blaine Johnson.

The District Computer Programmer/Analyst, Scott D. Bartholoma, was assigned to assist in development of the Water Resources Division's National Water Information System—Automatic Data Processing System in about 1984. In 1989 Bartholoma was assigned to work full-time, from the District office, on this system of managing the Division's data base, and he continued with this effort through 1994.

PUBLICATIONS

The Utah District continued its emphasis and excellent record in producing publications, which began in the early 1960's. During 1980–94, the District produced 2 Professional Papers, 10 Water-Supply Papers, 1 Circular, 2 Hydrologic Atlases, 12 Miscellaneous Investigations Maps, and 49 Water-Resources Investigations Reports. The use of Water-Resources Investigations Reports to release information increased substantially, from 2 during 1966–79 to 49 during 1980–94. The District also continued documenting many studies in several of the publication series of the State of Utah—39 Technical Publications of the Department of Natural Resources, 1 Water Circular and 3 Information Bulletins of the Division of Water Rights, 16 Cooperative-Investigations Reports of the Division of Water Resources, and 1 Water-Resources Bulletin and 5 Environment and Resource Maps of the Utah Geological Survey.

EPILOGUE

The most significant hydrologic occurrence of the 1979–94 period was the record flooding of 1983–87. The District was involved with documenting streamflow, ground-water levels, and the level of the Great Salt Lake during this period. The wet period began in September 1982 when Salt Lake City

received 7.04 inches of precipitation, about 10 times normal for the month and about 45 percent of the normal annual precipitation. On September 26, precipitation was 2.27 inches, a daily record. By June 1983, snowpack in the drainage basin of Great Salt Lake ranged from 2.4 to 5.2 times the average. Cool and wet weather continued longer than usual in the spring of 1983, extending through April and May. The first indication of serious trouble was a landslide in April near the town of Thistle in Spanish Fork Canyon, southeast of Utah Lake. The landslide buried the Denver to Salt Lake City railroad line and a U.S. highway, dammed the Spanish Fork River temporarily, and flooded the town of Thistle, causing $200 million in direct damages. When the weather warmed suddenly in late May, runoff began in earnest, along with other landslides and debris flows. Flooding was the largest and most widespread in Utah's history, with flows for several streams exceeding 100-year recurrence intervals and new discharge records set for many others. A dam failure on the Sevier River near Delta in June washed out two bridges and inundated the town of Deseret. Floodwaters from City Creek, which drains an area northeast of Salt Lake City, were routed down a sandbagged State Street. This flow was recorded by Rulon C. Christensen in a memorable photograph (it has been reported that an enterprising fisherman caught a trout on State Street).

Inflows to Great Salt Lake from its major tributaries ranged from 2 to 3.8 times average from September through December 1982 and 1.6 to 3.6 times average from January through May 1983. The lake level rose 5.1 feet from September 1982 to June 1983, a record seasonal rise. This rise of Great Salt Lake represented a volume increase of about 6 million acre-feet, equivalent to the annual water use of the population of Utah in 24 years. The total damages of flooding statewide were more than $600 million.

This was far from the end of the wet weather and its effects. Precipitation in all of 1983 and from January to June 1984 was much above normal, and more flooding and debris flows occurred in 1984. Several streams had flows representing recurrence intervals of more than 100 years, and flows at some sites exceeded those of 1983. Damages in 1984 were on the order of $50 million. The Great Salt Lake continued its rapid rise by an additional 4.5 feet. After this, much of the flooding from streamflow was over; but above-normal precipitation in the drainage basin of Great Salt Lake continued through 1986, and the lake continued to rise. By June 1986 the lake had risen another 2.6 feet, matching the historical record elevation of 4,211.60 feet. Although precipitation was below normal in 1987, the lake matched its record high in March 1987 before starting a year-to-year decline.

As the Great Salt Lake rose from 1982 to 1986–87, it threatened intercontinental railroad lines, an interstate highway, sewage-treatment plants, wildfowl-management areas, recreational facilities, and industrial installations located on what was formerly lakebed. In an effort to slow the rise of the lake, the State of Utah appropriated about $3 million in 1984 and constructed a 300-foot breach in the railroad causeway that separates the northern one-third of the lake, with higher salinity, from the southern two-thirds, which receives most of the inflow and is less saline. At the time of the breach, the southern part of the lake, which is where most of the potential damage could occur, had a water level almost 4 feet higher than the northern part. The breach was completed in August 1984, and the difference in level between the two parts of the lake decreased to about one-half foot.

When the Great Salt Lake continued to rise, the State appropriated about $72 million in 1986 to construct a pumping plant on the lake's northwest shore to move water to the west desert and to do additional diking. The $60-million pumping project used three giant pumps, with a capacity of 1.35 million gallons per minute, and began moving water in April 1987. Although the lake peaked in 1987 and began receding in response to below-normal precipitation, the pumping continued until June 1989. The pumps were then "mothballed" in case they are needed again.

In addition to the flooding, landslides and debris flows, and the rise of the Great Salt Lake caused by the wet period of the 1980's, some remarkable changes in ground-water levels also occurred. Water levels in major ground-water basins in southwestern Utah had been declining since the 1940's and 1950's in response to increasing withdrawals for irrigation. It was commonly believed that these declines, up to about 50 feet (larger in the Beryl-Enterprise area), were irreversible and representative of "ground-water mining." During the 1980's, however, larger volumes of recharge and less withdrawal resulted in reversals of water-level decline in all basins except the Beryl-Enterprise area in the driest part of the southwestern corner of the State. Water levels in a few areas recov-

ered to, or slightly above, their values during the 1940's and 1950's. Since about 1989, water levels have again been declining and have reached new record lows in a few wells.

The other notable occurrence during 1979–94 in the Utah District was the retirement of a number of prominent long-time employees. In addition to the retirements mentioned previously, Reed W. Mower, Engineer and Hydrologist who worked in many of the ground-water basins of western Utah, retired in 1980; James W. Hood, Geologist and Hydrologist who worked on ground-water studies in western Utah and in the Colorado Plateau of southeastern Utah, in 1984; Leon J. Jensen, Surface-Water Engineer, in 1980; Barbara A. LaPray, Editor, in 1983; Rulon C. Christensen, Surface-Water Engineer, in about 1989; Doris A. Vandruff, Supervisory Illustrator, in 1992; George E. Pyper, Supervisory Technician and later Hydrologist, in 1994; Loretta S. Conroy, Secretary and later Technician, in 1993; Carlton T. Sumsion, Hydrologist, in 1980; Gerald G. Plantz, Technician and former head of the District water-quality/sediment laboratory, in 1987; Carole A. Pearce, Secretary and later Writer/Editor, in 1994; and E. Blaine Johnson, Surface-Water Engineer, in 1992. In addition, Elmer C. Gerhart, Technician and head of the District water-quality laboratory, died in 1984 while employed by the District.

WASHINGTON

By Philip J. Carpenter, Charles H. Swift III, *and* Gilbert C. Bortleson

Reviews by Norman P. Dion, Kenneth L. Walters, *and* Edmund A. Prych

INTRODUCTION

Aside from years 1979 and 1994, when the principal programs in the Washington District were traditional for the State of Washington, much of the intermediate (1980–93) history of hydrologic data collection and investigation is unusual if not extraordinary. The intermediate history began with the explosive eruption of Mount St. Helens on May 18, 1980. From then until 1983, and tapering off to about 1985, the District was heavily involved in investigations related to the eruption in addition to the normal workload of more usual projects within the State. While Congress and the U.S. Geological Survey (USGS) Headquarters had responded to the eruption quickly with extra funding for work at the volcano, developing an adequate workforce was an initial problem. The Washington Office initially diverted personnel from their regular duties to perform Mount St. Helens work, often on overtime, which in turn put a number of previous ongoing projects behind schedule. In just a few short weeks, however, personnel from other Water Resources Division (WRD) Districts were detailed to Tacoma and Vancouver, Wash., to help cope with the workload.

In 1981, the Cascades Volcanoes Observatory (CVO) was created as a separate Western Region project office in Vancouver. USGS scientists from the WRD and the Geologic Division were brought together in one office building and asked to work side by side. Although WRD staff at the CVO and in Tacoma generally conducted different but coordinated investigations, manpower and equipment were shared as needed, and program funding for the WRD-CVO was administered from the Washington Headquarters office in Tacoma until 1990. As the number of investigative projects at the CVO grew rapidly, so did those in the Tacoma office, which continued to dedicate a portion of its manpower resource to Mount St. Helens water-related investigations until about 1985.

Another extraordinary change in the Washington District operations occurred in 1985. The Washington and Oregon offices were joined together as the Pacific Northwest District (PND) and remained as such with one PND Chief and two State Office Chiefs into 1991. In 1991 the two State Office Chiefs again became District Chiefs under a newly titled program manager called the Area Assistant Regional Hydrologist–Pacific Northwest (AARH–PN). The PND Chief to 1991 and the AARH–PN from 1991 administered funding for the two States from 1985 through 1993. Operations of the two States were combined mainly for two reasons: (1) to enable the temporary assignment of personnel with particular hydrologic expertise to projects across State borders, and (2) to apply uniform procedures and management to large areal projects that overlapped State boundaries.

