WATER-RESOURCES ACTIVITIES IN UTAH BY THE U.S. GEOLOGICAL SURVEY, OCTOBER 1, 1991, TO SEPTEMBER 30, 1992

Compiled by Ellen E. Hardy and Joseph S. Gates

U.S. GEOLOGICAL SURVEY
Open-File Report 93–467

Salt Lake City, Utah
1993

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Robert M. Hirsch, Acting Director

For additional information
write to:

District Chief
U.S. Geological Survey
Water Resources Division
1745 West 1700 South
Room 1016 Administration Building
Salt Lake City, Utah 84104

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Message from the District Chief

The U.S. Geological Survey, Water Resources Division, is entering its 103rd year of activities in Utah. As Utah's demand for water has increased, so has the need for quantitative, unbiased water-resources data and interpretive studies. The Utah District program is designed to provide this information and help the Water Resources Division meet its goal of assessing the quantity and quality of the Nation's water resources.

The Utah District experienced a significant growth in program size by increasing from $4.43 million in fiscal year 1991 to $5.29 million in fiscal year 1992. This growth reflects continued support from long-time cooperators and additional work associated with the U.S. Bureau of Land Management (Bonneville Salt Flats) and the U.S. Department of Defense (Hill Air Force Base).

Fiscal year 1992 was the sixth consecutive year of drought conditions for many parts of Utah. In the northern part of the state, precipitation ranged from 80 to 104 percent of normal. Streamflow for most stations in northern Utah was substantially less than normal. Reservoirs throughout the State ranged from 2 to 45 percent full on September 30, 1992.

Monitoring hydrologic conditions during this climatologic extreme presented special challenges and illustrated the usefulness of long-term records. As streamflow decreased, water managers and decision makers required accurate and timely discharge data to ensure that each user received the appropriate amount of available water. The long-term records were useful in placing the current drought into historical perspective and provided a basis for worst-case scenario planning. The stresses placed on the hydrologic system during this drought are providing an opportunity to better understand the many factors that influence the availability and quality of water in Utah.

The future promises the continued challenge of helping local, State, and Federal agencies meet their water-resources information needs. I look forward to another active year in which U.S. Geological Survey water-resources investigations and data collection help meet these needs.

H.L. Case, III
District Chief
U.S. Geological Survey, Water Resources Division
Salt Lake City, Utah

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INTRODUCTION

This report contains summaries of the progress of water-resources studies in Utah by the U.S. Geological Survey, Water Resources Division, Utah District, from October 1, 1991, to September 30, 1992. The program in Utah during this period consisted of 20 projects; a discussion of each project is presented in the main body of this report.

The following sections outline the origin of the U.S. Geological Survey, the basic mission of the Water Resources Division, the organizational structure of the Utah District, the distribution of District funding in terms of source of funds and type of activity funded, and the agencies with which the District cooperates. The last part of the introduction is a list of reports produced by the District from October 1991 to September 1992.

Origin of the U.S. Geological Survey

The U.S. Geological Survey was established by an act of Congress on March 3, 1879, to provide a permanent Federal agency to conduct the systematic and scientific "classification of the public lands, and examination of the geologic structure, mineral resources, and products of national domain." An integral part of that original mission includes publishing and disseminating the earth-science information needed to understand, to plan the use of, and to manage the Nation's energy, land, mineral, and water resources.

Since 1879, the research and fact-finding role of the U.S. Geological Survey has grown and been modified to meet the changing needs of the Nation it serves. As part of that evolution, the U.S. Geological Survey has become the Federal Government's largest earth-science research agency, the Nation's largest civilian map-making agency, the primary source of data on the Nation's surface- and ground-water resources, and the employer of the largest number of professional earth scientists. Today's programs serve a diversity of needs and users. Programs include:

- Conducting detailed assessments of the energy and mineral potential of the Nation's land and offshore areas.
- Investigating and issuing warnings of earthquakes, volcanic eruptions, landslides, and other geologic and hydrologic hazards.
- Conducting research on the geologic structure of the Nation.
- Studying the geologic features, structure, processes, and history of the other planets of our solar system.
- Conducting topographic surveys of the Nation and preparing topographic and thematic maps and related cartographic products.
- Developing and producing digital cartographic data bases and products.
- Collecting data on a routine basis to determine the quantity, quality, and use of surface and ground water.

- Conducting water-resource appraisals in order to describe the consequences of alternative plans for developing land and water resources.
- Conducting research in hydraulics and hydrology, and coordinating all Federal water-data acquisition.
- Using remotely sensed data to develop new cartographic, geologic, and hydrologic research techniques for natural-resources planning and management.
- Providing earth-science information through an extensive publication program and a network of public access points.

Along with its continuing commitment to meet the growing and changing earth-science needs of the Nation, the U.S. Geological Survey remains dedicated to its original mission to collect, analyze, interpret, publish, and disseminate information about the natural resources of the Nation—providing "Earth Science in the Public Service."

Mission of the U.S. Geological Survey, Water Resources Division

The mission of the Water Resources Division, which supports the overall mission of the U.S. Department of the Interior and the U.S. Geological Survey, is to provide the hydrologic information and understanding needed for the best use and management of the Nation's water resources for the benefit of the people of the United States.

To accomplish its mission, the Water Resources Division, in cooperation with State and local governments and other Federal agencies:

- Systematically collects data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources.
- Conducts analytical and interpretive water-resources appraisals to describe the occurrence, availability, and physical, chemical, and biological characteristics of surface and ground water and their interrelation.
- Conducts supportive basic and problem-oriented research in hydraulics, hydrology, and related fields of science and engineering to improve the basis for field investigations and measurement techniques and to understand hydrologic systems sufficiently well to predict quantitatively their response to stress, either natural or manmade.
- Disseminates water data and the results of investigations and research through reports, maps, computerized information services, and other forms of public releases.
- Coordinates the activities of all Federal agencies in the acquisition of certain water data.
- Provides scientific and technical assistance in hydrologic fields to State, local, and other Federal agencies, to licensees of the Federal Energy Regulatory Commission, and, on behalf of the U.S. Department of State, to international agencies.
- Acquires, develops, and disseminates information on water-related natural hazards such as droughts, floods, landslides, land subsidence, mudflows, and volcanoes.
- Administers the provisions of the Water Resources Research Act of 1984 that include the programs of the State Water Resources Research Institutes and the Research Grants and Contracts.
- Supports the provisions of the National Environmental Policy Act of 1969 and manages Geological Survey conduct of natural-resources surveys in response to the Compre-

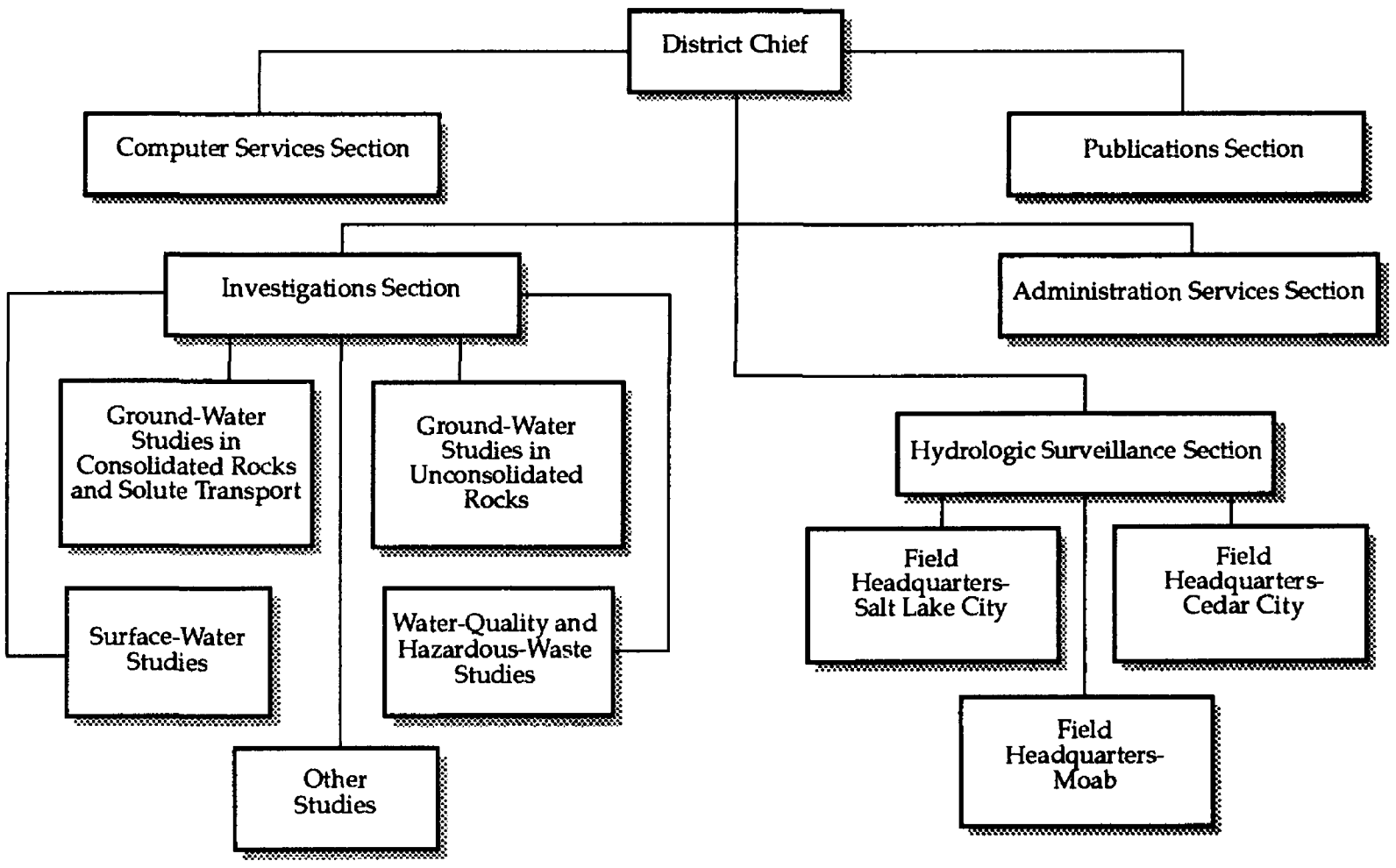
hensive Environmental Response, Compensation, and Liability Act (Superfund Act) of 1980.

Authority for carrying out this mission is derived from legislation of 1879, which created the U.S. Geological Survey, and legislation of 1888 and 1894, which provided for gaging of streams and determining the Nation's water supply. Congressional appropriations have been made annually since 1894 for gaging streams and performing other functions relating to water resources. In 1964, the U.S. Geological Survey's mission was broadened to include the role of lead agency in the coordination of the activities of all Federal agencies in the acquisition of certain water data. This responsibility was assigned to the Department of the Interior by the Office of Management and Budget Circular A-67.

Utah District Organization

The Utah District of the Water Resources Division is organized into five operating sections under the District Chief (see organization chart). Water-resources projects are done by the Investigations Section (primarily interpretive studies) and Hydrologic Surveillance Section (primarily collection of hydrologic data). Responsibility for each project is assigned to a project chief. Support for project work is supplied by the Publications Section, which processes and illustrates reports, and the Computer Services and Administrative Services Sections. The Utah District consists of the District Office in Salt Lake City and Field Headquarters in Salt Lake City, Moab, and Cedar City. The location of these offices and their areas of responsibility are shown in figure 1.

