WATER-RESOURCES ACTIVITIES IN UTAH BY THE U.S. GEOLOGICAL SURVEY, OCTOBER 1, 1990, TO SEPTEMBER 30, 1991

Compiled by Joseph S. Gates and Ellen E. Hardy

U.S. GEOLOGICAL SURVEY

Open-File Report 92-497

Salt Lake City, Utah

1992

U.S. DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

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Message from the District Chief

The U.S. Geological Survey, Water Resources Division, is entering its 102nd 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 has continued its slow but steady growth in program size by increasing from $4.14 million in Fiscal Year (FY) 1990 to $4.43 million in FY 1991. This growth reflects increased data-collection activities associated with the cooperative program and water-quality monitoring done for other Federal agencies.

FY 1991 was a year of significant organizational change for the Utah District because of our reassignment from Central to Western Region. This change provided the District staff with the challenge to familiarize the Western Regional staff with hydrologic issues in Utah and afforded the District and Regional staff with the opportunity to get to know each other.

Within the Western Region, Utah has been administratively assigned to the Great Basin Area and is grouped with the Arizona and Nevada Districts. Being part of the Great Basin Area provides an opportunity for the Utah District to draw upon technical expertise from nearby states with similar hydrologic processes, problems, and solutions, and to contribute expertise to these states.

The future promises the continued challenge of helping local, State, and Federal agencies meet their water-resources information needs within realistic budgetary constraints. I look forward to another active year in which the U.S. Geological Survey helps 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, 1990, to September 30, 1991. The program in Utah during this period consisted of 23 projects; a discussion of each project is given 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 1990 to September 1991.

U.S. Geological Survey Origin

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."

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

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:

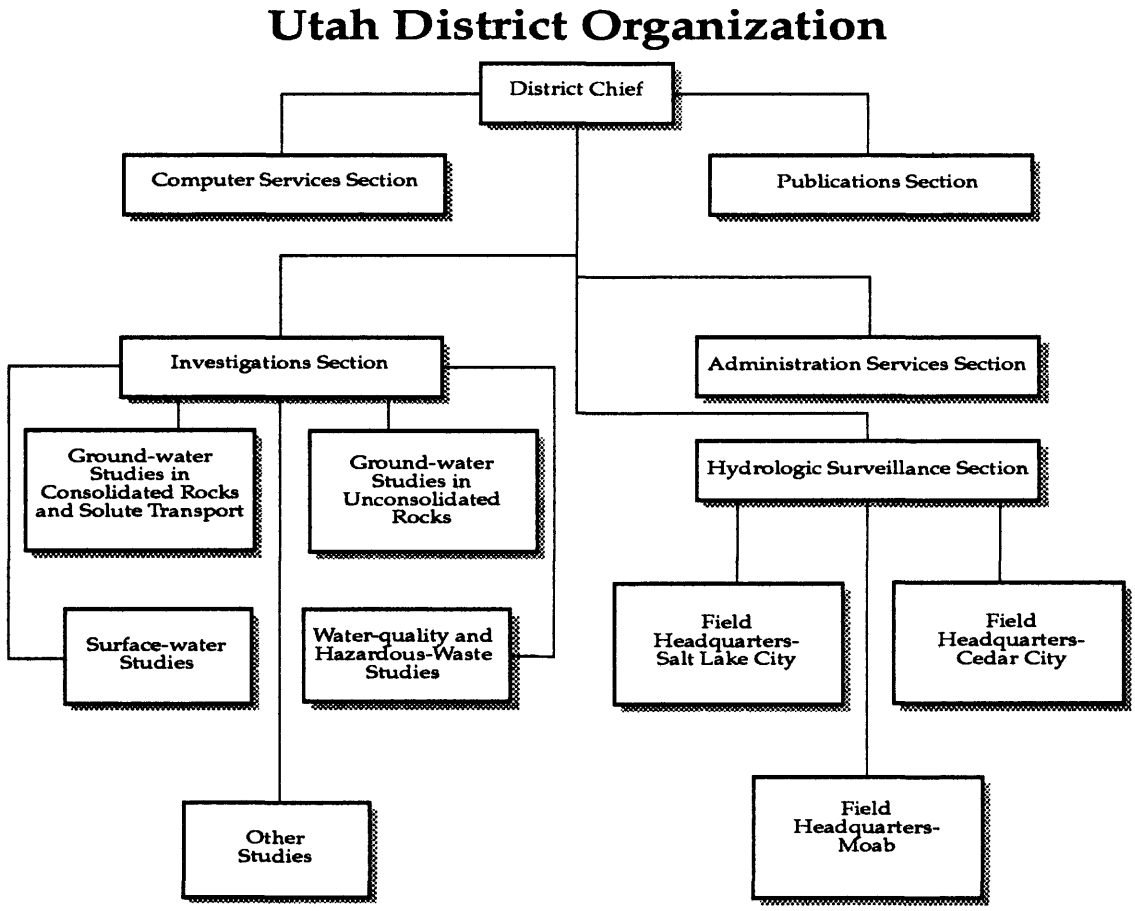
- Systematically collects data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources.
- Conducts analytical and interpretive water-resources appraisals to describe the occurrence, availability, and physical, chemical, and biological characteristics 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 Comprehensive 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 conducted 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.