More than 155 identifiable hydrologic projects were underway in the Washington office and CVO during the 1979–94 period. The data-collection and project activities that are described here have been selected for their significance or general interest. Descriptions of hydrologic investigations are divided into two parts to distinguish between the two major

time periods of activities and unique organization as follows: 1979–85, the Mount St. Helens Years and Earlier; and 1986–94, the PND Years and Later.

ORGANIZATION AND MANAGEMENT

The Washington District Office was located in Tacoma from 1979 to 1994. From 1979 to 1985 it was a traditional WRD District of the Western Region. From 1985 to 1991 it was the Washington State Office (WSO) of the PND, and from 1991 to 1994 it was again the Washington District, but under the management of the AARH–PN. Field Headquarters were located in Pasco, Spokane, and Tacoma during the entire period. The Vancouver Subdistrict Office was established in 1981 to conduct programs related to the 1980 eruption of Mount St. Helens. This Subdistrict Office was an integral part of the CVO, also established in 1981, and became a Project Office under the PND in 1985. Program funding for the Vancouver Subdistrict was administered from the Washington or PND Office through 1989.

Two District Chiefs and two State Office Chiefs served the Washington Office from 1979 to 1994. Charles R. Collier served as District Chief from 1979 to 1981. Collier retired from the position in 1981, and Leslie B. Laird became the District Chief in 1982, having transferred from WRD Headquarters. Laird accepted the position of PND Chief in 1984. Philip J. Carpenter became the WSO Chief in 1984 and transferred to the position of Alaska District Chief in 1989. Carl Goodwin, who transferred from Tampa, Fla., became the WSO Chief in 1990 and accepted the position of Washington District Chief under the AARH–PN in 1991.

Laird retired from the position of PND Chief in 1986 and Garald G. Parker, Jr., who transferred from Jackson, Miss., succeeded him. Parker retired in 1992. Marvin O. Fretwell served as the AARH–PN, from 1992 to 1994 following his tenure as Oregon District Chief.

Eleanor Smith held the position of Washington District Administrative Assistant until 1980, when she retired. John P. Bauer, who transferred from the National Park Service, held the position until 1984 when he returned to the National Park Service. Janet Thomas served in the Administrative Assistant position from 1985 until 1994. John David Wilson directed the activities of the Washington Computer Unit from 1979 to 1994 and Judith Wayenberg directed the activities of the Reports Section during the same time period. Gary L. Turney served as the Water Quality Laboratory Chief until 1992 when the laboratory was officially closed. Glen C. Roberts, Richard J. Wagner, Kathleen E. Green, and Gilbert C. Bortleson directed the activities of a "selected constituents" Laboratory Unit at various times during the period 1982–94. John R. Williams served as the Washington District Programs and Information Officer from 1979 until 1989 when he retired. Luis A. Fuste' held that position from 1989 through 1994. Arthur A. Seldal directed the activities of the Warehouse and Construction Unit from 1979 until 1980 when he retired, and Donald B. Reynolds directed those activities until 1983 when he, too, retired. John W. Bowlby directed the construction and warehouse activities from 1985 to 1990, and Bryan S. Peck directed them from 1990 through 1994.

Edwin H. McGavock served as Assistant District (WSO) Chief for Hydrologic Surveillance from 1979 to 1987 when he transferred to the Arizona District. He was responsible for all hydrologic data activities of the District (WSO). Field Headquarters Offices in Pasco, Spokane, and Tacoma covering the southeast quarter, northeast quarter, and western one-half of the State, respectively, were under his direction. Phillip R. Boucher held the position of Pasco Field Office Chief from 1979 until 1988 when he retired, and Gregory Ruppert held the position from 1988 through 1994. Edmund Nassar served as Spokane Field Chief from 1979 until 1981 when he transferred to Nevada; Robert Blazs served in the position from 1983 until 1989 when he transferred to Oklahoma; Raymond R. Smith held the position from 1991 through 1994. William D. Wiggins served as the Tacoma Field Office Chief the entire period.

William Meyer held the position of Assistant District (WSO) Chief for Hydrologic Investigations from 1979 to 1985. In this position he directed the activities of the General Hydrology, Hydrologic Applications, and Environmental Quality Sections of the District (WSO). In 1985 Meyer accepted the position of Assistant District Chief, PND, and in 1986 he transferred to Hawaii as District Chief. Kenneth L. Walters was Chief of the General Hydrology Section from 1979 until 1981 when he retired. Frank A. Packard held the position from 1983 until 1988 when he transferred to the Oregon Office. Edwin H. McGavock held the position in 1989, and Norman Dion held the position from 1991 through 1994. Charles H. Swift III served as Chief of the Hydrologic Applications

Section from 1979 until 1990 when he retired and William G. Sikonia replaced him. John M. Klein was Chief of the Environmental Quality Section in 1979 and served in that position until 1982 when he accepted the position of California District Chief. Earl L. Skinner held the position from 1984 until 1987 when he retired. Edmund A. Prych served in the position from 1988 to 1992 when the Section was eliminated.

In 1984 the Columbia River RASA (Regional Aquifer-System Analysis) Section was formed and John J. Vaccaro directed the activities of that Section through 1994. The Columbia River RASA was completed in 1987, and the Section initiated the Puget Sound–Willamette Trough RASA in 1988. The Central Columbia Plateau RASA Section was formed in 1992; Alex Williamson directed its activities through 1994. In 1989 Gary Ryals accepted the position of Chief of the Hanford Reservation Studies Section. He held this position through 1988 when Ward Staubitz became the Project Chief. Staubitz directed the activities of the project through 1994 when it was retitled the Nuclear and Hazardous Waste Project.

Richard Janda held the position of Vancouver Subdistrict Chief from 1981 until 1985 when the office became a Project Office of the PND. John Costa became the Chief of the Vancouver Project Office in 1985 and held the position until 1990 when it was moved to the Western Region. Janda and Costa were responsible for all hydrologic data and investigative activities of the CVO.

Personnel

The number of personnel and mix of hydrologist, hydro-technicians, and support personnel assigned to the Washington District (WSO) remained relatively stable during the 1979–94 period. In 1979 the number of personnel assigned to the District was 91. In 1981 the District size had grown to 97, but by 1983 it had decreased to 87. By 1986 the District size had again grown to 102, and by 1994 it had increased to 109. The above numbers do not include personnel assigned to the Vancouver Subdistrict Office. When that office opened in 1981, 25 people were assigned to it. By 1986 this number had grown to 43, and by 1990 it had decreased to 32.

In 1979 there were 37 hydro-technicians assigned to the Washington District, and that number decreased to 29 by 1990 before increasing to 44 in 1994. Thirty-five hydrologists were assigned to the District in 1979 and that number increased to 46 by 1986 but decreased to 41 in 1994. The steady decrease in hydro-technicians between 1979 and 1990 can be attributed to implementation of the results of the National Surface Water Branch Stream Gaging Analysis conducted in the mid-1970's. The increase of technicians by 1994 was related to the relative large data requirements associated with the hydrologic investigations done in cooperation with other Federal agencies (OFA). The steady increase of hydrologists from 1979 to 1986 can be attributed to the Washington District's (WSO's) emphasis on interpretive studies and research. The number of support personnel assigned to the District remained constant at about 20–25 from 1979 until 1994.

Funding

Total funding of hydrologic surveillance programs and water-resources investigations for the Washington District (WSO) was $5,200,000 in 1983, steadily increased to $6,200,000 by 1990, and increased at a greater rate to $8,400,000 by 1994. There are no reliable funding records available for the period 1979–83, but it estimated that the total funding for 1979 was about $4,000,000. The Federal/State cooperative (Coop) programs totaled $2,700,000 in 1983 and increased slowly to $3,100,000 by 1984. Funding for Federal programs was $2,900,000 in 1983, rose to $4,000,000 by 1990, and fell to $2,300,000 by 1994. Other Federal agency (OFA) program funding for 1983 totaled $1,200,000, remained at that level through 1989, and then increased rapidly to $3,000,000 by 1994.

Funding for steam-gaging stations by the Federal Power Commission (Federal Energy Regulatory Commission) remained level at less than $250,000 per year during the entire period. Unmatched funding in the Federal/State Coop program also remained constant during the period at less than $500,000 per year, and funding for direct services by cooperator agencies remained nearly constant at less than $400,000 per year. The increase in funding experienced between 1979 and 1990 for Federal programs was in response to the Columbia River and Puget Sound–Willamette Trough RASA projects and initiation of the National Water-Quality Assessment (NAWQA) pilot study for the Yakima

River Basin; the decrease in funding for the Federal Programs through 1994 reflects phasing out of these projects. The substantial increase in OFA funding from 1990 to 1994 was in response to initiation of studies related to the U.S. Department of Energy (DOE) Basalt Waste Isolation Project at the Hanford Nuclear Reservation and the U.S. Environmental Protection Agency (USEPA) study of sediment chemistry in Franklin D. Roosevelt Reservoir.