Utah District Organization



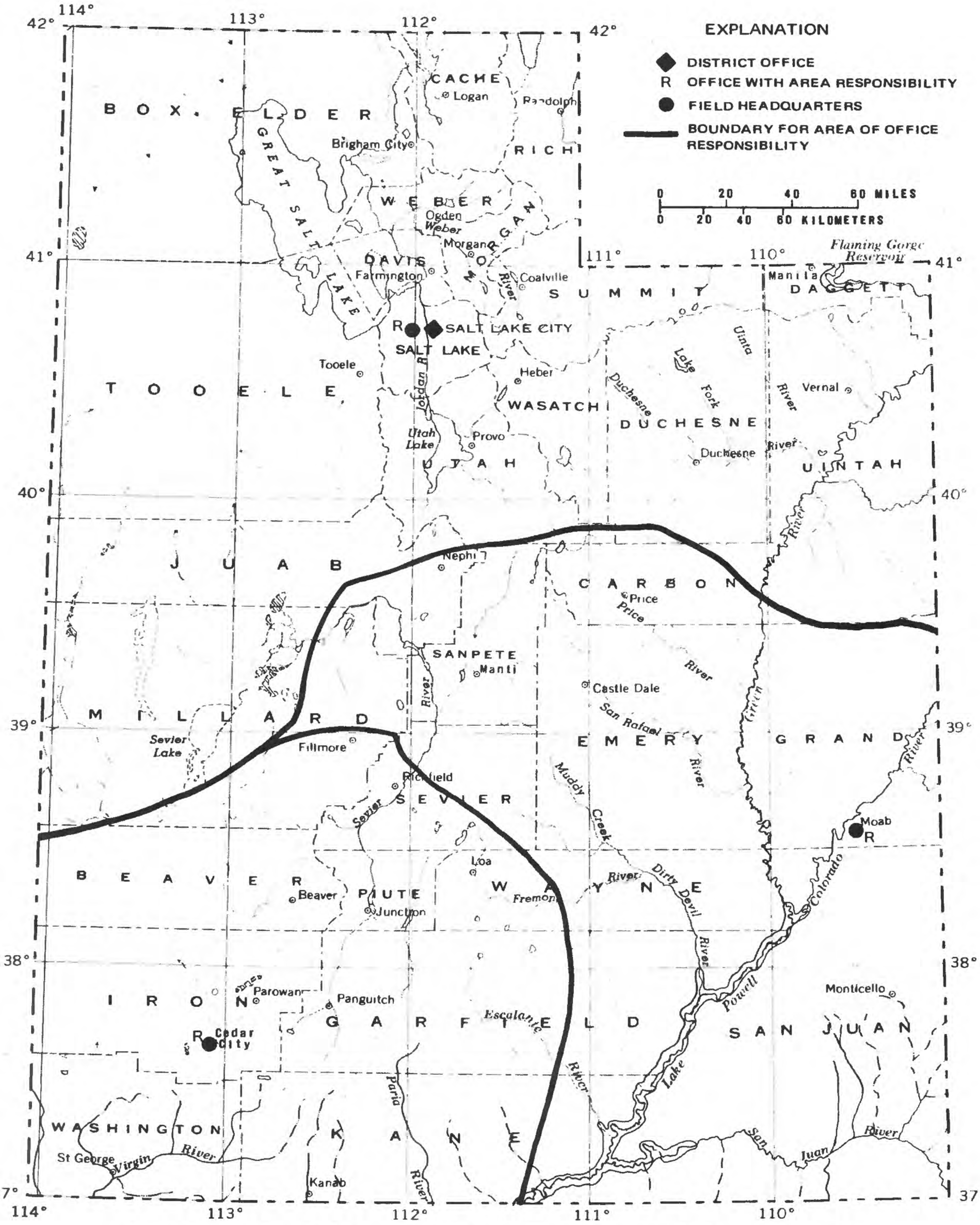


Figure 1.--Location of U.S. Geological Survey, Water Resources Division, offices and general areas of responsibility.

Utah District Office Addresses

Inquiries regarding projects described in this section may be directed to the District Office or the office in which the work originated.

District Office
and Salt Lake City Field Headquarters
(801) 975-3350

U.S. Geological Survey
Water Resources Division
Room 1016 Administration Building
1745 West 1700 South
Salt Lake City, Utah 84104

Cedar City Field Headquarters
(801) 586-4543

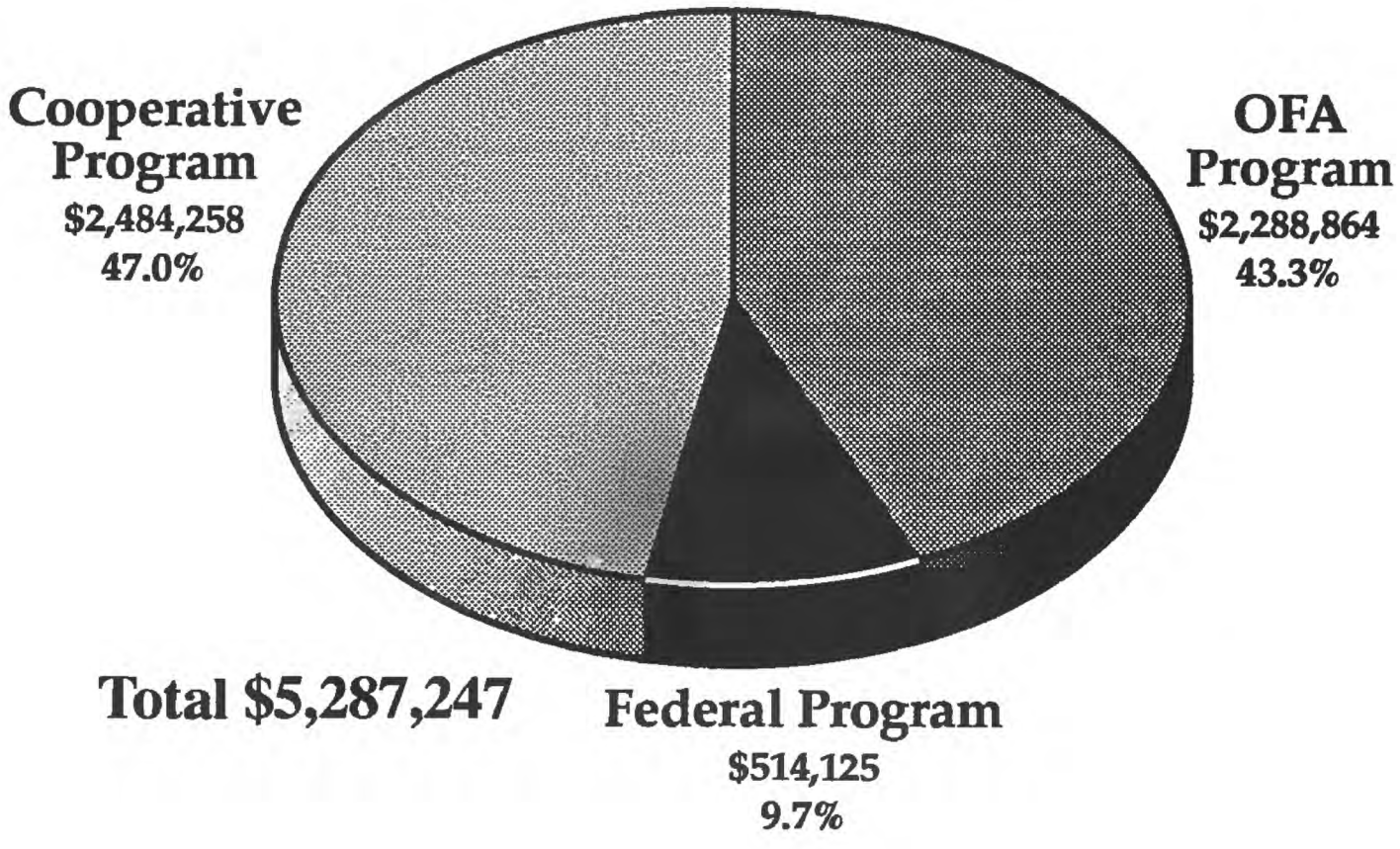
U.S. Geological Survey
Water Resources Division
82 North 100 East
P.O. Box 1066
Cedar City, Utah 84720

Moab Field Headquarters
(801) 259-5495

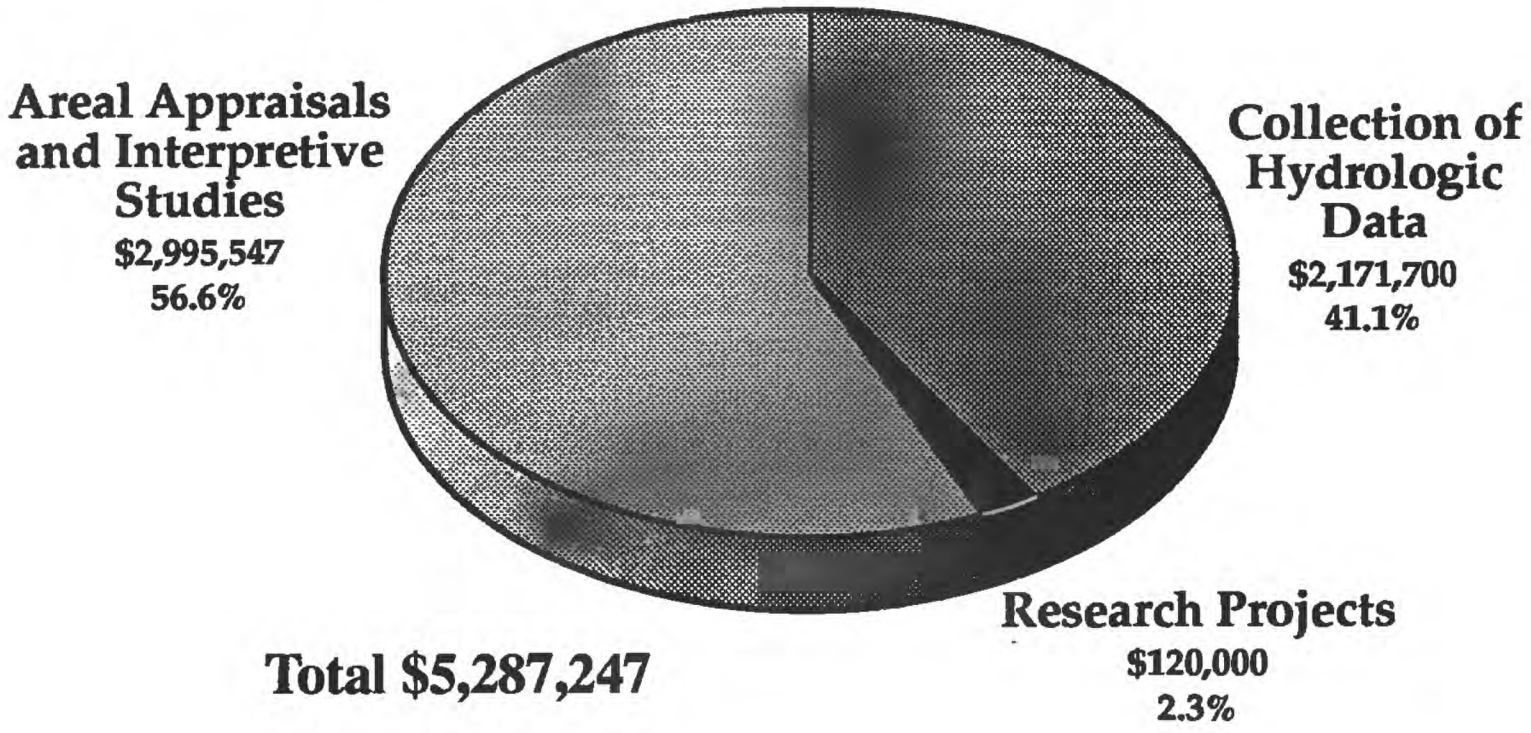
U.S. Geological Survey
Water Resources Division
50 East Center Street
P.O. Box 490
Moab, Utah 84532

Program Funding and Cooperating Agencies

Funds to support water-resources work by the Utah District are from three sources. Cooperative-program funds and services are provided from State and local government agencies and generally are matched by Federal funds on a 50-50 basis. Funds transferred from other Federal agencies (OFA) are part of the OFA Program, and funds appropriated directly to the U.S. Geological Survey by Congress are part of the Federal Program. In fiscal year 1992, total financial support from these programs for the Utah District was about $5.29 million. The distribution of funds among the three sources is shown below:



In fiscal year 1992, the Utah District pursued three broad categories of studies: (1) collection of hydrologic data, (2) areal appraisals and interpretive studies, and (3) research projects. About 41.1 percent of the program was for collection of hydrologic data, 56.6 percent was for interpretive studies and appraisals, and 2.3 percent was for research projects. These studies provide water managers and planners with information about the availability and quality of Utah's water resources. The distribution of funds among the three categories is as follows:



From October 1, 1991, to September 30, 1992, the cooperating agencies for District projects were:

State Agencies

Utah Department of Natural Resources
- Division of Oil, Gas, and Mining
- Division of State Lands and Forestry
- Division of Water Resources
- Division of Water Rights
- Geological Survey

Local Agencies

Bear River Commission
Central Utah Water Conservancy District
East Juab County Water Conservancy District
Ogden River Water Users Association
Salt Lake County Division of Flood Control and Water Quality
Weber Basin Water Conservancy District
Weber River Water Users Association

Federal Agencies

Federal Energy Regulatory Commission
U.S. Air Force
U.S. Bureau of Indian Affairs
U.S. Bureau of Land Management
U.S. Bureau of Reclamation
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Soil Conservation Service

Reports Released or Published

Reports prepared by or in cooperation with the Utah District can be obtained at the following locations:

Utah District Office: Open-File Reports; Water-Resources Investigations Reports; Hydrologic-Data Reports; Water-Data Reports; and Utah Department of Natural Resources Technical Publications, and Cooperative Investigations Reports.

U.S. Geological Survey Earth Science Information Center: U.S. Geological Survey Water-Supply Papers, Professional Papers, Circulars, and Hydrologic Investigations Atlases.

Utah Department of Natural Resources, Division of Water Rights: Technical Publications, Water Circulars, Hydrologic-Data Reports, and Water-Use Reports.

Utah Department of Natural Resources, Division of Water Resources: Cooperative Investigations Reports.

The following reports were published during October 1, 1991 to September 30, 1992:

Baskin, R.L., 1992, GPS finds its place on the lake, *in* GPS World: Eugene, Oreg., v. 3, no. 5, p. 27.

Batty, D.M., Herbert, L.R., and others, 1992, Ground-water conditions in Utah, spring of 1992: Utah Division of Natural Resources Cooperative Investigations Report Number 32, 91 p.

Clark, D.W., 1991, Ground-water resources and simulated effects of withdrawals in the Bountiful area, Utah: Utah Department of Natural Resources Technical Publication 95, 58 p.

Freethey, G.W., and Cordy, G.E., 1990, Geohydrology of Mesozoic rocks in the Upper Colorado River Basin in Arizona, Colorado, New Mexico, Utah, and Wyoming, excluding the San Juan Basin: U.S. Geological Survey Professional Paper 1411-C, 118 p.