Funding for hydrologic surveillance programs decreased steadily from 50 percent of the District's (WSO) total funding to 40 percent during the 1979–94 period, and funding for water-resource investigation increased from 50 percent to 60 percent during the same period. The decrease in hydrologic surveillance programs can be attributed to implementation of the Surface Water Branch Stream-Gaging Analysis completed in the mid-1970's. The increase in funding for water-resources investigations during the period resulted from an increased emphasis on research and investigations by the District (WSO), Western Region, national Headquarters, and cooperator agencies.

None of the above funding statistics include those for the Vancouver Subdistrict (Project Office). Funding for that program was about $2,300,000 in 1983, rose to about $2,500,000 by 1986, and fell to about $2,300,000 by 1990. Information on funding during the years of 1981 and 1982 was not available from the Washington District.

Funding Agencies

Forty-three State and local agencies provided funding for hydrologic surveillance programs and water-resources investigations conducted by the Washington District (WSO) in 1979. These agencies included 4 Washington State departments, 15 public utilities, 7 Indian Nations, 10 counties, 5 cities, 2 universities, and 1 irrigation district. This general mix of State and local cooperator agencies continued through 1994 with some decrease in city cooperators and some increase in county cooperators. Major cooperators included the State Departments of Ecology (WDOE), Transportation, and Fisheries; King, Pierce, Thurston, Cowlitz, and Island Counties; the Cities of Bellevue and Pullman; the Municipality of Metropolitan Seattle; Seattle Water and Light Departments; Tacoma Departments of Public Utilities and Public Works; Puget Sound Energy Utility; and the Puyallup, Quinault, and Tulalip Indian Nations.

Several OFA's provided funding for water-resources projects conducted by the Washington District (WSO) during 1979–94. Some of these agencies included the U.S. Army Corps of Engineers (Corps), the Bureau of Reclamation, DOE, USEPA, Bureau of Indian Affairs, National Park Service, USDA Forest Service, and the Bonneville Power Administration.

PRINCIPAL PROGRAMS

Hydrologic Surveillance

Surface water

The number of continuous-record stream-gaging stations operated in Washington during 1979–94 remained nearly constant at 225. The number and location of stations in the statewide network were defined as a result of the national Surface Water Branch Stream-Gaging Analysis conducted in mid-1970. Results of that analysis showed that records from continuous-record stream gages were needed to define long-term trends in streamflow and to satisfy cooperator agency needs for current purposes. The analysis also showed that streamflow statistics would not be significantly improved by operating the existing stream gages for longer time periods or by adding additional gages of the same type to the network. The number of partial-record stream-gaging stations operated in Washington declined from about 300 in 1979 to about 90 in 1994, again reflecting the results of the national Surface Water Branch Stream-Gaging Analysis and the needs of the cooperator agencies.

The most significant change in the Washington stream-gaging program during the period was implementation of a real-time data telemetry network. Beginning in 1979, data from 22 stream-gaging stations were telemetered by radio to a computer in Tacoma and relayed to cooperator agencies. By 1994 data from more than 190 stream-gaging stations were similarly telemetered and relayed to the cooperators' agencies as well as to an Internet Web page. Robert Adsit and Len Tunnell, working with Charles H. Swift III, established the original network. Stewart Tomlinson assumed the duties of Chief of the Data Relay Section in 1986, and Scott Knowles took over those duties in 1991.

Monitoring of lakes and reservoirs reached a peak of 70 sites in 1989 and decreased to 32 sites in

1994. Stage and contents were measured at most of the reservoirs, and stage data were collected for all lakes.

Surface-water-quality data were collected at 100 Washington sites in 1979. The number of sites decreased to 18 National Stream-Quality Accounting Network (NASQAN) and Hydrologic Benchmark (HBN) sites by 1981 and then increased to 37 sites by 1994. Data collected under the hydrologic surveillance program were used for water-resources planning and for assessment of water-quality conditions statewide. Much more surface-water-quality information was collected during 1979–94 in support of water-resources investigations. Sediment records were collected at 18 NASQAN and HBN stations beginning in 1979. By 1989 sediment records were collected at an additional 18 stations, and by 1991 the number of stations had reverted to the original 18 NASQAN sites. Stream temperature and specific-conductance information was collected at most gaging stations at the time of each discharge measurement.

Ground water

Ground-water-level data for Washington were collected at 194 sites in 1979, 30 sites by 1981, and 345 sites by 1991. Ground-water-quality data were collected at 39 sites in 1989 and 327 sites by 1991. Ground-water-level and quality data collected under the Hydrologic Surveillance program were used for water-resources planning and for assessment of water-quality conditions statewide. Similar data were collected in support of several water-resources investigations.

Meteorological information

Precipitation data were collected at 51 sites in 1979, decreased to 30 sites in 1989, and increased to 121 sites in 1991. In 1991, the Washington District began a program to collect information required to assess evaporation, particularly in the dry basalt area of the State. Four relative humidity, 18 air temperature, four solar radiation, and four net radiation sensors, plus two snow pillows, were placed in operation.

Water use

The Washington water-use program was initiated in 1979 and run by the WDOE. The type, amount, and availability of water used by public utilities were inventoried in the first year. Irrigation water use was added to the inventory in 1980. Water-use information was entered into the National Water Use Data Base System, and water-use reports and fact sheets were generated.

HYDROLOGIC INVESTIGATIONS—1979–85, The Mount St. Helens Years and Earlier

Interpretive Studies

One of the more significant interpretive studies resulted in the development of a Hydro-Meteorological Model in 1979 by Wendell Tangborn. The model used relationships between annual precipitation measured in lowland gages to estimate expected annual runoff from high-altitude, sometimes snow-packed, drainages. The model was tested in 1980 for the National Academy of Sciences and is still in use by three major electrical power companies in Washington to predict inflow to their reservoirs.

Beginning in 1979 Bill Haushild, Jim Ebbert, and Ed Prych conducted a study to measure the quantity and quality of water flowing from street drains into and along storm sewers in the city of Bellevue. One goal of the study was to determine if street cleaning improved the quality of runoff.

Coal from open-pit mines near Chehalis and Centralia, in Lewis County, is used to power the steam generators at the Centralia Power Plant. In 1979 Frank Packard and Luis Fuste' conducted an investigation of the effects of runoff from coal wash-water holding ponds on aquatic invertebrates in receiving streams. Using the findings, the mine operators were able to consider more effective methods of containing the runoff.

In 1980, John Vaccaro developed a digital hydrologic flow model for the Spokane area that demonstrated the relationship between the aquifer, the flow of the Spokane River, and ground-water pumpage. Those findings and the results of a study of the water-quality characteristics of the aquifer by Vaccaro and Ed Bolke later became the basis for designation of the aquifer as a Sole Source Aquifer.

Areal Investigations

Over the years, the Washington District has conducted a number of hydrologic investigations for various Indian Tribes, which number more than 20 in

the State. None have been more extensive than those conducted in the Yakima River Basin in south-central Washington for the Yakima Indian Nation and the WDOE. The Toppenish Basalt Model, developed by Jim Skrivan and Bill Meyer and documented in a 1979 report, was one of the earliest attempts to model ground water in volcanic basalt layers. The Toppenish Basalt Model and a digital three-dimensional coarse-grid model of a large area of basalt aquifers underlying the Columbia Plateau developed by Dave Sapik in 1981 were forerunners of the RASA studies in succeeding years. South of the Yakima River Basin in an upland dry wheat-farming area called Horse Heaven Hills, Frank Packard began measurements of ground water in deep wells in a 1983–85 investigation of ground water in that area. In 1981, Ed Prych reported the results of his numerical study of water logging from irrigation in the lower Satus Creek Basin, which is on the Yakima Indian Reservation.

In another forerunner to RASA, Gil Bortleson and Karen Schurr conducted a 1983–84 investigation of the quality of ground water in the basalt aquifers of eastern Washington. The purpose of the study was to determine the areal extent and causes of high sodium concentrations in ground water used to irrigate wheat and other crops. Results of sampling over 400 wells showed that the highest concentrations of sodium were in the oldest, deepest water located downgradient in the regional flow path. A conceptual geochemical model showed that high-sodium water in the flow path could be explained by natural evolution. The project was the first in Washington to use a "home-made" flow chamber to measure unstable water-quality constituents and to extensively apply carbon-14 methods to date water samples.

The intrusion of seawater into coastal aquifers of western Washington was a concern and the basis for several investigations in the early and mid-1980's. In 1982 Norm Dion and Steve Sumioka undertook a comprehensive investigation of coastal aquifer vulnerability to seawater intrusion based on natural factors and pumping influences. A ground-water assessment of Island County was begun in 1979 by Denzel R. Cline to log wells and obtain measurements of water levels with the objective of locating dependable sources of water supply unaffected by seawater intrusion. The county, which consists of two large Puget Sound islands, Whidbey and Camano, depends mainly on ground water for a potable supply. During the same time period, Christy Whiteman made an assessment of seawater intrusion in San Juan County, another group of islands. In a continuation of the work for Island County, Dave Sapik and others conducted a 1983–84 study to determine the extent of seawater intrusion and used a flow-simulation model to locate the freshwater/seawater interface. In a related effort called System 2000, Lyn Topinka worked with others in the early 1980's to code well driller's logs into a computer data base of well data for Washington.

Flood Insurance Studies to define flood-hazard areas for urban communities for the U.S. Department of Housing and Urban Development (HUD) flood insurance program were a major component of surface-water studies in 1979. Although several such studies were completed prior to 1979, minor work and final community meetings were still being conducted with city and county officials in four countywide studies. In a great loss, the hydrologist in charge of these studies, David LaFrance, died unexpectedly in April 1979. Two hydrologists, Len Nelson and Dave Kresch, and two experienced hydrologic technicians, Ron Lombard and Tom Higgins, were assigned to complete the studies. The District Surface-Water Specialist, Jack Bartells, helped where he could until he retired in February 1980. The combined experience that the four remaining men had gained in this project in the areas of photomapping contracts, land surveying, flood-frequency analysis, and step-back-water analysis of flood profiles would prove to be invaluable in the investigations of the effects of the 1980 eruption of Mount St. Helens.

An unusual project to investigate the chemistry of particulates in snow in the Sierra Nevada and the Cascade Range of Washington, Oregon, and California was initiated and completed by Les Laird in 1983 and 1984. Laird, Ron Lombard, and others from Tacoma spent many helicopter hours collecting numerous snow samples and transporting them to the laboratory for analysis. The objective of the study was to relate the patterns of fallout from anthropogenic and naturally occurring chemical constituents to wind patterns associated with storm and nonstorm periods.

Topical Studies

The Stillaquamish Instream Flow project (a merit project) was conducted by Sandra Embrey (1983–85) for the Stillaquamish Indian Tribe. It was an application of the IFIM (Instream Flow Incremental Methodology) technique of evaluating stream habitat

for salmon at all stages of life in freshwater. The U.S. Fish and Wildlife Service at Fort Collins, Colo., developed this technique for anadromous fish in part using salmon habitat measurements made by Mike Collings and Charles Swift in Washington streams. The purpose of this IFIM study, the first in Washington, was to determine optimum stream-discharge ranges to maintain a quality habitat for anadromous fish in the river. Knowledge of those discharges was needed by the Tribe to establish a conjunctive right to manage the water resource in accord with an earlier court decision regarding Indian treaty rights.

One of the major concerns of the Yakima Indian Nation was the flow of the Yakima River, both in support of salmon propagation and as a source of irrigation water for reservation land. A project begun in 1979 by LaFrance and Swift and then continued by John Vaccaro, called "Yakima River Regulated versus Unregulated Flow," was designed to ascertain what the historical flows of the river might have been had river water not been diverted for irrigation use for many years upstream from the reservation. The Tribe contended that they should be entitled by the treaty of 1855 to the diverted water, whether for themselves or for the salmon that the river would have supported. Preliminary estimates of the difference between regulated and "reconstituted" flows indicated substantial losses due to regulation and diversion. In 1980, Vaccaro conducted a second study (Phase II) in which he applied a digital storage-routing model for 52 years of record at two stream-gaging stations on the lower Yakima River, thus documenting the amounts of the losses. In 1983, Vaccaro also developed a simulation model for water temperatures of streams in the Yakima River Basin, an important element affecting the migration and reproduction of salmon.

In 1977 a strong storm combined with a very high natural tide to produce a tide level in Puget Sound nearly equaling that computed for a 100-year probability and damaging or destroying beachfront properties in the process. In 1979 a study managed by Len Nelson was completed to document the height of that tide at shorelines throughout the sound so property owners could determine potential flood hazards from tides. The work entailed determining the altitudes of the 1977 high-tide marks at many locations around the sound and correlating them with altitudes recorded at official tide stations.

In 1979, Maury Miles worked on a study called "Cowlitz River Flood Profiles." He and others used high-water marks from recent floods, river channel data, and flood-plain maps from the Corps of Engineers and flood insurance study contractors to calculate flood-elevation profiles for the Cowlitz River from its mouth upstream to its confluence with the Toutle River. That portion of the Cowlitz River is extensively leveed along both banks to protect the communities of Castle Rock, Kelso, and Longview. Cowlitz County, the communities, and the Corps of Engineers were all interested in knowing if the levees were adequate to provide protection from a major water flood. No one anticipated that the mudflow produced in the Toutle and Cowlitz Rivers by the May 1980 eruption of Mount St. Helens would bury unleveed flood-plain areas and come very close to topping the existing levees. However, the river data that had been collected earlier proved invaluable for estimating the amount of mud filling the river channel and the reduced flood-carrying capacity of the channel after the eruption.

A ground-water study by Denny Cline (1979–84) in cooperation with the WDOE provided useful information on the water-bearing characteristics of deep aquifers not usually tapped by wells. In this study, deep wells drilled into the basalt of eastern Washington (some western Washington wells were included late in the study) were isolated and piezometers were installed to allow monitoring of water levels in the aquifer zones. In an interesting aspect, television was used to locate well-casing collars and aid in logging the strata for a well near George.

Other Activities

Certain equipment used and developed in 1979 and earlier proved relevant to work in Washington in later years, especially pertaining to Mount St. Helens. The Washington office had been involved in land-based radio telemetry of hourly water-level data from stream-gaging stations in western Washington since 1970. In 1979, the office was just becoming involved in the transition to satellite telemetry using the GOES satellite for transmission of those data and was also involved in the process of procuring a new system control and data-distribution computer. Land-based telemetry from three of the existing automated gaging stations provided the only data available for the mudflow levels produced by the eruption of Mount St. Helens before the gages were destroyed or put out of operation. Additionally, the handheld radios that were normally used to communicate through repeater

stations from the existing automated stations initially provided the only means of communication to Tacoma from the volcano. Not long after the eruption a new GOES satellite receiver and a new system control and data-distribution computer were installed in Tacoma, which began distributing data from GOES telemetry field platforms installed at Mount St. Helens and elsewhere. That effort continued to expand, and by 1992 GOES platforms were being operated at 134 of the 205 stream-gaging stations in Washington. The Washington office was fortunate to have Bob Adsit and Len Tunnell as equipment technicians with years of prior experience in radio telemetry installation, operation, and maintenance to manage the system.

Another item of equipment, procured in 1979, was being tested for discharge measurements from boats on large streams such as the Columbia and Snake Rivers. That item was a microwave distance-measuring system with a 3-mile range called a trisponder that used two remote transmitters onshore and a portable receiver aboard the boat to provide rapid updates of distance from the boat to each transmitter. It provided a means for maneuvering the boat to a stationary position while water measurements were made or, conversely, to record positioning while making moving boat measurements of water depth and velocity. Combined with a recording fathometer formerly used in flood insurance study work, the system also provided the means later in 1980 for surveying the water volume of uplifted Spirit Lake at Mount St. Helens.

A sturdy aluminum jet boat had been acquired some years earlier to provide a means for rapidly surveying river channels that could not be readily waded in flood insurance projects. Equipped with inboard engine and a jet pump designed in New Zealand, it could cross gravel bars and small logjams. The jet boat and another similar but larger boat procured in 1979 for work on large rivers provided a means for navigating and surveying the Cowlitz River after the 1980 mudflow. Although the jet-boat pumps were not designed to pump mud, they performed this task adequately.

Mount St. Helens Investigations

The WRD Headquarters in Reston, Va., developed several primary objectives for investigations at Mount St. Helens very quickly after the eruption. The first, which focused mainly on the Tacoma office, was to document the hydrologic events that had occurred and the effects of those events on surface and ground water in the region. The second, which focused on the Tacoma and CVO offices, was to evaluate and warn of existing hydrologic and geomorphic hazards and those that might develop as physical changes evolved in the near future. A third objective, which focused mainly on the CVO, was to document the immediate and evolutionary geomorphology of this (1980) and prehistoric eruptions at Mount St. Helens and apply that knowledge in hazard studies of other volcanic mountains in the Cascade Range.

Apart from the risks of additional eruptions at Mount St. Helens, the most imminent threats to public safety appeared to be the possible saturation, failure, and downvalley movement of the debris blockage from the eruption avalanche; the structural failure of debris dams blocking former lakes and newly formed lakes with resultant downstream flooding; changes in the quality of surface or ground water that might affect the health of downstream residents; the transport of waterborne sediment downvalley to further reduce the flood capacity of river channels already largely filled with mud; and the potential for flooding from a major storm in the denuded drainages before downstream river channels could be cleared.