Heilweil, V.W., and Freethey, G.W., 1992, Hydrology of the Navajo aquifer in southwestern Utah and northwestern Arizona, including computer simulation of ground-water flow and water-level declines that could be caused by proposed withdrawals, *in* Harty, K.M., ed., Engineering and environmental geology of southwestern Utah: 1992 Field Symposium, Utah Geological Association Publication 21, p. 213-231.

Heilweil, V.M., and Freethey, G.W., 1992, Simulation of ground-water flow and water-level declines that could be caused by proposed withdrawals, Navajo Sandstone, southwestern Utah and northwestern Arizona: U.S. Geological Survey Water-Resources Investigations Report 90-4105, 51 p.

Herbert, L.R., Burden, C.B., and Thomas, B.K., 1992, Seepage study of the Timpanogos, Wasatch, Sagebrush and Spring Creek, Upper Charleston, and Lower Charleston Canals, Wasatch County, Utah, 1989: Utah Department of Natural Resources Technical Publication 104, 44 p.

Kimball, B.A., Broshears, R.E., McKnight, D.M., and Bencala, K.E., 1992, Effects of instream modification on aluminum, *in* Water-rock interaction: Proceedings of the 7th International Symposium on Water-Rock Interaction, Park City, Utah, p. 393-396.

Kimball, B.A., Broshears, R.E., Bencala, K.E., and McKnight, D.M., 1992, Estimated rates of net chemical reactions in a mountain stream transporting sulfide oxidation products, *in* Proceedings of the 204th American Chemical Society, August 25-27, 1992: Washington, D.C.

Peltz, L.A., and Waddell, Bruce, 1991, Physical, chemical, and biological data for detailed study of irrigation drainage in the middle Green River basin, Utah, 1988-89, with selected data for 1982-87: U.S. Geological Survey Open-File Report 91-530, 213 p.

ReMillard, M.K., and others, 1992, Water resources data, Utah, water year 1991: U.S. Geological Survey Water-Data Report UT-91-1, 375 p.

Roark, D.M., and Hanson, K.M., 1992, Selected hydrologic data for Cache Valley, Utah and Idaho, 1969-91: U.S. Geological Survey Open-File Report 92-173, 65 p.

Spangler, L.E., 1992, Records of wells in sandstone and alluvial aquifers and chemical data for water from selected wells in the Navajo aquifer in the vicinity of the Greater Aneth Oil Field, San Juan County, Utah: U.S. Geological Survey Open-File Report 92-124, 44 p.

Spangler, L.E., 1992, Physical extent, thickness, and quality of water of the principal aquifers, western Kane County, Utah, *in* Harty, K.M., ed., Engineering and environmental geology of southwestern Utah: 1992 Field Symposium, Utah Geological Association Publication 21, p. 201-212.

Susong, D.D., 1992, Application of unsaturated zone monitoring techniques to help define urban nonpoint source contamination, *in* Proceedings of the Utah Nonpoint Source Pollution Conference, October 1-2, 1992: Ogden, Utah.

Thiros, S.A., and Cordy, G.E., 1990, Hydrology and effects of mining in the Quitchupah and Pines coal-lease tracts, central Utah: U.S. Geological Survey Water-Resources Investigations Report 90-4084, 63 p.

Waddell, K.M., Gwynn, J.W., Burden, Carole, and Wold, S.R., 1992, Salt budget for West Pond, Utah, April 1987 to April 1988: U.S. Geological Survey Water-Resources Investigations Report 91-4117, 29 p.

Waddell, K.M., Freethey, G.W., Susong, D.D., and Pyper, G.E., 1991, Review of water demand and water utilization studies for the Provo River drainage basin and review of a study of the effects of the proposed Jordanelle Reservoir on seepage to underground mines, Bonneville Unit of the Central Utah Project: U.S. Geological Survey Open-File Report 91-514, 74 p.

Wilberg, D.E., 1991, Hydrologic reconnaissance of the Sevier Lake area, west-central Utah: Utah Department of Natural Resources Technical Publication 96, 51 p.

CURRENT PROJECTS BY NUMBER AND TITLE

Collection of Hydrologic Data

Surface-Water Data

Number: UT-00-001

Cooperating Agencies: U.S. Bureau of Reclamation; U.S. Soil Conservation Service; Utah Division of Water Rights; Utah Division of Water Resources; Utah Geological Survey; Bear River Commission; Weber Basin Water Conservancy District; Salt Lake County Division of Flood Control and Water Quality; Weber River Water Users Association; Ogden River Water Users Association; Federal Energy Regulatory Commission

Staff: L.R. Herbert, Hydrologic Technician, Project Chief (part time)
Other District personnel as assigned

Period of Project: Continuing

Problem: Information on surface water is needed for the planning, design, operation, and management of Utah's surface-water resources and for warning of hazards related to surface water. Such information is used in water-related fields such as water supply, hydroelectric power generation, irrigation, flood control, bridge and culvert design, wildlife management, pollution abatement, flood-plain management, and water-resources development. To provide this information, an appropriate data base on discharge of streams and contents and stages of reservoirs and lakes is necessary.

Objectives: To obtain data on stream discharge and reservoir and lake contents and stages at selected sites throughout Utah.

Approach: Standard methods for the operation and maintenance of streamflow-gaging stations and for the computation, computer storage, and publication of the data are used.

Progress: Data collection and computation necessary for the publication of discharge records for 186 streamflow-gaging stations and contents and stage records for 19 reservoir- and 3 lake-stage stations continued during the year. In addition, streamflow data were collected at seven partial-record sites. Also, periodic measurements were made of flow of water through the breach in the causeway across Great Salt Lake. The locations of the stations and station numbers are shown in figure 2. Data collected at these stations, as well as larger-scale maps showing station locations, are presented in the series of reports entitled "Water resources data for Utah," U.S. Geological Survey Water-Data Reports. The stations are classified as follows:

	Number of stations
Discharge	
Current use	131
Hydrologic data for planning and design	44
Benchmark for long-term trends	11
Contents of lakes and reservoirs	20
Stage of Great Salt Lake	2

Twelve streamflow-gaging stations were discontinued as of September 30, 1992. These were:

Dingle Inlet Canal
Bear River below Stewart Dam
Montezuma Creek at G C at Monticello
Little Bear River below Davenport Creek near Avon
Blacksmith Fork above Hardware Ranch
North Willow Creek near Grantsville
Sulphur Creek below reservoir near Evanston, Wyoming
Bear River near Randolph
Thomas Fork near Wyoming-Idaho State line
South Fork Rock Creek near Hanna
Price River at Woodside
Spanish Fork below Halls Falls near Thistle

Streamflow-gaging stations established as of September 30, 1992, for use in fiscal year 1993 were:

East Fork Virgin River near Mt. Carmel
Beaver Dam Wash at mouth at Beaver Dam, Arizona
Little Bear River near Paradise

Seepage studies:

A report on the seepage study of the Bear River and Cutler Reservoir in Cache Valley, Utah-Idaho, was published.

Plans for Next Year: Continue operation of network. Prepare 1993 water-year records for publication. Continue monitoring flow through the breach in the Great Salt Lake causeway. Complete report on floods in the Great Basin during 1983-84 and on the flood resulting from the Quail Creek Reservoir dike failure. Complete report on floods near Lake Powell. Complete report on surface-water reconnaissance of the Sevier River basin upstream from Sevier Bridge Reservoir.

Reports:

ReMillard, M.D., and others, 1992, Water resources data for Utah, water year 1991: U.S Geological Survey Water-Data Report UT-91-1.

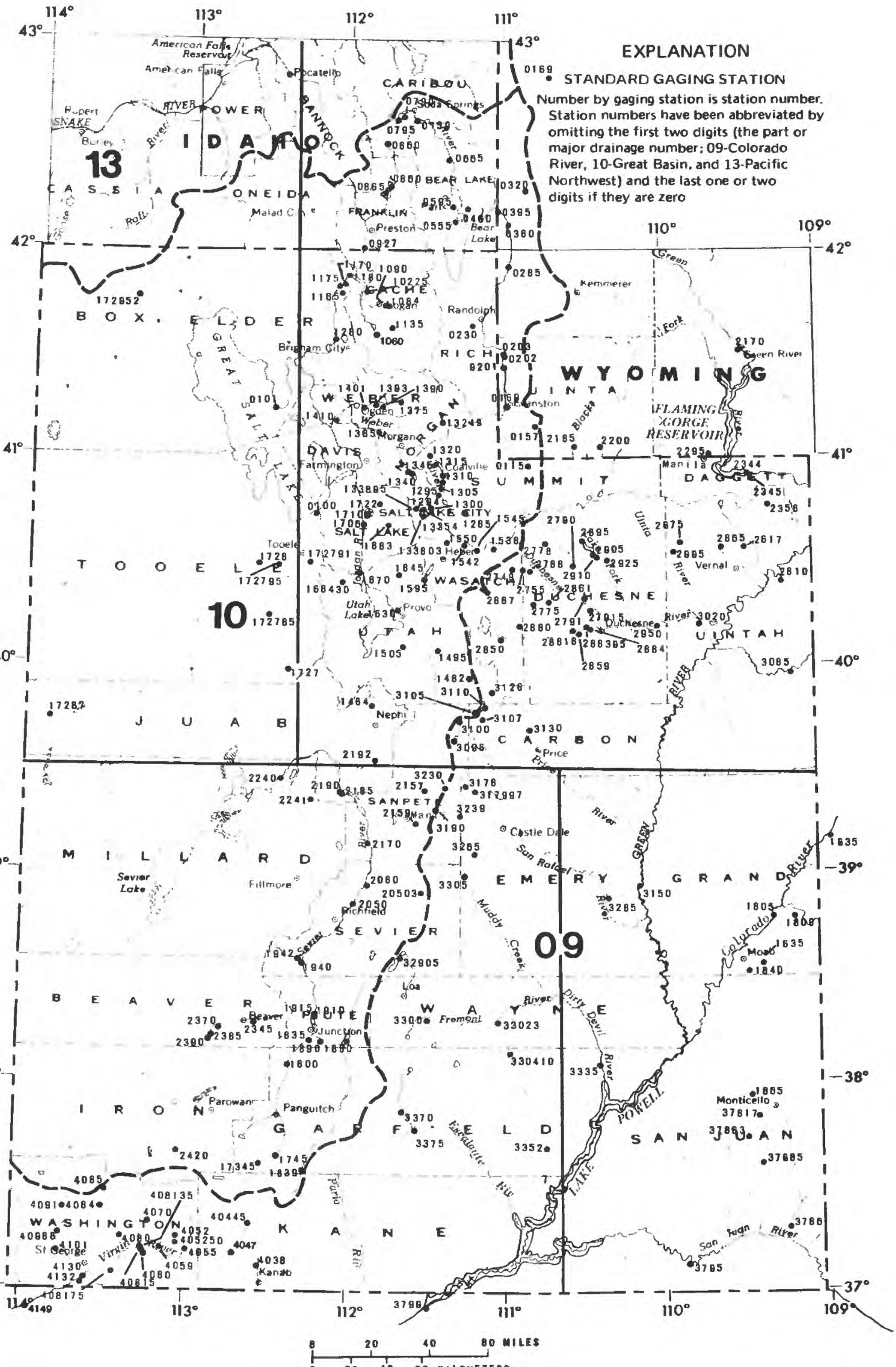


Figure 2. Location of gaging stations.

Ground-Water Data and Ground-Water Conditions in Utah

Number: UT-00-002

Cooperating Agencies: Utah Division of Water Rights; Utah Division of Water Resources

Staff: L.R. Herbert, Hydrologic Technician, Project Chief
D.M. Batty, Hydrologic Technician and editor of annual ground-water conditions report (part time)
J.S. Gates, Hydrologist (part time)
Other District personnel as assigned

Period of Project: Continuing

Problem: Long-term records of water levels and ground-water withdrawals are needed to evaluate the effects of climatic variations, to determine the effects of withdrawals from aquifers on water levels, to assist in the prediction of future conditions of aquifers, and to provide data for management of ground-water resources.

Objectives: (1) To obtain long-term records of ground-water levels for determination of water-level changes for yearly or other periods, (2) to determine withdrawals from aquifers in the State, and (3) to make an annual evaluation of ground-water conditions in Utah and publish the information in a report.

Approach: Measure water levels annually or semiannually (normally February to March and September) and operate continuous water-level recorders on selected wells (fig. 3). Visit selected discharging irrigation wells, measure discharge, determine the ratio of water produced to energy consumed, and use the ratio along with energy-consumption data to compute total annual pumpage. Visit selected flowing wells and measure discharge. Obtain estimates of ground water withdrawn from wells for public supply and industrial use from the Utah Division of Water Rights. Obtain additional selected estimates of industrial use of water from wells by interviewing users, or by rating pumps and using the ratio of water produced to energy consumed with energy-consumption records. Determine the number and diameter of new wells drilled annually from well drillers' reports filed with the Utah Division of Water Rights. Prepare an annual report on ground-water conditions in Utah that includes data, graphs, and maps showing water-level changes; withdrawals from wells; number of wells drilled in defined ground-water basins or areas; changes in ground-water quality; and a discussion of ground-water conditions in each basin or area with significant withdrawals. Store water-level data in computer files and publish selected data in the annual report of water-resources data for Utah.