Documenting the magnitude of the hydrologic events that had occurred posed enormous difficulties. Roads and bridges were destroyed, blocked, or buried in drainages filled with debris, mud, and ash; helicopters provided the only access in those drainages. With few exceptions, pre-eruption topographic maps of the stream channels lacked sufficient detail to calculate mudflow discharges in those channels now filled with mud and debris. Blocks of glacial ice had been entrained in the heated materials of the main debris avalanche. As they melted they formed small caverns subject to sudden collapse or small lakes subject to unexpected breakout. In addition to the caverns and lakes, quicksandlike ash and mud posed hazards for workers and equipment for many months after the eruption.

The first Mount St. Helens project, conducted by the Tacoma office, was to calculate the volume of ash, sand, and pumice deposited in the Cowlitz River and to determine the flood capacity of its mud-filled channel. A crew of people led by Len Nelson, Maury Miles, Ron Lombard, and Tom Higgins surveyed cross sections of the mud-filled river and calculated the flood elevations, resulting in a determination that the

mud deposits in the river had indeed created a very definite water-flood hazard to adjacent communities. Accordingly, the Corps of Engineers immediately contracted with a large number of companies to dredge and clear the river channel. Dredging was continued for about 2 years because occasional high flows and sediment transport from the Toutle River would replenish the mud deposits in the Cowlitz River. The Tacoma survey crew would eventually resurvey 20 miles of Cowlitz River channel and about 2 miles of Toutle River channel more than 20 times over those 2 years.

Low-altitude aerial photography of the river channels made shortly after the eruption provided an opportunity to calculate the mudflow discharges at a few locations where stream-gaging stations had been destroyed, but flood surveys had been made in years prior to the eruption. Photogrammetric interpretation provided the necessary post-eruption cross-section data for the gage sites and the calculation of new stage-discharge relationships for those sites.

The original topography of the Mount St. Helens area was disturbed significantly as a result of eruption-associated slide debris, ash, and mudflow deposits. Early on, the Topographic Division used high-altitude photography to create a large map of the entire region, but it proved to be of insufficient accuracy to allow detailed hydrologic and geomorphic work. As a result, in June 1980, Chuck Swift and Dave Kresch wrote specifications for an aerial photography contract along the lines of those written previously for flood-insurance study projects. The purpose of the contract was to provide detailed topography of the area disturbed by the eruption by using photogrammetric methods from low-altitude photographs. The winning contractor achieved ground control by using helicopter-transported ground crews to survey and establish elevation marks along the 40- to 70-mile lengths of three major Mount St. Helens stream drainages. An inertial navigation system in one helicopter was also used to obtain elevation data in support of that obtained by the ground crews. The three lines of vertical control tied together at Spirit Lake within 1 foot of elevation, and the maps began arriving in the Tacoma office in autumn of 1980.

John Cummans made two significant contributions to the documentation of the mudflows. In the early weeks after the eruption, he gathered information from eyewitness accounts that defined the time of arrival and average velocity of peak stages of the mudflows originating in the South Fork and North Fork Toutle Rivers. Months later, his second contribution was a determination of the combined magnitude of the Muddy River and Pine Creek mudflows, based on water-level records maintained at the Swift Reservoir Dam on the Lewis River.

In the summer of 1980, John Klein compared the water quality, before and after the eruption, of rivers affected by the ashfall and by the debris deposits. All showed marked increases in turbidity and levels of sulfate, chloride, total nitrogen, total organic nitrogen, and trace metals. The increases were short-lived in the rivers affected by ashfall but persisted for several months in rivers draining the debris deposits. In the volcanic blast area, the byproducts of heat-affected trees and other organic materials were noted in 1981 to have created a number of organic compounds in water similar to effluents generated by the pulp and paper industry. Norm Dion and Sandra Embrey compared the water quality, before and after the eruption, in selected lakes in Washington both statewide and in the blast zone of the volcano.

By 1981, Spirit, South Fork Castle, and Coldwater Lakes were the only remaining lakes on the debris pile where the debris dams had not already breached. All three were large, filling, and contained by unstable debris deposit material. Breaching of any one of those lakes posed a major flood hazard to residents downstream on the Toutle and Cowlitz Rivers, but by far the greatest hazard was posed by Spirit Lake, the largest. Monitoring the stability of the dams became an immediate priority. Accordingly, the Tacoma Field Office was directed by Phil Carpenter to install precipitation gages in the drainage basins and water-level gages equipped with GOES radio telemetry on each of the lakes to measure the rate of increase in lake levels, and Bill Meyer directed the drilling of many test holes and installation of numerous piezometers to measure the level of ground water in the debris dams at each lake. This hydrologic information, along with bathymetry of the three lakes, was used to compute a water budget for them and to predict the time of their filling. The projected times of filling for the three lakes was provided to Cowlitz County and State and Federal Emergency Management Agency (FEMA) and led to stabilization of the lakes by the Corps of Engineers. Outflow channels were constructed for South Fork Castle and Coldwater Lakes and an outflow tunnel was constructed for Spirit Lake.

The high degree of hazard posed by a breach of Spirit Lake led to three major project efforts by the Tacoma Subdistrict. The first, conducted by Kresch and Swift, was to use a digital dam-break model to create a dam-breach scenario that would release most of the contents of Spirit Lake. The next step was to use another digital model to route the resulting hypothetical flood down the Toutle River to and along the Cowlitz River, and finally to develop flood-elevation profiles for the hypothetical Cowlitz River flood. This work continued into 1984 as sediment deposition and dredging continued to change the river channels.

The second project, for comparison with the dam-break work, was the construction by John Vaccaro of a digital rainfall-runoff model for the denuded drainage of the Toutle River Basin. The purpose of this conceptual model was to estimate the magnitude of the flood discharge into the Cowlitz River that a major but hypothetical winter rainfall storm would create. A year or two later the dam-break hazard was largely put to rest when the Corps of Engineers stabilized Coldwater Lake by constructing an outflow channel and Spirit Lake by boring an outlet tunnel through a mountain to Coldwater Lake.

The third major project effort resulting from the hazard of a Spirit Lake breach was called the Mount St. Helens Monitoring project. Four individuals—Carpenter and Swift of the Tacoma Subdistrict, Dallas Childers of the CVO, and Gary Gallino of the Portland office—were assigned to 24-hour, 7-day monitoring of data for GOES telemetry platforms at the lakes and at stream-gaging stations recently established along the Toutle and Cowlitz Rivers. Each individual was provided a pager, a personal computer terminal, and a special voice telephone line for contacting and alerting officials at the National Weather Service in Seattle. It was a National Weather Service responsibility to warn emergency officials in the community of Longview of any major flood event, a warning that could conceivably result in the evacuation of some 60,000 residents. The new data-distribution computer in Tacoma, linked to the new GOES receive station also in Tacoma, was programmed to send an alarm message to all four pagers if certain water-level criteria were exceeded at the pertinent Mount St. Helens gaging stations. The four individuals rotated on 24-hour shifts from late 1980 through 1983, and it was their duty, after reviewing on their computer terminal the cause of any alarm, to advise the National Weather Service whether the alarm was true or false. Bob Adsit and Len Tunnell were also assigned to the 24-hour, 7-day monitoring effort to evaluate and correct any monitoring and telemetry equipment failures.

Sediment transport and deposition in and from streams draining Mount St. Helens watersheds were major concerns, and CVO personnel installed a number of sediment-measurement stations to monitor bedload movement and the concentration of transported sediment. The laboratory for analysis of sediment samples for all of Washington and Oregon was centered at the CVO and staffed with experts in that science. The collection of Mount St. Helens sediment data began in 1981 and continued through 1994. The data and information gathered at those stations aided in the calibration of a digital sediment-transport and deposition model that was applied to the Cowlitz River by Bill Sikonia in about 1984 to evaluate the potential for blockage of the Columbia River by sediment that might originate from the earlier flood simulation by Swift and Kresch. The Trojan Nuclear Plant, upstream from the Cowlitz River a few miles along the Columbia River, was potentially at risk from flooding if such a blockage were to occur.

HYDROLOGIC INVESTIGATIONS—1986–94, The PND Years and Later

Interpretive Studies

The Puyallup Flood Capacity study that began in 1983 was a multifaceted project involving the Puyallup Indian Tribe, Pierce County, Washington Department of Fisheries, Corps of Engineers, and commercial companies that mined gravel from the river under county permits. The three major parts of the project included (1) calibration of a sediment-transport model based on measured sediment transport and deposition during high flows, and use of that model to investigate the effects of alternative plans for trapping and mining gravel; (2) application of the U.S. Fish and Wildlife Service IFIM technique to evaluate the fish habitat and estimate the effect on that habitat of alternative plans developed in part 1; and (3) the use of a hydraulic model to determine the effect on flood conveyance and water elevations of alternative plans developed in part 1. Ed Prych, Bill Sikonia, and Len Nelson conducted part 1 of the study, Sandra Embrey conducted part 2, and Morey Miles and Ron Lombard conducted part 3.