Progress: Water levels were measured in about 1,040 wells in February and March. In addition, water levels in about 600 of these wells were measured in September, water levels in 12 of these wells were measured monthly, and water levels in 18 of these wells were measured quarterly. Continuous water-level recorders were maintained on 30 of these wells. During the irrigation season, about 500 discharging irrigation wells were visited; discharge was measured at about one-half of the wells, and the ratio of water production to energy consumption was determined. Natural flow was measured for about 50 wells during the irrigation season. Number and diameters of wells drilled during the past year were compiled. The twenty-ninth in the series of annual reports on ground-water conditions in Utah was completed. The brochure on how the U.S. Geological Survey conducts ground-water studies was submitted for approval and was approved.

Plans for Next Year: Continue collecting, recording, and publishing data on water levels, ground-water withdrawals, and wells drilled. The thirtieth in the series of annual ground-water reports will be compiled. Prepare final illustrations and text for the brochure on ground-water studies, and print the brochure.

Reports:

Batty, D.M., Herbert, L.R., and others, 1992, Ground-water conditions in Utah, spring of 1992: Utah Division of Water Resources Cooperative Investigations Report 32.

ReMillard, M.D., and others, 1992, Water resources data for Utah, water year 1991: U.S. Geological Survey Water-Data Report UT-91-1.

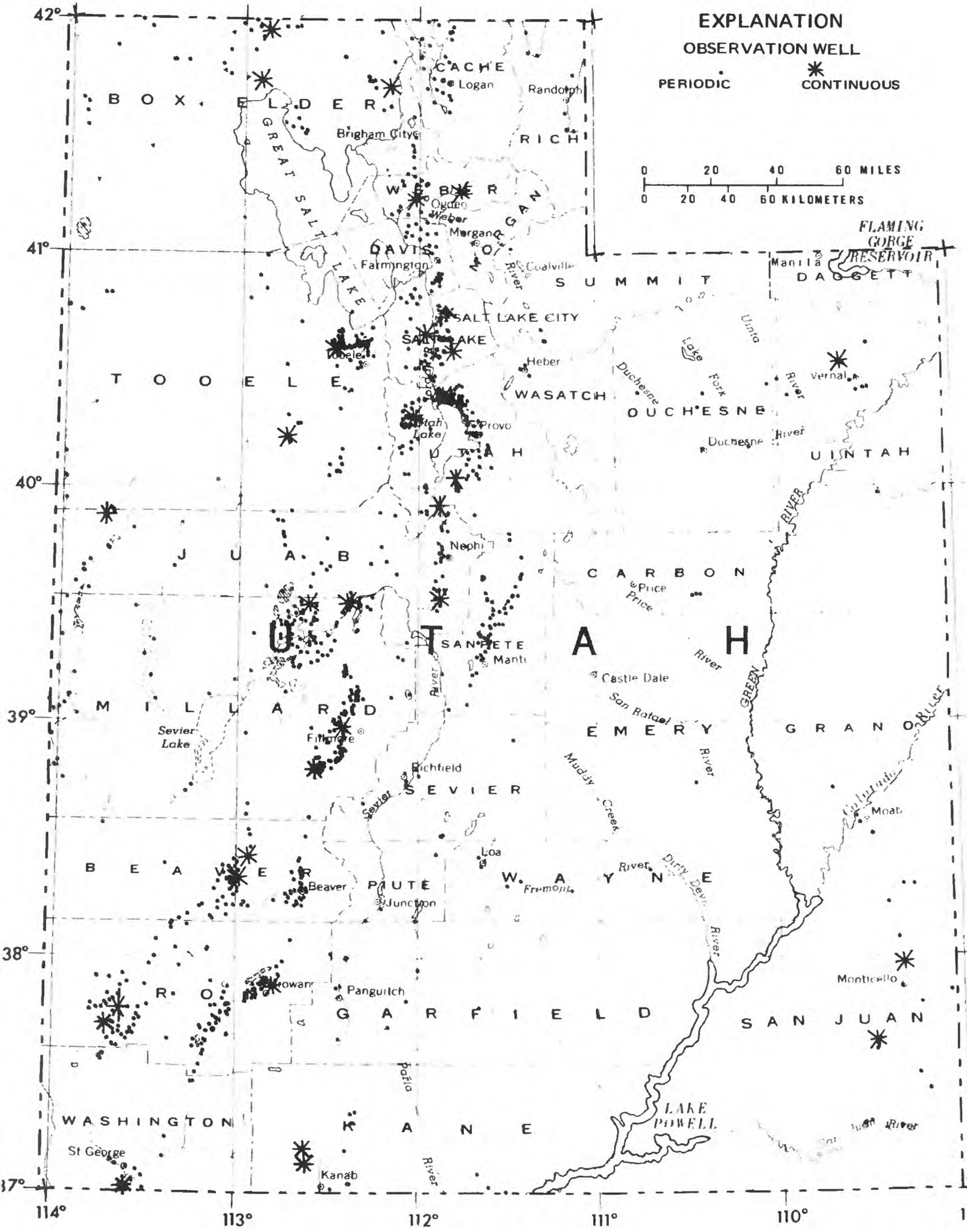


Figure 3. Location of observation wells in which water levels were measured.

Water-Quality and Fluvial-Sediment Data

Number: UT-00-003; UT-00-004

Cooperating Agencies: Utah Division of Water Resources; Utah Division of Water Rights; Utah Geological Survey; U.S. Bureau of Reclamation; U.S. Soil Conservation Service

Staff: L.R. Herbert, Hydrologic Technician, Project Chief (part time)
Other District personnel as assigned

Period of Project: Continuing

Problem: Data on the quality of surface and ground water are needed for surveillance, planning, design, and management of water-resources activities. Water-quality problems can affect industries, water-treatment facilities, irrigators, and individuals. Sediment reduces storage in reservoirs, contaminates water supplies, and harms fisheries. Sediment data are needed for erosion studies, reservoir design, evaluation of water quality, and water-resources management. Data bases are needed to provide the appropriate water-quality and sediment information.

Objectives: To obtain records of the quality of water from streams and wells and records of sediment at selected sites throughout Utah, including Great Salt Lake.

Approach: Use standard methods for the collection and analysis of chemical-quality, fluvial-sediment, and biological samples, and computer storage and publication of data.

Progress: Water samples for chemical analysis were obtained periodically at 21 stream sites (fig. 4). In addition, continuous or daily temperature and/or specific-conductance data were obtained at 12 of these stream sites. About 200 wells are in the ground-water-quality monitoring program (fig. 5), but water samples for chemical analysis of ground water were obtained from a total of 215 wells. Water from 10 water-supply wells was sampled in an area of oil-field brine injection in the Uinta Basin. All water-quality data for streams and wells are listed in the annual water-resources data reports. Physical and chemical data for surface and ground water also were obtained for long-term sites on Great Salt Lake and at the West Pond of the West Desert Pumping project. Seasonal and areal variations in water quality in the north part of Great Salt Lake were defined by sampling three times a year at five sites and four times a year at six sites. Sampling also was done three times a year at six sites and four times a year at five sites in the south part of Great Salt Lake. Quarterly measurements of temperature, density, and velocity of flow were made along several verticals through cross sections at both the upstream and downstream sides of the breach through the causeway between the south and north parts of the lake. Water quality was monitored in 18 observation wells near the dikes of West Pond.

Plans for Next Year: Continue collecting and processing data and preparing records for publication. Continue monitoring the temperature and specific gravity of water at different depths in Great Salt Lake. Continue monitoring water quality in observation wells statewide and in the wells near the dikes of West Pond. Continue monitoring water quality in selected water-supply wells in the brine-injection area of the Uinta Basin.

Reports:

ReMillard, M.D., and others, 1992, Water resources data for Utah, water year 1991: U.S. Geological Survey Water-Data Report UT-91-1.

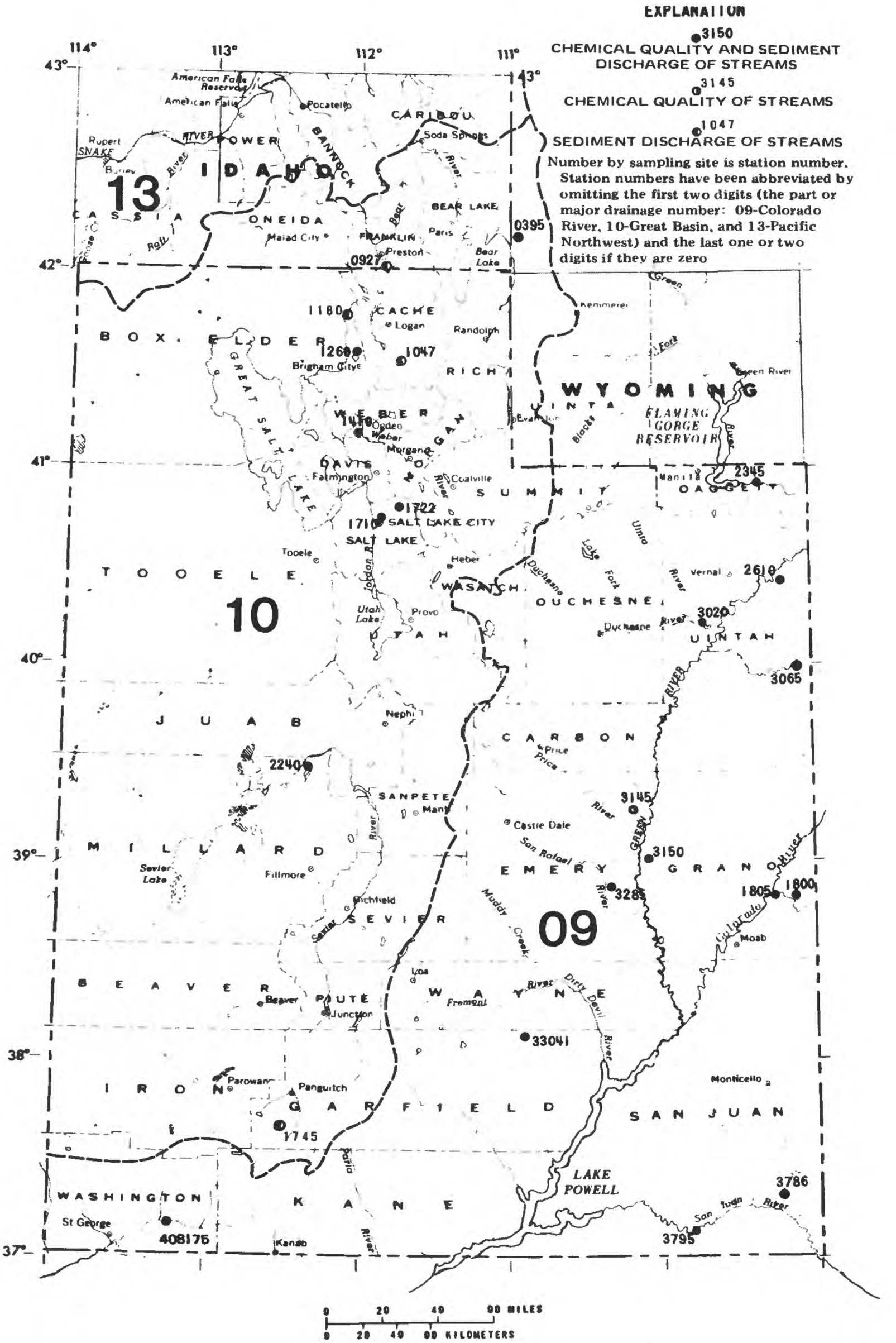


Figure 4. Location of surface-water-quality stations.

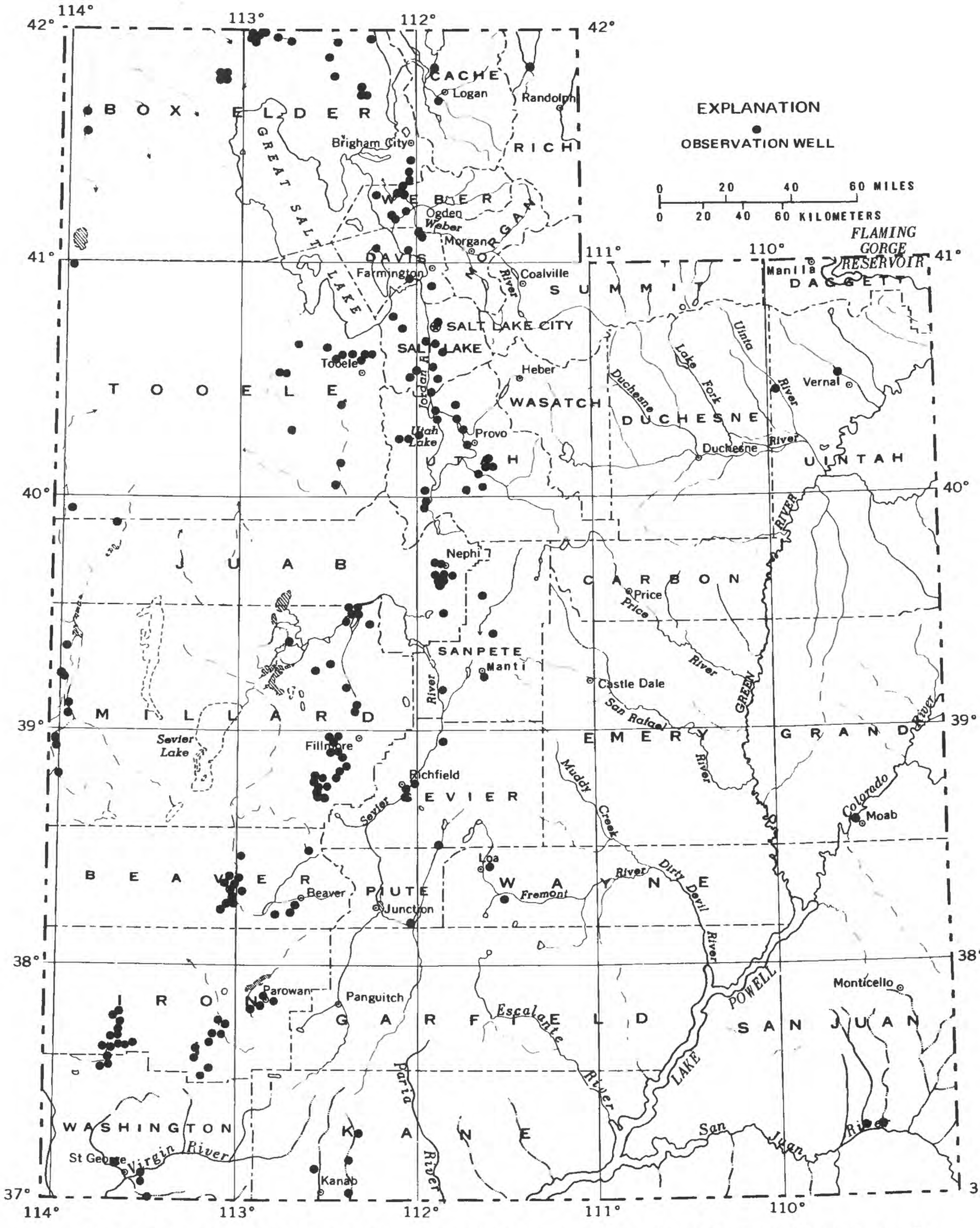


Figure 5. Location of observation wells where water samples were collected for monitoring water quality.

Interpretive Studies

Locations of interpretive studies discussed in this section are shown in figure 6.

Statewide Water Use

Number: UT-00-007

Cooperating Agencies: Utah Division of Water Rights; Utah Division of Water Resources

Staff: H.K. Hadley, Hydrologist, Project Chief (part time)
G.E. Pyper, Hydrologist (part time)
K.K. Wilson, Hydrologic Technician (part time)

Period of Project: Began July 1977, continuing

Problem: In 1977, the U.S. Congress recognized the need for consistent, current, and reliable information on water use for the entire United States and directed the U.S. Geological Survey to set up a program to collect, compile, and publish such data. These data are needed to document trends in total use of water and in the different categories of use, and to aid in the management of the Nation's water resources.

Objective: To obtain information about withdrawals and return flows of water for different uses, and consumptive use of water in connection with each type of withdrawal.

Approach: Determine total water diversions and consumptive use by verification of user measurements and records and, where possible, by field inventory and measurement of surface-water diversions and selected types of ground-water diversions. Use acreage and crop surveys to aid in estimating consumptive use by irrigation. State personnel are collecting data on public-supply and industrial use; U.S. Geological Survey personnel are collecting data on irrigation use.

Progress: Mail surveys were done by the Utah Division of Water Rights to determine water use by about 390 public water suppliers and about 110 major self-supplied and public-supplied industries. Text and graphics for a 1985 and 1990 State water-use report are being prepared for editorial review.

Plans For Next Year: Develop a written 3-year (1993-95) plan for the Utah Water-Use program, emphasizing a strategy for improving collection or estimation of current and reliable irrigation data (more than 80 percent of the water used in Utah is for irrigation). Begin to determine commercial consumptive use for a rapidly growing city in southwestern Utah to aid city planners in demand forecasting. Assist the Utah Division of Water Resources with their annual agricultural land-use survey.

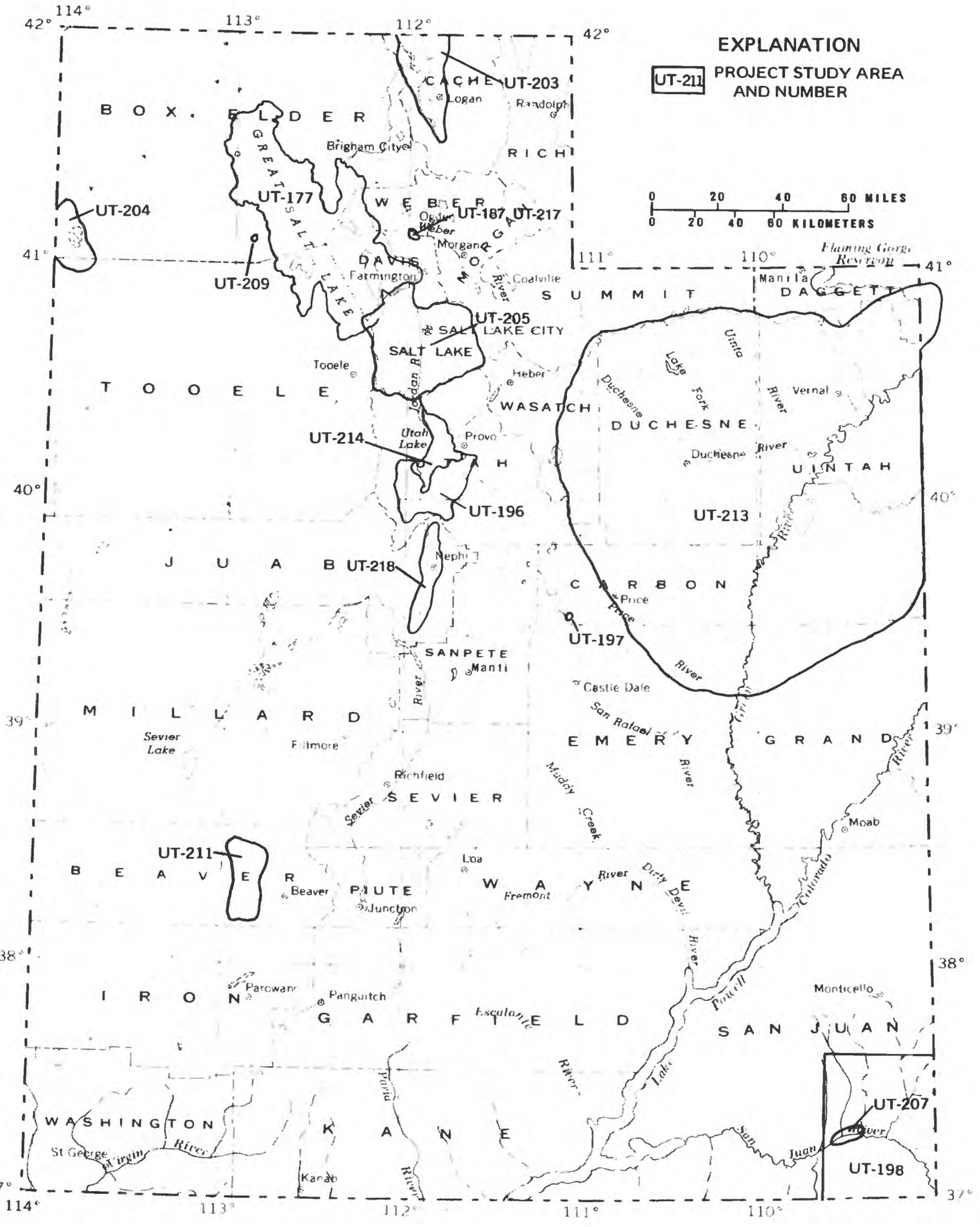


Figure 6. Location of interpretive studies.

Model for Predicting the Water and Salt Balance of Great Salt Lake for Selected Lake Levels

Number: UT-87-177

Cooperating Agency: Utah Division of State Lands and Forestry

Staff: K.M. Waddell, Hydrologist, Project Chief (part time)
S.R. Wold, Hydrologist

Period of Project: January 1986 to December 1987

Problem: A model was developed by the U.S. Geological Survey in 1973 for estimating the water and salt balance of Great Salt Lake. Because of the high lake levels during the 1980s and modification of the causeway that affected its conveyance properties, the model no longer meets the originally defined constraints.

Objective: To update the existing model of the water and salt balance of Great Salt Lake so that it can be used to estimate the water and salt balance between the north and south parts of the lake for variable volumes of freshwater inflow. The existing model does not simulate the high water levels recorded during 1983 to 1987 or the modifications of the causeway between the north and south parts of the lake since 1973. Variations in stratification in the south part of the lake will be incorporated into the model, if possible.

Approach: Apply equations used for flow through the causeway breach from Holley and Waddell (1976), and develop new equations for stratified flows through the submerged culverts. Simulate flow through the causeway fill using the two-constituent solute-transport model of Sanford and Konikow (1985). Calibrate the fill-flow model by indirectly estimating flow through the causeway fill as the unknown variable and computing the fill-flow values using equations that describe the water and salt balance for the north and south parts of the lake. Determine the effects of different variables on stratification patterns by plotting time trends of density for each sampling section and then contrasting the trends for other parameters, such as surface inflow and breach width, that affect the water and salt balance of the lake.

Progress: Completed work on estimating flow through causeway fill for several boundary conditions using the fill-flow model. Substantial progress was made on calibration of the overall water- and salt-balance model. Continued preparation of draft of final report, which is close to being ready for review.

Plans for Next Year: Complete calibration of overall model. Complete draft of report and submit for review.

Ground-Water Contamination at Hill Air Force Base, Landfills 1 and 2

Number: UT-88-187

Cooperating Agency: U.S. Air Force

Staff: K.M. Waddell, Hydrologist, Project Chief
D.E. Wilberg, Hydrologist
L.J. Gerner, Hydrologist
S.R. Wold, Hydrologist (part time)
R.W. Puchta, Hydrologist (part time)
V.M. Heilweil, Hydrologist
J.L. Mason, Hydrologist (part time)
P.L. Haraden, Hydrologic Technician (part time)
L.C. Conroy, Hydrologic Technician (part time)
Other District and Regional personnel as assigned

Period of Project: October 1987 to September 1993

Problem: Trichloroethylene and benzene have been identified in shallow ground water downgradient from landfills 1 and 2 at Hill Air Force Base, Utah. These sites are near the installation boundary, and the possibility for contaminant migration off the installation exists. Under the Department of Defense Installation Restoration Program, the U.S. Air Force must characterize the wastes, determine the extent of contamination, and determine if remedial action is required.

Objectives: (1) To conduct a remedial investigation/feasibility study at landfills 1 and 2, Hill Air Force Base, to identify the existence of hazardous waste and to evaluate the source, extent, and degree of contamination of ground water; (2) to assess the risk to human health and the environment; and (3) to define and assess alternative actions that will control or eliminate the risk.

Approach: Determine the hazard level of the site so that proper safety equipment can be used. Define the source, extent, and degree of contamination by sampling and analyzing soil gas, by drilling and logging test holes and completing them as monitoring wells, by analyzing borehole-geophysical logs, and by sampling and analyzing drillhole cuttings and water. Conduct surface-geophysical surveys and use data from test holes to characterize the local hydrogeologic system. Measure water levels in monitoring wells to determine directions of ground-water movement. The data collected at the site will be used by a subcontractor to prepare a risk assessment. Construct a three-dimensional computer model of the ground-water-flow system to aid in assessing several methods of contamination remediation at the site.

Progress: The final Remedial Investigation report (vol. 1), June 1992, was approved by the U.S. Environmental Protection Agency and the Utah Department of Environmental Quality in July 1992. Additional data were collected to address uncertainties in the conclusions of the final report. A draft of an Addendum Report (vol. 11), which includes the new data and discusses their interpretation, is now in review. The draft of the report on the ground-water model (vol. 3) was completed.

Plans for next year: Complete review and revision of the Addendum Report and ground-water-model report (vols. 11 and 3) and submit them for approval.

Ground Water in Southern Utah and Goshen Valleys, Utah County

Number: UT-88-196

Cooperating Agency: Utah Division of Water Rights

Staff: L.E. Brooks, Hydrologist, Project Chief
B.J. Stolp, Hydrologist
J.E. Dishart, Hydrologic Technician (part time)

Period of Project: October 1988 to September 1993

Problem: Southern Utah and Goshen Valleys are along the Wasatch Front, where most of Utah's population is located and where population growth is rapid. Thick basin-fill deposits contain large volumes of good-quality water that has been developed for irrigation, municipal, and industrial use. Further development of ground water, most of which is proposed for municipal use, has been limited because of the probable effects on surface water that drains to Utah Lake and the effects on the lake itself, which is a source of water for irrigation downstream. In addition, many wells flow under artesian pressure, and additional ground-water development would likely cause some wells to stop flowing. The State would like to know the effects that additional ground-water development would have on water levels, surface water, and water quality, and the effects of importing additional surface water, by the Central Utah project, on the ground-water system.