Rick Dinicola, in three separate but related projects, developed computer-based rainfall-runoff models that described the effect of precipitation on surface runoff and ground-water recharge in small urban and suburban drainage basins of King, Thurston, and Pierce Counties. Land-use managers in those county governments had become concerned with the increases in flood magnitudes and damages and with the decreases in recharge to ground water that was occurring as a result of rapidly expanding population growth and land development.

A 1990–93 study by Dave Kresch and Bill Sikonia led to development of a method for estimating streamflow and precipitation at ungaged sites in different regions of the State. Using records for 55 long-term stream-gaging stations, they applied statistical methods to develop a method for estimating monthly streamflow and precipitation at ungaged sites from monthly values at gaged sites. They also developed an index of water-resource availability that provides a quantitative measure of present hydrologic conditions relative to historical streamflow and precipitation records.

Areal Investigations

The RASA investigation of the Columbia Plateau basalt region of eastern Washington and Oregon, conducted by John Vaccaro, Henry Bauer, and others, was a part of the USGS RASA program. Although the project was originally designed to last 4 years beginning in 1982, it lasted more than 7 years and resulted in more than 35 reports related to the aquifer system. Concerns relating to domestic, community, and agricultural water use on the Columbia Plateau included progressive water-level declines, water logging from irrigation, allocation of the surface-water and ground-water resources to water users, changes in the quality of surface and ground water, and the future possibility of using the basalt system as a repository for high-level nuclear wastes. The objective of the study was to obtain knowledge of the system sufficient for planning comprehensive management and use of the ground-water resource.

As part of the Columbia Plateau RASA, Bill Steinkampf and Gil Bortleson made additional interpretations of the ground-water chemistry data obtained in Bortleson's 1983–84 study of sodium levels in basalt formations composing the aquifer.

The Columbia Plateau Pumpage project, another RASA-related study, was a 4-year effort conducted by Denny Cline that began in 1982. The purpose of this project was to calculate the quantity of ground-water pumpage for the entire Columbia Plateau for 1984, for every other year from 1983 back to 1963, and for every fifth year from 1960 back to 1945. The calculations were mostly made using measured electric power consumption at wells, but a part was calculated using early Landsat photographs and a relationship between water pumpage, crop type, and crop coverage. These relationships, using Landsat photographs, were developed in a project by Cline beginning in 1984. The pumpage data were required for developing the ground-water models included in the Columbia Basin RASA program.

The objective of the Washington State Hazardous Waste project (1984–91), directed by Norm Dion and Theresa Olsen, was to assess the geological, hydrological, and cultural factors that affect the suitability of land-based waste-disposal sites and to show the results of that assessment on maps of the entire State. Eighteen selected factors were used to make the assessments and maps. The operator, WDOE, planned to use the maps to evaluate the suitability of proposed waste-disposal sites. A series of studies, guided by Ed Prych, began in 1987 to determine the baseline concentrations of heavy metals in soils throughout the State. These data were needed by various agencies for the comparison of metal concentrations in contaminated soils with those in "clean" background soils.

NAWQA studies in Washington began in 1986 with a pilot study in the Yakima River Basin, one of several pilot studies nationwide. The leader of this pilot study was Stuart McKenzie of the Oregon Office. A major goal of the NAWQA studies was to determine conditions and trends in water quality in each study area. In addition, all NAWQA studies were firmly focused on the biological component of water quality and the effects of water quality on biota. New protocols for the collection and analyses of water-quality samples and data were implemented for the pilot studies. The success of the pilot studies led to full-scale implementation of NAWQA studies nationwide, and in 1992 an ongoing NAWQA for the Central Columbia Plateau began under the direction of Alex K. Williamson. Another ongoing NAWQA for the Puget Sound region began in 1994 under the direction of Ward Staubitz, who was succeeded by Jim Ebbert. The addition of biologists such as Mark Munn to the staff

of the Central Columbia NAWQA and Bob Black and Jim Tesorjero to the staff of the Puget Sound NAWQA provided the Washington Office (WSO) with expertise in biology and ecology and provided opportunities to conduct other biologic investigations.

The State of Washington passed legislation in 1986 placing responsibility for the management and protection of ground water to local Ground Water Management Area (GWMA) committees. The Washington District became involved from 1986 through 1994 in a series of investigations of the geologic and hydrologic framework of a number of those areas, which were mainly within county boundaries. The objective of a GWMA investigation was to provide the committees the data and information needed to determine allowable ground-water pumpage for use in planning for the effective long-term utilization of available ground-water supplies. The first of these studies was for southwest King County and was conducted by Dennis Woodward. Studies for Thurston County by Norm Dion, West Snohomish County by Blake Thomas and Sandy Embrey, Whatcom County by Steve Cox, and East King County and Clark County by Gary Turney followed. The geologic and ground-water data for Thurston County were used in the construction of a ground-water flow model for the county in 1990–93 by Bill Lum and provided another tool for the management of ground-water resources of that county. Each of the GWMA studies required that Washington personnel spend large amounts of time at meetings to communicate and coordinate with area committees and consultants. Statewide ground-water samples collected previously by Gary Turney complemented the usefulness of the GWMA studies.

The objective of a ground-water-quality study beginning in 1986 in Benton and Franklin Counties in eastern Washington was to identify the causes and extent of rising water levels, water logging, and high levels of nitrate in ground water of that area. Recharge to ground water in the area was found to consist of low-nitrate water from irrigation canals and high-nitrate water from applied irrigation water. The study, directed by Jim Ebbert and aided by Brian Drost, demonstrated that water managers needed to address separately the integrated problems of water logging and the excessive application of fertilizers to irrigation water. Beginning in 1990 and through 1994, similar ground-water contamination studies were made in the Toppenish agricultural area in eastern Washington by Steve Sumioka and in western agricultural areas of Washington in Whatcom County by Drost, the Long Beach peninsula by Blake Thomas, and Clallam County by Drost.

Topical Studies

In 1992, Gil Bortleson and others from the Washington District undertook a study of the chemistry of sediments in Franklin D. Roosevelt Reservoir in northeastern Washington for the USEPA. Citizen activists were instrumental in bringing attention to the potential environmental effects of years of dumping large quantities of slag from ore smelting into the Columbia River upstream from the international border with Canada. To further complicate the matter, for years a wood pulp mill had also discharged wastewater into the river upstream from the border. The main concern was the accumulation of metal leachates and dioxin compounds in fish consumed from the lake by people. The study focused on the contamination of bed sediments by metals and organic compounds and used an integrated approach to assessing the contamination of the sediments. In addition to assessing the chemical contamination, the abundance and diversity of benthic invertebrates also were analyzed, as was the toxicity of organisms exposed to the sediments. The resulting data showed that the most affected sediments and biota were in the most upstream part of the lake and in the free-flowing part of the river upstream from the lake.

Poorly permeable glacial till soils mantle an extensive part of the Puget Sound lowland, limiting the amount of precipitation that can percolate through the till to the underlying aquifers. Henry Bauer conducted a 1992–93 study designed to quantify the amount of precipitation that percolates through the till and also to generalize the flow paths through the till. The results of this study were directly applicable in the Puget Sound/Willamette Trough RASA, a study in collaboration with the Oregon District.

In association with Dinicola's rainfall-runoff models developed for Pierce County, during 1990–93, Ebbert conducted an investigation of the major factors that influence the quality of surface water in the Clover Creek Basin, one of the basins modeled by Dinicola. In different parts of the basin, water quality was variously affected by drainage from septic tanks, applied fertilizers, nutrient buildup in lakes, and high concentrations of sediment, ammonia, and phosphorus. In response to the findings and the relation of

those findings to land use, Pierce County implemented a long-term water-quality-monitoring network that is supplemented with remedial work and data collection by volunteer stream-improvement organizations in the basin.

In 1990 the USGS began providing the USEPA with technical assistance for their regulatory and oversight activities at the Hanford Nuclear Reservation. Ward Staubitz was the original project leader of this activity, succeeded by Brian Drost. Two other projects at Hanford were a natural recharge tracer project conducted by Ed Prych and a rainfall-runoff project for two nearby watersheds conducted by Dinicola. Prych's project began in 1990 and continued into 1994 with the objective of estimating the long-term, deep percolation of rainfall at the Hanford reservation. The two methods he used to obtain the estimates, a mass-balance method for chloride and a chlorine-36 bomb-pulse method, provided estimates in general agreement with each other and with the findings of other investigators for shallow-rooted and deep-rooted plants in other areas.

The purpose of Dinicola's rainfall-runoff project, which also started in 1990 and continued into 1994, was to estimate for the two watersheds the long-term portion of average surface-water discharge that contributes to recharge of the unconfined aquifer underlying the Hanford reservation. The two watersheds in dry, sagebrush terrain were heavily instrumented to measure water evaporation and plant transpiration (evapotranspiration) in addition to precipitation and surface runoff. The data through 1993 indicated very little runoff generated or contributed to recharge by a wide variety of weather conditions.