Objectives: (1) To assess current hydrologic conditions in terms of recharge, movement, and discharge of ground water, water levels, ground-water quality, and volumes of ground water in storage; (2) to better define the ground-water system and how its components interact; and (3) to estimate the effects of additional ground-water withdrawals on water levels, water quality, and surface water and the effects of importation of additional surface water on the ground-water system.

Approach: (1) Compile existing data on wells, springs, water levels, ground-water quality, and surface-water flow; (2) inventory or estimate ground-water discharge from wells and springs, to drains and streams, and by evapotranspiration and seepage to Utah Lake; (3) estimate recharge, where feasible, from streams, irrigation, precipitation, and subsurface flow from consolidated rock; (4) conduct aquifer tests to improve knowledge of hydraulic characteristics of the basin fill; (5) construct a three-dimensional digital model of the ground-water system to simulate and better understand ground-water flow, and estimate effects of proposed changes in water use on the system; and (6) prepare a basic-data report and an interpretive report for publication by the Utah Department of Natural Resources.

Progress: Estimated the rates of ground-water inflow from consolidated rock, ground-water discharge to Utah Lake, and ground-water flow from southern Utah Valley to Goshen Valley. Continued calibration of the ground-water-flow model to steady-state conditions. Estimated or computed annual recharge and discharge for 1949-90 and created data files for use in the transient-state calibration process for the model. Began comparison of model-computed water-level changes to historical water-level changes. Prepared a basic-data report, which is in review. Began preparation of the final interpretive report.

Plans for Next Year: Submit the basic-data report for approval and publication. Complete calibration of the ground-water model to steady-state and transient-state conditions. Complete interpretive report, submit for review, revise, and submit for approval.

Hydrologic Response to Land Subsidence Caused by Underground Coal Mining, Carbon County, Central Utah

Number: UT-89-197

Cooperating Agency: Utah Division of Oil, Gas, and Mining

Staff: C.B. Slaughter, Hydrologist, Project Chief
G.W. Freethey, Hydrologist (part time)
L.E. Spangler, Hydrologist (part time)

Period of Project: October 1988 to September 1992

Problem: Land subsidence caused by underground coal mining usually is accompanied by vertical fracturing and bed separation in rocks overlying the mined area. The Utah Division of Oil, Gas, and Mining (UDOGM) is concerned about the effects that subsidence could have on ground-water and surface-water systems above mines in Utah. UDOGM must look critically at mining in areas where the thickness of overburden is less than 500 feet. Specific effects on streamflow, ground-water levels, and the quality of surface and ground water are not known. Thus, UDOGM must consider where mining companies can recover all the coal in the seam using the longwall method, and where they must leave pillars of coal to minimize the effects of mining on ground water and surface water.

Objectives: (1) To determine the effects of longwall mining of coal on overlying ground water and surface water in an area where the thickness of overburden is less than 500 feet; and (2) to develop methods of determining the hydrologic effects of mining-related land subsidence.

Approach: (1) Install monitoring wells and collect and analyze data during pre-mining and mining of the Wattis coal seam in the Cyprus Plateau Mine; (2) monitor ground water less intensely after removal of the Wattis seam; and (3) collect ground- and surface-water data during mining of the Third coal seam. Because of decreased funding, long-term monitoring to document the degree of recovery of the hydrologic system has been eliminated from the project objectives.

Progress: Collection of data on water levels, spring discharge, stream discharge, and chemical analyses of water from wells, springs, mine inflows, and the North Fork of the Right Fork of Miller Creek during and after mining of the Third seam was completed. Report is being written.

Plans for Next Year: The report will be completed, reviewed, revised, and submitted for approval.

Investigation of Salinity of Water in the Navajo Sandstone Aquifer in the Aneth Area, San Juan County, Utah

Number: UT-89-198

Cooperating Agencies: Utah Division of Oil, Gas, and Mining; U.S. Environmental Protection Agency; U.S. Bureau of Land Management; U.S. Bureau of Reclamation, U.S. Bureau of Indian Affairs

Staff: L.E. Spangler, Hydrologist, Project Chief (part time)
M. Hawkins, Hydrologic Technician (part time)

Period of Project: October 1988 to September 1995, suspended in fiscal years 1990 and 1991 because of lack of funding.

Problem: Many wells that penetrate the Navajo aquifer in the area of the Greater Aneth Oil Field yield water that is slightly to very saline, which is anomalous for this aquifer in southern and southeastern Utah. During the last 35 years, salinity levels in water from several wells in the Navajo aquifer have increased. The largest concentrations of dissolved solids in water are present near the town of Aneth and in outlying areas to the east and southeast. Large concentrations of dissolved solids may have resulted indirectly from the injection of oil-production water rather than upward migration of brines from underlying geologic units. Because neither the extent nor the severity of the problem is known with any accuracy, an understanding of the regional hydrology and geochemistry of the Navajo aquifer is necessary to better evaluate the extent of contamination and the remedial measures that are required to alleviate continued migration of the saline brines.

Objectives: To determine (1) the extent of the area of saline water in the Navajo Sandstone aquifer; (2) the cause(s) of the salinity; (3) the direction and rate of movement of the saline water; and (4) the character of the source of salinity (single point, multiple points, or a uniformly distributed source).

Approach: Continued acquisition of hydrologic, geochemical, and geologic information is necessary to determine the source, direction, rate of movement, and areal extent of saline water in the study area, and to understand the cause(s) of salinity. Additional water samples will be collected from known and yet to be located water wells to establish an adequate database of geochemical data for the Navajo aquifer. Samples also will be collected from other aquifers and sources of water for comparison with water from the Navajo aquifer.

Progress: A resumption of funding during fiscal year 1992 allowed field work to continue. Water samples were collected from 25 wells and a brine-injection facility. Several new wells with flowing, saline water were located. Analysis for total organic carbon was added to the other water-quality parameters. Discharge and pressure-head measurements for flowing wells were begun. In March 1992, an open-file report summarizing well records and chemical data from all wells within the study area was completed and published.

Plans for Next Year: If funding is continued at an appropriate level, sampling of water from fresh and saline wells in the Navajo and other aquifers will resume, with emphasis on collection of selected constituents from previously sampled wells for use in pattern-recognition modeling. A flow-through chamber will be used to obtain data for ferrous iron, sulfide, and dissolved oxygen while pH, temperature, specific conductance, and Eh are monitored. Several wells will be pumped to obtain water samples for analysis. Samples from precipitation and surface-water sites will be

collected. A reverse-osmosis unit will be used at selected wells to collect samples for detailed organic characterization. Collection of all water samples should be completed by fall 1993. A quality-assurance/quality-control plan for major ions and trace elements will be instituted for all collecting trips. Preliminary surface geophysical surveys will be carried out in the vicinity of several selected saline wells for delineation of salt-water plumes. Additional information on well construction and history will be gathered. A journal article entitled "Using geochemical techniques to identify salinity sources in the freshwater Navajo aquifer, Aneth Oil Field, Utah," will be prepared.

Reports:

Spangler, L.E., 1992, Records of wells in sandstone and alluvial aquifers and chemical data for water from selected wells in the Navajo aquifer in the vicinity of the Greater Aneth Oil Field, San Juan County, Utah: U.S. Geological Survey Open-File Report 92-124, 44 p.

Ground Water and Ground-Water/Surface-Water Relations In Cache Valley, Cache County, Utah, and Adjacent Part of Idaho

Number: UT-89-203

Cooperating Agencies: Utah Division of Water Resources; Utah Division of Water Rights

Staff: K.A. Kariya, Hydrologist, Project Chief
D.M. Roark, Hydrologist
K.M. Hanson, Hydrologic Technician

Period of Project: September 1989 to September 1992

Problem: Cache Valley is a north-south trending valley of about 660 square miles in northeastern Utah and southeastern Idaho. The State of Utah would like to know the potential for increased ground-water development and the possible hydrologic effects of such development. The State would also like to know how different patterns of ground-water development would affect water levels, streamflow, spring discharge, water quality, and evapotranspiration.

Objectives: (1) To assess current ground-water conditions including water levels, well and spring discharge, ground-water quality, and volumes of water in storage, and to document changes in conditions since the last study in 1967-69; (2) to better define the components of the ground-water system in terms of recharge, movement, and discharge, with emphasis on ground-water/surface-water relations; and (3) to determine how the components of the system interact, and to estimate the effects of additional ground-water withdrawals, in various geographic patterns, on water levels, streamflow, spring discharge, and evapotranspiration.

Approach: Compile available data on wells, springs, water levels, ground-water quality, and streamflow, focusing on post-1969 data, and collect data on wells drilled since the last study in 1967-69. Measure or estimate ground-water discharge from wells and springs, to drains and streams, and by evapotranspiration. Estimate recharge from streams; irrigation, including that from canals; precipitation; and subsurface flow from consolidated rock. Conduct seepage runs on streams to define ground-water/surface-water relations and estimate recharge from and discharge to streams. Prepare a map of the potentiometric surface and, if sufficient data are available, prepare maps showing aquifer thickness. Conduct aquifer tests to improve knowledge of hydraulic characteristics of the basin fill. Construct a three-dimensional digital model of the ground-water system to help understand how the components of the system interact and how increased development of ground water in different parts of the valley might affect water levels, spring discharge, streamflow, and evapotranspiration. Prepare a basic-data report and an interpretive report for publication by the Utah Department of Natural Resources.

Progress: A basic-data report entitled "Selected hydrologic data for Cache Valley, Utah and Idaho, 1969-91" was compiled and published. A digital model to simulate the ground-water system was constructed and calibrated to 1969 steady-state and 1982-90 transient-state conditions in Cache Valley. A final interpretive report that describes current ground-water conditions, sources of ground-water recharge and discharge, changes in the system since 1969, and the digital model was submitted for supervisory review. Project is complete except report.

Plans for Next Year: Submit final report for colleague review, revise, and submit for final approval.

Reports:

Roark, D.M., and Hanson, K.M., 1992, Selected hydrologic data for Cache Valley, Utah and Idaho, 1969-91: U.S. Geological Survey Open-File Report 92-173, 65 p.

Identification and Quantification of Mechanisms Causing Decreasing Salt-Crust Thickness, Bonneville Salt Flats, Western Utah

Number: UT-90-204

Cooperating Agency: U.S. Bureau of Land Management

Staff: J.L. Mason, Hydrologist, Project Chief
W.S. Brothers, Hydrologist
G.E. Pyper, Hydrologist (part time)
P.S. Muir, Hydrologic Technician
K.L. Kipp, Hydrologist, National Research Program, Denver, Colorado (part time)

Period of Project: January 1990 to September 1994

Problem: From 1960 to 1988, decrease of the salt-crust thickness at the Bonneville Salt Flats equated to a decrease in volume of 34 million cubic yards (40 million tons). The decrease is of concern to the U.S. Bureau of Land Management because the Bonneville Salt Flats are a unique geologic feature and recreation area, and according to management plans drafted in 1985, should be preserved for future generations.

Objectives: (1) To document changes in the hydrologic system of the Bonneville Salt Flats since the Utah District's study by Lines (1979); (2) to establish a data-collection network to monitor changes in water levels, water chemistry, and salt thickness at the Bonneville Salt Flats; (3) to assess the potential for removal of salts from the salt-flats area through wind-driven ponds; and (4) to assess the effects of current and projected brine withdrawals, other man-induced variations, and climatic changes on the hydrologic system. This includes effects on ground-water chemistry, water levels, and salt deposits in the Bonneville Salt Flats.

Approach: (1) Prepare a detailed plan of study and review entire plan with the U.S. Bureau of Land Management (BLM) and the Technical Review committee formed by BLM. (2) Define formation and movement of ponds using LANDSAT data and available aerial photography of the salt-flats area. (3) Develop a three-dimensional solute-transport model. (4) Compile data collected or available since the Lines (1979) study, including brine-withdrawal, water-level, chemical, meteorological, soil-moisture, and other pertinent data for the past 12 years. (5) Locate observation wells drilled during and prior to Lines' study. (6) Establish an observation-well network to measure water levels monthly and collect samples of brine for density analysis. (7) Drill new observation wells on and adjacent to the salt flats. Cores will be collected and analyzed for mineralogical content. Salt thickness and water levels will be measured, samples of brine will be collected and analyzed, and the wells will be added to the observation-well network. Nested wells (adjacent wells completed at different depths) will be part of the drilling plan to determine vertical variation in water levels, water density, and chemistry. One or more production wells (8 inches or larger) and several observation wells near each production well will be drilled for use in an aquifer test or tests. (8) Conduct and analyze aquifer tests. (9) Conduct geochemical studies to estimate geochemical flow paths and reactions along these paths and to describe processes that may increase or decrease salt thickness and areal extent. (10) Design and construct a transport model to simulate the flow rates, flow paths, and chemical concentrations and migration of selected constituents. The model will be used to simulate future water levels and ground-water chemistry. (11) Prepare reports documenting the results of the study.

Progress: Twenty additional observation wells were drilled and completed in the shallow-brine aquifer. Five sets of nested piezometers were installed in wells completed in the alluvial-fan and basin-fill aquifers to obtain data on vertical hydraulic gradients and to use as observation wells during a test of the alluvial-fan aquifer. A 72-hour aquifer test was completed, and water-level changes in observation wells indicated that recharge to the alluvial-fan aquifer from water at land surface is rapid. Water levels and brine density were measured in observation wells during spring and summer months. Samples were collected from 40 observation wells for chemical analysis. Of these 40 samples, 17 were analyzed for oxygen and deuterium isotopes, and 6 were analyzed for tritium. Four cores were collected from directly below the salt crust, and pore fluids were extracted and analyzed. A set of black-and-white infrared aerial photographs of the study area was made during the winter to develop a method for estimating salt movement by wind-driven ponds. Solute-transport modeling was begun using the HST model developed by K.L. Kipp.

Plans for Next Year: Continue measuring water levels and brine density in observation wells located on the Bonneville Salt Flats and in Pilot Valley. Collect additional brine samples from wells for chemical analysis if necessary. Continue monitoring flow in the brine-transport ditch on Federal lease lands. Drill additional observation wells on the Bonneville Salt Flats to obtain an areal distribution for the vertical hydraulic gradient between the shallow-brine aquifer and the underlying basin-fill aquifer. Collect additional shallow cores from beneath the salt crust and analyze pore fluids from these cores for chemical constituents. Compare the chemistry of pore fluids to the chemistry of water collected from observation wells to help evaluate dual porosity. Use brine-chemistry data for geochemical modeling. Continue development of the variable-density solute-transport model. Evaluate LANDSAT and ground-truth data to determine if the quantity of salt moving in wind-driven ponds can be determined.

Ground-Water Flow and Solute Migration in the Salt Lake Valley, Utah

Number: UT-90-205

Cooperating Agencies: Utah Division of Water Rights; Utah Division of Water Quality; and local municipalities and water agencies

Staff: G.W. Freethey, Project Supervisor (part time)
S.A. Thiros, Hydrologist
P.M. Lambert, Hydrologist
V.M. Heilweil, Hydrologist (part time)
M.F. Bradbury, Hydrologic Technician (part time)

Period of Project: March 1990 through September 1994

Problem: The Utah Divisions of Water Rights and Water Quality are facing a dilemma as ground-water resources are developed in Salt Lake Valley. Currently allocated water rights are thought to exceed the total annual inflow of good-quality ground water to basin-fill sediments in the valley. The Division of Water Rights needs to know the effects of additional ground-water development on the hydrologic system. Both Divisions need to determine the source area for water withdrawn from proposed wells at several locations within the valley to anticipate and prevent migration of poor-quality water to points of withdrawal, and thus to better manage development of the principal aquifer.

Objectives: (1) To better define the quality of water in the shallow unconfined aquifer and the underlying confining unit in Salt Lake Valley; (2) to determine the hydraulic properties of the shallow unconfined aquifer and the confining unit; (3) to better define the valley's ground-water-flow/hydrochemical-flow system, including three-dimensional variation of hydrologic properties and ground-water quality; and (4) to provide the Utah Divisions of Water Rights and Water Quality with a means of determining the quantity of water that can be withdrawn from different areas in Salt Lake Valley without causing undesirable water-level declines and without inducing water with large concentrations of dissolved solids or contaminants to migrate toward wells used for municipal and industrial supply.

Approach: The approach to achieving the objectives will involve several components of field investigation and information interpretation. These components are integrated, and each is necessary to accomplish the objectives stated. In general, these components are: (1) determine properties of the shallow unconfined and principal aquifers and the confining unit and chemical composition of the water by drilling, field testing of water-level response to withdrawals from wells, and laboratory testing of cores and water samples; (2) determine the extent of the effects of variable-density fluid on fluid movement; (3) update and refine the existing ground-water-flow model; (4) conduct particle-tracking and solute-transport simulations using the model to increase knowledge about the source and movement of water with high concentrations of dissolved solids; and (5) synthesize collected information and prepare reports.

Progress: Single-well tests were done at 38 wells in the valley to obtain information on hydrologic properties of the shallow aquifer and confining units. Analyses of the slug-test data have been completed. A computer program was used to check the analyses. Two multi-well aquifer tests were done in February 1992 to obtain information on hydrologic properties of the principal aquifer and to estimate vertical hydraulic conductivity of the confining layer. Data from one of the tests

have been analyzed. In addition, data from two multi-well aquifer tests done in February 1991 have been analyzed.

Water-quality data obtained from chemical analyses of water collected at 52 observation wells, including wells drilled during this project and nearby public-supply wells and flowing wells, have been compiled. Water samples from selected hydrologic-data sites also were analyzed for the isotopes oxygen-18, deuterium, and tritium. Some data analysis has been done.

A basic-data report containing much of the hydrologic data collected during this study from selected wells and drill holes was submitted for review in April 1992. The report lists field data such as well-completion information, lithologic logs, and water-level and water-quality measurements; geochemical and geotechnical properties determined from core-material analyses; and water-quality data other than isotope analyses. Comments from reviewers and cooperators have been received, and the report is now in editorial review.

Work continues on updating and refining the existing ground-water-flow model. Development of a new seven-layer steady-state ground-water-flow model is nearly complete. Data obtained from drillers' logs, geologic logs, and geophysical surveys were used to define new grid-cell dimensions. The definitions of boundary conditions and internal hydrologic properties have been reviewed and refined where necessary. Results from the steady-state model are currently being matched to measured horizontal and vertical hydraulic gradients and estimated recharge and discharge.

Plans for Next Year: Complete aquifer-test analysis and update the ground-water-flow model with the results. Submit basic-data report for approval for publication. Analysis of the water-quality and isotope data will be a priority. Continue writing draft interpretive report as work progresses.

Model development will focus mainly on calibration to steady-state and transient-state conditions. Values for horizontal and vertical hydraulic conductivity determined from field tests done during this study will be incorporated into the model. Relations between fluctuations in ground-water recharge and annual variations in precipitation, supply of irrigation water, and discharge in streams crossing principal recharge areas will be examined during the transient-state calibration process. Model input simulating discharge from public-supply, industrial, and large-diameter irrigation wells for the simulation period will be completed. Estimates of annual ground-water discharge to the Jordan River will be updated for 1991 to compare with model-computed flow. Documentation of model development and simulation of ground-water flow in Salt Lake Valley will be presented in a draft model report that is being written as work progresses.

Determination of Channel-Migration Processes, San Juan River Near Bluff, Utah

Number: UT-90-207

Cooperating Agency: U.S. Bureau of Indian Affairs

Staff: H.L. Case, Hydrologist, Project Chief
R.L. Baskin, Hydrologist (part time)
Other District personnel as assigned

Period of Project: July 1990 through September 1992

Problem: The U.S. Bureau of Indian Affairs and the Navajo Nation requested that the U.S. Geological Survey conduct a study to determine if the San Juan River near Bluff, Utah, has moved by either accretion or avulsion. The middle channel of the river is the northern boundary of the Navajo Reservation. If the river channel has migrated gradually by accretion to the south, the new area of land north of the present channel that was formerly to the south would belong to the entity owning the land on the north side of the original channel. If, however, the river channel has migrated suddenly to the south by avulsion, the entity owning the land to the south of the original channel (the Navajo Nation) would retain title to the new area of land north of the new channel. The U.S. Bureau of Indian Affairs and the Navajo Nation would like to define the type of movement of the river channel in order to clarify the legal status of the area of new land north of the present channel.

Objective: To determine the change in course of the San Juan River near Bluff, Utah, from 1899 to the present, and to define the historical channel-migration process. The first phase of the study will provide information to assist the U.S. Bureau of Indian Affairs in determining if additional work to document historic flows and channel changes is practical and warranted.

Approach: (1) Search for and document all available records of historical hydrologic events in the area related to potential shifts in channel location of the San Juan River (Phase I). (2) Determine areal extent of present and past channels, map geographic features, and conduct geologic mapping and sampling necessary to substantiate amount, direction, and type of channel migration (Phase II). (3) Determine effects of riprapping and other man-made structures as well as the effect of major floods on the position of the channel. (4) Prepare a report describing movement of the channel of the San Juan River near Bluff, Utah, and its cause (accretion or avulsion) during the approximate period 1899 to the present. The report will include analysis of all available evidence, including data on sedimentation, to establish the cause of changes in the location of the river.

Progress: Revised draft of the report. Permission to publish from the U.S. Bureau of Indian Affairs was received but later rescinded at the request of the Navajo Nation. The U.S. Bureau of Indian Affairs and the Navajo Nation are concerned that information in the report may be useful to opponents in potential litigation. Project has been suspended.

Plans for Next Year: Obtain permission to publish the report. Estimated release date of the report is September 30, 1993.

Characterization of the Hydrology in the Vicinity of the Solid-Waste Landfills, Utah Test and Training Range, Box Elder County, Utah

Number: UT-91-209

Cooperating Agency: U.S. Air Force

Staff: Michael Enright, Hydrologic Technician, Project Chief
W.F. Holmes, Hydrologist (part time)
Other District personnel as assigned

Period of Project: October 1990 to March 1993

Problem: Hill Air Force Base operates two solid-waste landfills at the personnel complex at the Utah Test and Training Range in Puddle Valley. The Air Force believes it is in their best interest to implement a ground-water-monitoring program that will facilitate compliance with U.S. Environmental Protection Agency and State of Utah proposed rules. These rules will require owners and operators of solid-waste landfills to pattern their operations after chemically secure hazardous-waste landfills.

Objectives: To design, construct, and implement a ground-water-monitoring system for the basin-fill aquifer at the solid-waste landfills at the Utah Test and Training Range.

Approach: Three monitoring wells will be located to determine the direction and rates of regional and local ground-water movement. Lithologic logs, laboratory geotechnical and chemical analyses of sediments, and geophysical logs will help to qualitatively evaluate the potential for migration of leachates from the landfills through the unsaturated zone to the water table. Hydraulic properties of the principal aquifer will be determined from aquifer tests. Ground-water samples will be collected for chemical analysis to determine if leachates from the landfills have reached the principal aquifer.

Progress: In December 1991, arrangements were made to use a U.S. Geological Survey drill rig and crew from Santa Barbara, California, to construct the monitoring wells. Drilling began in April 1992. Three wells were completed and geophysically logged. During May, the wells were developed and dedicated pumping systems were installed for future monitoring. All remaining field activities associated with this project were completed by October 1992. These activities included collecting water samples from each well for chemical analysis, aquifer tests for each well, and surveying to determine land-surface altitude at each well. Report writing began in September.

Plans For Next Year: Complete a draft administrative report by March 15, 1993.

Recharge to Basin-Fill Aquifers from Irrigation, Southwestern Utah

Number: UT-91-211

Cooperating Agency: Utah Division of Water Rights

Staff: D.D. Susong, Hydrologist, Project Chief
Other District personnel, as assigned

Period of Project: October 1991 to September 1994

Problem: Irrigators are converting from flood- to sprinkler-irrigation systems in some areas of Utah and are requesting to expand irrigated acreage based on water saved because of conversion. This change in irrigation methods probably will affect recharge to basin-fill aquifers, and these effects are largely unquantified. An understanding of how this change in irrigation methods might affect the quantity of ground-water recharge to the basin-fill aquifers is needed to manage future ground-water withdrawals and to determine whether it is justified to permit expansion of irrigated acreage based on water savings using sprinkler systems.

Objective: Determine the quantity of recharge to basin-fill aquifers from flood- and sprinkler-irrigation methods.

Approach: Recharge to basin-fill aquifers will be determined by water-budget and infiltration-rate methods. Study sites of paired flood- and sprinkler-irrigated fields in four southern Utah areas will be instrumented with (1) monitoring wells and neutron-access tubes, (2) tensiometers, (3) weirs, (4) flow meters, and (5) automated weather stations. The VS2D unsaturated-flow model will be used to evaluate infiltration and downward flow at each site.

Progress: Access tubes for soil-moisture measurements, tensiometers, and a weather station were installed at the field site. Soil-moisture, soil-matric potential, applied water, and weather data were collected throughout the growing season. Soil cores were collected and submitted to a laboratory for analysis. Evapotranspiration was calculated on an hourly basis for the growing season.

Plans for Next Year: The instrumentation will be maintained, and more data will be collected. A water budget will be estimated for both the sprinkler- and the flood-irrigated field. An unsaturated-flow model of the field will be developed, and the flux of water through the site will be computed. Geographic information system coverages for mapping recharge areas will be created.

Hydrologic Study of Lower Ashley Creek, Uintah County, and Monitoring for Remedial Activities Related to Selenium Contaminants, Middle Green River Basin, Utah

Number: UT-91-213

Cooperating Agencies: U.S. Bureau of Reclamation; U.S. Fish and Wildlife Service

Staff: D.W. Stephens, Hydrologist, Project Chief
Other District personnel, as assigned

Period of Project: October 1990 to September 1994

Problem: Studies completed at Stewart Lake Waterfowl Management Area (WMA), Ashley Creek, and Ouray National Wildlife Refuge (NWR) identified several areas where selenium was adversely affecting the beneficial use of water and creating a hazard to wildlife. The studies showed the source of contamination at Stewart Lake WMA to be drainwater from soils derived from Mancos Shale. Median concentrations of selenium in drainwater discharged to Stewart Lake exceeded the State standard of 5 micrograms per liter (µg/L) established for wildlife protection and were as large as 140 µg/L. The lake was an effective sink for dissolved selenium and retained 75 percent of the total inflow load in sedimentary deposits. Selenium concentrations in waterbird tissue at Stewart Lake WMA were large, ranging from 1.9 micrograms per gram (µg/g) (dry weight) in Canada goose muscle to 87 µg/g in American coots.