The objectives of a 1990 study continuing into 1994 by Dinicola and Stewart Tomlinson were to define evapotranspiration for several climate and plant regimes in Washington and to investigate the use of easily or routinely collected data to accurately determine evapotranspiration. Data collected in 1990 and 1994 by instruments at four grassland sites and two sagebrush sites in eastern Washington, one of them at Hanford, were used to make comparisons of evapotranspiration determined by several methods. Evapotranspiration measured directly with weighing lysimeters was compared with that estimated using other measurements and with evapotranspiration calculated from two different equations.

A 1983–92 project to monitor water quality in Goat Lake in the Cascade Range by Norm Dion and the project to sample lake water in Mount Rainier National Park by Gary Turney were both related to the investigation of snow chemistry by Les Laird in 1983–84. All were essentially designed to determine signs of acidification from air-borne pollutants. In general, these studies indicated that lakes in the Cascade Range were sensitive to acidification but they had not yet shown evidence of acidification, such as the reduction of bicarbonate concentration.

Other Activities: Investigations in Collaboration with Oregon

A number of projects were conducted in Washington and Oregon during the PND years (1985–91) and beyond wherein personnel with particular expertise were temporarily exchanged between the two States. Some of those projects are described here.

A large-scale study, the Puget Sound/Willamette Trough RASA, began in 1988 and continued through 1994. The "trough" exists as a north-south-trending lowland area crossing the Columbia River between the Coastal Range and the Cascade Range of mountains in Washington and Oregon. The Puget Sound part of the study was led by John Vaccaro, and the Oregon part of the study was led by Dennis Woodward. The objective was to estimate the amounts of ground water available to wells to depths of 300 feet in the two distinct but similar aquifer systems.

The 1986 pilot NAWQA study discussed in the "Areal Investigations" section was conducted under the leadership and expertise of Stuart McKenzie of the Oregon District with a professional support team from Oregon. The Pasco Field Office in Washington assisted with work in the Yakima River Basin. Sandy Embrey from the Tacoma Subdistrict (WSO) was responsible for analysis and interpretation of bacteria samples. The success of the several nationwide pilot studies led to the implementation in 1991 of a NAWQA study in the Willamette River Basin of Oregon.

Perhaps the largest personnel interaction between the Washington and Oregon Offices involved the Coos Bay iron geochemistry study on the coast of Oregon from 1986 through 1991. The Coos Bay–North Bend Water Board requested in 1985 that the PND determine the sources and causes of high dissolved-iron concentrations in the area's sand-dune

aquifer. The aquifer was used for the local municipal and industrial water supply, and the water board wanted to minimize high iron concentrations in new wells and to pump the wells at rates low enough to avoid saltwater intrusion. The principal investigators were Bortleson and Myrtle Jones from Tacoma. In addition, Bill Meyer and Ed Prych of Tacoma guided the development of a digital ground-water model to describe the conditions observed and the influence of pumping water from wells in the area.

In 1992, Washington and Oregon personnel again joined to begin a study of eutrophication in Klamath Lake in southern Oregon under the general guidance of Bortleson. The objective was to make an assessment of the causes of excessive nutrient fertilization (hypereutrophication) in this lake, a formidable task due to the large size of the lake and its drainage basin. To narrow the scope of the study and work, several agencies collaborated in preparing a report that limited the possible causes of hypereutrophication in the lake to several hypotheses. Although the work began as a joint project, the Oregon Office completed it independently in cooperation with the Bureau of Reclamation.

Since its inception in 1984 and subsequent development, the GIS (geographic information system) has supplemented and aided almost every hydrologic project in Washington. Using the ARC/INFO system, data are coded into a computer as separate map files for single planimetric hydrologic parameters, such as land-surface altitudes, stream-channel networks, top and bottom altitudes of geologic formations, and ground-water levels. For any study, GIS data can be recalled from the computer and combined as layers of map information in any configuration of two or three dimensions or time sequence. Karen Schurr has been prominent in coding GIS data for Washington.

Epilogue

The Washington District had three major challenges during the period—two major reorganizations and the eruption and aftermath of Mount St. Helens—and survived very well. Throughout the three challenges, the core of the Washington District (WSO) programs remained focused on the needs of the cooperator agencies and responsive to national program initiatives. Funding and staffing grew at steady rates. The hydrologic-surveillance data networks remained stable and incorporated new technology when it became available. The Washington District became one of the lead Districts nationwide in establishing a real-time stream-gage network. The Water Resources Investigations Section of the Washington District (WSO) was able to do those studies required to meet the cooperator needs while also conducting many studies related to national interests. Some of these national programs were the RASA (three study areas), the flood insurance studies (many were completed), and the NAWQA (three study areas).

CHAPTER III – POSTSCRIPT, AWARDS, AND INDEX

POSTSCRIPT

By Philip Cohen

My friends and former colleagues have done an excellent job detailing in this volume the history of WRD during the time I served as Chief Hydrologist (1979–94). Although there is little factual that I can add, I would like to share with the reader some of my perspectives on several issues.

A major concern of any Government agency is to demonstrate the need for the services and information it provides. In that regard, WRD was almost continually challenged in the budget and program justification process by our supervisors in the USGS and the Department of the Interior, by the Administration, and by the Congress to convince them that the Nation should allocate a given amount of scarce taxpayer dollars for our programs. In general, they did not question the scientific credibility our work. However, they pressed us to demonstrate that our work was useful and timely. We responded in many ways, but one argument I thought was particularly persuasive related to the sources of WRD funding. In 1979, 57 percent of WRD's budget was appropriated by the Congress and 43 percent was provided by hundreds of State and local agencies, other Federal agencies, and Indian Tribes. In 1994, these numbers were 43 percent and 57 percent, respectively. During the same period, WRD's total annual budget increased from about $166 million to $400 million ($240 million in 1994 when adjusted for inflation). What better argument could be made regarding the perception of the usefulness and timeliness of our work than the fact that hundreds of public agencies willingly transferred hundreds of millions of dollars to WRD to do work that supported their mission responsibilities?

Some within WRD, the Director's Office, and Congressional staff questioned whether it was wise to allow the amount of funds obtained from other agencies to increase to more than 50 percent of WRD's total budget. The line managers within WRD, especially the Regional Hydrologists and District Chiefs, supported this position, and they were right. In addition to the good work that was done using the so-called reimbursable funds, tens of millions of dollars of overhead funds obtained as a percentage of total available funds (including funds from other agencies) were used to develop WRD's nationwide integrated computer system (described in detail elsewhere in this volume). It is probable that we would not have been able to develop the system as configured in 1994 if we had had to rely on the normal Federal budget process.

None of this would have been possible were it not for the wonderful people who built the organization that we were privileged to work for. Those who preceded us defined many aspects of the modern science of hydrology and were responsible for providing WRD with its stellar national and international stature. Likewise, the people who worked for WRD in 1979–94 (increasing from about 2,800 in 1979 to about 5,000 in 1994) made major advances to science and continued to enhance our scientific stature. This was as fine a staff of scientists, engineers, and support staff as ever was assembled. I am proud and humbled to have had the opportunity to serve with them.

Finally, WRD as we knew it could not have existed outside the USGS. We were part of the best scientific governmental agency in the world.

AWARDS

RECIPIENTS OF DISTINGUISHED SERVICE AWARD
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James F. Blakey	1989
John D. Bredehoeft	1981
Thomas J. Buchanan	1986
Edith Chase	1991
Rodney N. Cherry	1990
Alfred Clebsch, Jr.	1979
Philip Cohen	1979
T. John Conomos	1994
James L. Cook	1987
Hilton H. Cooper	1982
Elliott M. Cushing	1979
James F. Daniel	1991
Dan A. Davis	1988
George H. Davis	1979
Robert J. Dingman	1981
William W. Dudley, Jr.	1994
John N. Fischer	1990
Donald Hillier	1991
Edgar Imhoff	1991
Blair F. Jones	1986
Irwin H. Kantrowitz	1994
Vance C. Kennedy	1994
Samuel Luoma	1991
Gerald Meyer	1981
David W. Moody	1987
Richard W. Paulson	1994
Henry C. Riggs	1979
William H. Robinson	1979
Stanley P. Sauer	1989
Vernon B. Sauer	1988
Francis T. Schaefer	1986
Verne Schneider	1991
Keith V. Slack	1987
Victor T. Stringfield	1979
Ren Jen Sun	1991
Kiyoshi J. Takasaki	1989
Donald E. Vaupel	1989
Edwin P. Weeks	1988
Isaac J. Winograd	1986
Roger G. Wolff	1990