The studies showed that the source of contamination in Ashley Creek was inflow of shallow ground water and surface water that originates from a sewage-lagoon system and flows through Mancos Shale, mobilizing selenium. Selenium concentrations in the ground water seeping into Ashley Creek were as large as 16,000 µg/L. Waterfowl contained selenium concentrations as large as 50.3 µg/g in liver and 27.2 µg/g in muscle tissue.

Selenium contamination of ponds at Ouray NWR was limited to a small area on the western part of the refuge, and the studies showed the contamination to be a result of seepage of shallow ground water into ponds used by waterfowl. The U.S. Bureau of Reclamation needs additional information on selenium contamination in the middle Green River basin and assistance in designing a monitoring system to evaluate any remedial activities they may undertake.

Objectives: Further define the hydrologic system for Ashley Creek and complete a selenium mass-balance model. Design and implement a monitoring program for selenium contamination at Stewart Lake WMA, Ouray NWR, and in the Green River that will provide data needed to evaluate possible remedial actions. Formulate and evaluate potential remedial actions.

Approach: (1) Sample water and sediment to determine the sources of selenium entering Ashley Creek and the Green River; (2) quantify the extent of sediment contamination in ponds at Ouray NWR and in Stewart Lake; (3) design a monitoring program to assess changes in the aquatic systems with time and in response to remedial action in the middle Green River basin; and (4) obtain public input on potential remedial options and then assemble and evaluate options to select the preferred package for remediation.

Progress: Water and sediment sampling were done in 1992, and data are being compiled. Results of sediment analyses show that Stewart Lake contains sediment at least as contaminated by selenium as that at Kesterson National Wildlife Refuge in California (greater than 200 parts per million). Seepage studies showed about 3 cubic feet per second of ground-water inflow to Ashley Creek as

a result of leakage from a sewage lagoon. The leakage mobilizes selenium from Mancos Shale and discharges it to the creek. A water-quality monitoring program was continued. The team from the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and U.S. Geological Survey continued to formulate and screen potential remedial actions.

Plans for Next Year: Prepare annual workplan, continue monitoring, complete mass-balance model of flow and selenium load in Ashley Creek, and complete formulation of remedial options.

Investigation of Springs in and Adjacent to Utah Lake, Utah County, Utah

Number: UT-91-214

Cooperating Agency: Central Utah Water Conservancy District

Staff: R.L. Baskin, Hydrologist, Project Chief
L.E. Spangler, Hydrologist (part time)
W.F. Holmes, Hydrologist (part time)

Period of Project: February 1991 to September 1993

Problem: The Central Utah Project (CUP) is a State/Federal project to develop water in the Colorado River Basin of eastern Utah for diversion to and use in the Great Basin of western Utah. As part of the CUP, some of the freshwater streamflow to Utah Lake, in Utah Valley, will be diverted for use in Utah and Salt Lake Valleys. As a result of this potential diversion of freshwater before it flows into Utah Lake, the salinity of the lake is predicted to rise. In an effort to reduce the salinity of the lake, the Central Utah Water Conservancy District (CUWCD), the operator of CUP, would like to control and divert sources of saline-water inflow to Utah Lake. The CUWCD needs information on the discharge of saline and freshwater springs to Utah Lake to quantify water and chemical budgets for the lake and manage water quality.

Objectives: The objectives of the project are (1) to study known thermal saline springs in the Bird Island-Lincoln Point area of Utah Lake to identify, as closely as possible, their geologic source; to determine, if possible, the paths that thermal saline water takes to points of discharge in and adjacent to Utah Lake; and to obtain better estimates of the location, discharge, and quality of water from known thermal saline springs; and (2) to study previously unidentified thermal saline springs and other major saline and fresh-water springs in and adjacent to Utah Lake to determine their location, discharge, and quality of water.

Approach: For known thermal springs, (1) compile and evaluate data from all significant studies in and adjacent to Utah Lake, and evaluate all studies of geothermal ground water along the Wasatch Front and the relevance of these studies to thermal springs in Utah Lake; (2) conduct hydrologic reconnaissance of all springs and wells that can be inventoried readily on land or in shallow water in the Bird Island-Lincoln Point area; (3) map lake-bed topography at Bird Island and Lincoln Point to help define geologic conditions related to spring locations; (4) conduct a geophysical (marine seismic) survey of the part of Utah Lake around Bird Island and Lincoln Point (about 40 miles of profiles) to help estimate the paths that thermal saline water might take to the lake; (5) conduct an aquifer/interference test using a well completed in consolidated rock at or near Lincoln Point; and (6) conduct a thermal mass-balance survey of Utah Lake in the vicinity of Bird Island and Lincoln Point.

For previously unidentified springs, (1) compile and evaluate all studies of Utah Lake and its known springs; (2) conduct a thermal-imagery survey of Utah Lake to help locate all springs; (3) measure discharge of selected freshwater springs and use measurements to develop a relation between thermal anomalies and discharge that can be used to estimate the discharge of other springs; and (4) collect water samples from representative springs for chemical analysis, including selected isotope analysis.

Progress: The topographic and bathymetric surveys of shore/near-shore areas have been completed. The surveys included the topography of on-shore travertine and tufa deposits, known spring

locations, locations of flumes, wells, and springs monitored during the interference test, submarine topography to a depth of about 5 feet, and notes on the composition of bottom materials encountered during the bathymetric survey.

An interference test was completed in the Lincoln Point area by pumping from an existing well. Observation points included one nearby well, a staff gage installed in a spring-fed pond, and four flumes installed to measure spring discharge. Discharge, pH, temperature, and conductivity of water from the pumped well, and water level or stage at the observation points, were measured during the test period.

The marine-seismic survey has been completed in the area between Lincoln Point and Bird Island. Thirteen cross-sections were completed with geographic control determined using a global positioning system. The geographic data have been reduced, entered into the computer, and plotted on maps. The original geophysical data have been copied onto work sheets, and evaluation of the data is complete. An interpretive report is being prepared.

Thermal data from NASA's Thermal Infrared Multispectral Scanner have been collected for the entire lake, and the data have been returned to Utah for evaluation. Processing of the data is nearly complete.

Nineteen springs above the current level of Utah Lake in the Lincoln Point-Bird Island area have been found and the discharge measured. Two submarine springs near Bird Island have been identified; discharges were measured beneath the surface of the lake.

Water from all the major springs above current lake level in the Lincoln Point - Bird Island area has been measured for temperature, pH, and specific conductance. Water samples from three of the larger springs and three wells in the Lincoln Point area have been collected for analysis of major constituents. Water samples from one of the large springs also has been collected for tritium analysis.

Samples for stable-isotope (oxygen/deuterium) analysis have been collected from three springs and three wells. Water from the two submarine springs at Bird Island has been measured for temperature, pH, and specific conductance, and samples have been collected for analysis of major constituents. In addition, a spring above current lake level on Bird Island has been measured for temperature, pH, and specific conductance, and water for laboratory analysis of major constituents has been collected.

The first phase of data collection for the project has been completed and the data have been incorporated into an interpretive report. This first interpretive report is currently in editorial review and next will be prepared for colleague review.

Plans For Next Year: Complete review and revision of the first interpretive report and submit for approval. Complete preparation of an interpretive report on the results of the marine-seismic survey and submit for review. Evaluate results from the thermal-imagery survey, and prepare a technical report on methods of investigation (journal article) and submit for review. Collect and analyze samples from additional springs located by thermal imagery, and prepare a final interpretive report on results from the thermal imagery survey, water-quality analyses, stable-isotope studies, geothermometer calculations, and other associated investigations.

Geochemistry of Contaminated Area near Landfills 1 and 2, Hill Air Force Base, Utah

Number: UT-92-217

Cooperating Agency: U.S. Air Force

Staff: Kidd Waddell, Hydrologist, Project Supervisor (part time)
D.E. Wilberg, Hydrologist, Project Chief
Briant Kimball, Hydrologist (part time)

Period of Project: October 1991 to September 1993

Problem: Remedial Investigation (RI) of landfills 1 and 2, which make up much of Operable Unit 4 at Hill Air Force Base, Utah, was begun by the U.S. Geological Survey (USGS) as project UT-187 in July 1988. Data collected as part of the RI have shown the need for a more detailed geochemical investigation to verify the location of the sources of sulfate and the types of compounds from which sulfate was derived near landfill 1. Mass-balance computations that used the major inorganic ions could not distinguish whether sulfate was from gypsum board, which possibly was disposed of in landfill 1, or from reactions between sulfuric acid waste and the soil and aquifer matrix. Also, data were not adequate to determine if observed dissolved trace metals were associated with leachates that may have seeped from the landfill.

Objectives: (1) To determine the location of the source of the sulfate, (2) to determine the compound(s) from which the sulfate is derived, (3) to distinguish between trace metals that originate from the source area (landfill 1) and those that occur naturally, and (4) to estimate the probable fate of the sulfate and other associated major inorganic contaminants.

Approach: Additional wells will be drilled during 1992, both upgradient and downgradient from landfill 1. Ground water will be sampled along selected flow paths that include both contaminated and uncontaminated areas and analyzed for stable isotopes of sulfur, hydrogen, oxygen, carbon, and nitrogen, and major ions and metals.

Progress: Collected isotope samples at existing wells along specified flow paths. Drilled additional wells in the vicinity of landfills 1 and 2 as well as on the Weber River flood plain and at other previously identified locations that required additional data. Collected isotope samples from the new wells and resampled a few of the existing wells that were originally sampled (for verification of quality assurance/quality control).

Plans for Next Year: If the results of laboratory analyses arrive in a timely manner, the plans are to (1) identify and evaluate the variation of stable-isotope ratios; (2) assess the most probable reactions between solutes, ground water, and aquifer materials; (3) determine the most probable source area for sulfate; (4) determine the amount of mixing between contaminated and uncontaminated sources for each flow path from mass-balance calculations; and (5) summarize findings in a journal article.

Ground Water in Juab Valley, Juab County, Utah

Number: UT-92-218

Cooperating Agency: Central Utah Water Conservancy District; East Juab County Water Conservancy District

Staff: J.I. Steiger, Hydrologist, Acting Project Chief (part time)
H.K. Hadley, Hydrologist (part time)
C.L. Millard, Geologist (part time)

Period of Project: January 1992 to September 1995

Problem: Water will be imported into Juab Valley, mostly for irrigation, and possibly through Juab Valley to the Sevier River basin, as part of the Central Utah Project. The Central Utah Water Conservancy District wants to optimize the size of the pipeline delivering water to and through Juab Valley and needs to know how much of local peak demand can be met by ground water. The East Juab County Water Conservancy District wants to optimize use of water in the valley, including local surface water, local ground water, and imported water, and needs information on ground water and the effects of its development in order to integrate ground-water use and development into the overall water-management plan for Juab Valley.

Objectives: (1) To assess current ground-water conditions and document changes since previous studies during 1962-66; (2) to define and quantify the ground-water system of the valley—aquifers and aquifer coefficients, estimated recharge, movement, estimated discharge, and water quality; (3) to evaluate current and potential sources of ground-water contamination and ground-water salinity in the southern end of the valley; and (4) to provide a tool to understand the valley's ground-water system and to estimate the effects of changes in ground-water withdrawals or recharge on water levels, natural discharge, and water quality.

Approach: (1) Compile all available data and inventory significant new wells and selected springs; (2) measure water levels in wells and prepare a potentiometric-surface map; (3) use geophysical logs to improve definition of aquifers and to map the recharge area; (4) conduct aquifer tests to improve definition of aquifer coefficients; (5) estimate and measure the components of recharge and discharge; (6) identify areas of ground-water quality deterioration and analyze water samples to better define water-quality problems; and (7) construct and calibrate a three-dimensional model of ground-water flow.

Progress: A search for wells and springs in Juab Valley for which data are available has been completed. This search included all wells in the U.S. Geological Survey's (USGS) Ground-Water Site Inventory (GWSI) file, wells and springs included in past USGS studies, and wells for which logs are on file with the Utah Division of Water Rights. A field inventory has been done of all sites the USGS has inventoried, plus any wells drilled since the 1962-66 USGS studies. The field inventory probably included more than 75 percent of all wells in Juab Valley. The pumpage inventory for 1992 is complete, and five new wells were added to the list of pumped wells that are monitored each year. A specific search also was done for all wells and springs that have been sampled for water-quality analyses. Water from 15 wells, 4 springs, and 2 surface-water sites in southern Juab Valley was sampled and analyzed for major ions and stable isotopes of oxygen and deuterium, and immunoassays were done for herbicides. For sites not in GWSI, digitizing site locations and coding of data-input forms has begun. The existing observation-well network, used to obtain annual

water levels and water-level changes, is being augmented to obtain data at additional wells for project needs.

Plans for Next Year: Remeasure the water levels in all wells inventoried in 1992. Begin monthly measurements of water levels in wells in the observation-well network in March 1993. Inventory significant springs. Sample wells, springs, and surface-water sites in northern Juab Valley for chemical analyses in early summer of 1993. Contact local water officials to obtain data on surface-water diversions and areas and locations of irrigated acreage, and obtain land-use data from the Utah Division of Water Resources. Begin obtaining data on and estimating aquifer coefficients and areas and rates of recharge and discharge to construct a preliminary digital model of the ground-water system for steady-state calibration.

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