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1979 to 1994

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Charles A. Appel	1992
Jeffrey Armbruster	1989
Theodore Arnow	1984
Robert C. Averett	1985
William Back	1982
Mary Jo Baedecker	1991
James F. Bailey	1981
Ivan K. Barnes	1981
Daniel P. Bauer	1990
Norman H. Beamer	1983
Paul R. Beauchemin	1992
Marion S. Bedinger	1985
Gordon D. Bennett	1983
James P. Bennett	1985
James F. Blakey	1984
Richard M. Bloyd	1989
Lawrence D. Bonham	1982
Charles W. Boning	1985
Ernest H. Boswell	1982
Phillip M. Brown	1979
Charles R. Burchett	1990
Eurybiades Busenberg	1994
Albert N. Cameron	1981
Joseph D. Camp	1992
William J. Campbell	1985
Frank T. Carlson	1989
Philip J. Carpenter	1993
P. Hadley Carrigan, Jr.	1983
Rodney N. Cherry	1985
David E. Click	1985
James E. Cloern	1990
Ernest D. Cobb	1992
Gary D. Cobb	1992
Donald L. Coffin	1989
Alberto Condes	1985
T. John Conomos	1984
James L. Cook	1981
Richard L. Cooley	1985
Tyler B. Coplen II	1992
James F. Daniel	1984
James D. Davis	1992
George A. Dinwiddie	1989
William W. Dudley, Jr.	1985
Melvin D. Edwards	1985
Philip A. Emery	1985
William Emmett	1982
Herman R. Feltz	1983
John H. Feth	1979
John N. Fischer	1985
Bruce L. Foxworthy	1982
Herbert Freiberger	1989
Marvin O. Fretwell	1993
John R. George	1984
Bruce K. Gilbert	1983
Harold G. Golden	1989
Donald A. Goolsby	1988
Phillip E. Greeson	1990
David B. Grove	1985
Richard Hadley	1982
William E. Hale	1980
Eugene R. Hampton	1989
Bruce Hanshaw	1982
Arlen W. Harbaugh	1991

Ralph C. Heath	1981
Aaron L. Higer	1993
Donald Hillier	1985
Robert M. Hirsch	1988
Charles L.R. Holt	1980
David W. Hubbell	1988
Hugh H. Hudson	1979
Jerry L. Hughes	1990
Ivan C. James II	1985
Marshall E. Jennings	1991
Harvey W. Jobson	1988
Richard H. Johnston	1985
Benjamin L. Jones	1989
Blair F. Jones	1981
J. Ronald Jones	1988
James R. Jones	1981
Donald G. Jorgensen	1994
Irwin Kantrowitz	1988
Vance Kennedy	1982
Yousif K. Kharaka	1993
James E. Kircher	1994
Robert Kirkland	1988
Howard Klein	1979
Darwin Knochenmus	1989
Leonard F. Konikow	1985
Solomon M. Lang	1981
George Leavesley	1988
Jerry A. Leenheer	1985
Gerald F. Lindholm	1993
Miguel A. Lopez	1989
Nancy Lopez	1989
Samuel N. Luoma	1985
Robert D. MacNish	1990
William B. Mann IV	1985
Lawrence Martens	1982
Howard F. Matthai	1979
Jerald F. McCain	1985
Stuart W. McKenzie	1992
John S. McLean	1993
Jesse M. McNellis	1989
Robert H. Meade	1985
Linda E. Meadows	1983
Wanda C. Meeks	1992
William D. Miles	1992
James A. Miller	1989
John P. Monis	1984
John E. Moore	1985
Joe A. Moreland	1990
Marshall E. Moss	1983
Dorothy E. Niles	1979
Franklin Olmstead	1979
Ronald S. Oremland	1992
Garald G. Parker	1990
Charles A. Pascale	1990
Eugene P. Patten, Jr.	1985
Richard W. Paulson	1984
Ranard J. Pickering	1981
George M. Pike	1981
Leonard H. Plummer	1985
Austin S. Post	1984
Fred Quiñones-Marquez	1990
David A. Rickert	1992
Stephen E. Ragone	1989
John B. Robertson	1983
Charles J. Robinove	1979
Joseph S. Rosenshein	1984
Joan M. Rubin	1991
Stanley P. Sauer	1979
Vernon B. Sauer	1980
Norman E. Schmidt, Jr.	1992
Verne R. Schneider	1985
Kevin M. Scott	1988
Robert J. Shedlock	1992
Charles R. Showen	1985
Pat W. Skinner	1988
Keith V. Slack	1979
Winchell Smith	1979
Helen C. St. John	1980
Jerry C. Stephens	1988
Ren Jen Sun	1985
Charles H. Swift	1989
Kiyoshi J. Takasaki	1984
Donald M. Thomas	1981
Wilbert O. Thomas	1991
Donald C. Thorstenson	1988
Earl M. Thurman	1988
Frank W. Trainer	1982
James F. Turner	1990
Donald E. Vaupel	1985
John Vecchioli	1985
Kenneth L. Wahl	1991
Porter E. Ward	1983
John W. Wark	1982
Edwin P. Weeks	1982
John B. Weeks	1985
Walter F. White, Jr.	1979
William G. Wilber	1992
Joe R. Willmon	1992
James F. Wilson	1990
Isaac J. Winograd	1982
Allen G. Winslow	1979
Thomas C. Winter	1985
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Warren W. Wood	1991
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Janet N. Arneson	1994
David A. Aronson	1988
Mark A. Ayers	1992
Colleen A. Babcock	1994
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Claud H. Baker, Jr.	1992
Stanley Baldys III	1994
Jerad D. Bales	1992
Mary W. Barker	1986
James H. Barks	1991

Jack T. Barraclough	1984
Daniel P. Bauer	1988
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Curtis S. Bennett III	1991
James P. Bennett	1983
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Deroy L. Bergman	1985
Darleen K. Berry	1994
Julio L. Betancourt	1994
James M. Bettandorff	1993
Harry E. Blanchard	1985
Edward J. Blank	1984
Nancy C. Bley	1989
John P. Borland	1993
Ruth D. Bourland	1983
John V. Brahana	1994
Farrell A. Branson	1981
Owen P. Bricker	1985
Gaylia C. Brock	1992
David P. Brown	1994
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Roz D. Czajkoski	1985
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Jay H. Diamond	1989
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William R. Glass	1984
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Gregory B. O'Neill	1993
Nancy I. Ordazzo	1993
Ronald Oremland	1988
Garald G. Parker, Jr.	1984
Bruce Parks	1992
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Charles Parrett	1988
Charles A. Pascale	1985
Glenn C. Patterson	1991
Quentin F. Paulson	1983
Gary L. Pederson	1988
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Mary D. Perkins	1979
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James G. Rankl	1989

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Jack Rawson	1981
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Thomas E. Reilly	1988
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Sam E. Rickly	1985
George P. Rigatti	1993
Joseph F. Rinella	1992
A. Jean Roberts	1987
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Donald O. Rosenberry	1994
Thomas G. Ross	1990
Emeretta F. Rudy	1992
Roger P. Rumenik	1994
Barbara Ryan	1991
Elsie Sanchez	1987
Curtis L. Sanders, Jr.	1991
John E. Schefter	1988
Norman E. Schmidt, Jr.	1983
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Robert Schoen	1988
James C. Schornick, Jr.	1992
Brenda Scott	1985
Jonathon C. Scott	1991
John C. Scott	1993
William B. Scott	1994
Fletcher C. Sedberry	1993
William Shampine	1987
Allen M. Shapiro	1992
James O. Shearman	1992 and 1988
Wallace F. Shelton	1992 and 1992
Marvin G. Sherrill	1994
William G. Shope	1988
Michael V. Shulters	1992
Clyde E. Simmons	1988
Robert H. Simmons	1993
John Skelton	1991
Earl L. Skinner	1989
Connie L. Smith	1992
Eileen R. Smith	1987
Charles W. Smoot	1993
Floyd L. Snow	1994
Betty M. Spahn	1988
Richard L. Stahl	1987
Geraldine R. Stallworth	1991
John K. Stamer	1992
Ronnie D. Steger	1993
Jennie Steinheimer	1993
Joe E. Stewart	1984
Gloria J. Stiltner	1985
William R. Stokes	1989
Jeffrey D. Stoner	1994
Dennis J. Sulam	1988
Eric T. Sunquist	1988
Lindsway A. Swain	1994
Leanna E. Sweet	1990
Gary D. Tasker	1988
Howard E. Taylor	1988
O. James Taylor	1987
John E. Terry	1994
Janet T. Thomas	1992
Charles H. Tibbals	1994
Beverly J. Tirrell	1987
C. Larry Togans	1989
Jimmy W. Tucker	1989
James F. Turner	1987
Robert Ugland	1986
Santos Valenciano	1987
Stephen J. Vandas	1991
Otto VanderBrug	1984
Bobbie W. Vines	1985
Kidd M. Waddell	1988
C. Russell Wagner	1984
Robert F. Wakelee	1994
Raymond H. Wallace, Jr.	1982
Robert O. Walsworth	1988
Amy J. Watanabe	1979
Robert H. Webb	1994
George E. Welder	1987
Deborah H. Weldon	1992
Frank C. Wells	1991
Judith C. Wheele	1994
Frances Whetstone	1988
William Wilber	1987
Joe A. Wildman	1994
George E. Williams	1987
J. Rod Williams	1988
James F. Wilson	1985
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