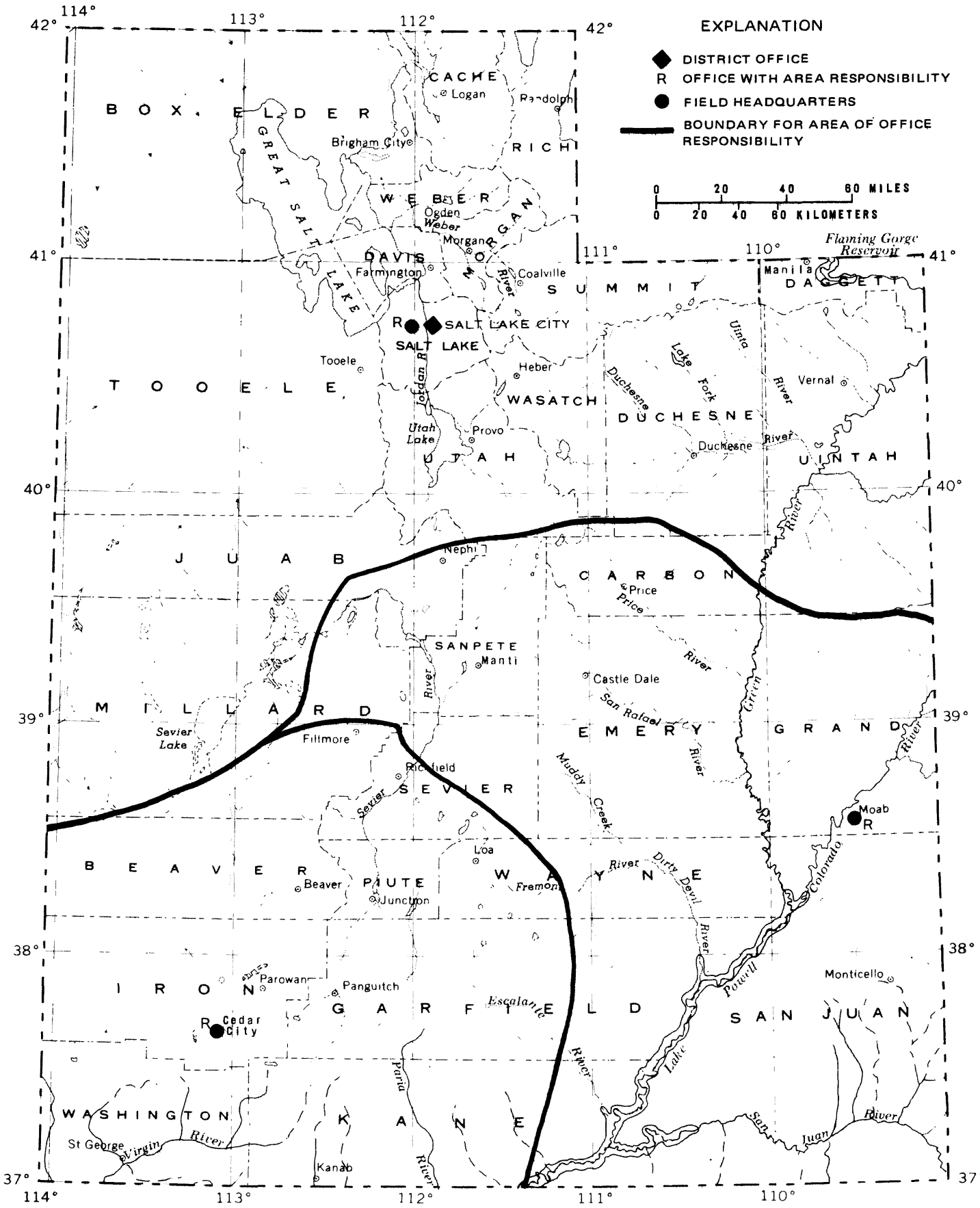


Figure 1.--Location of U.S. Geological Survey, Water Resources Division, offices and general areas of responsibility.

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

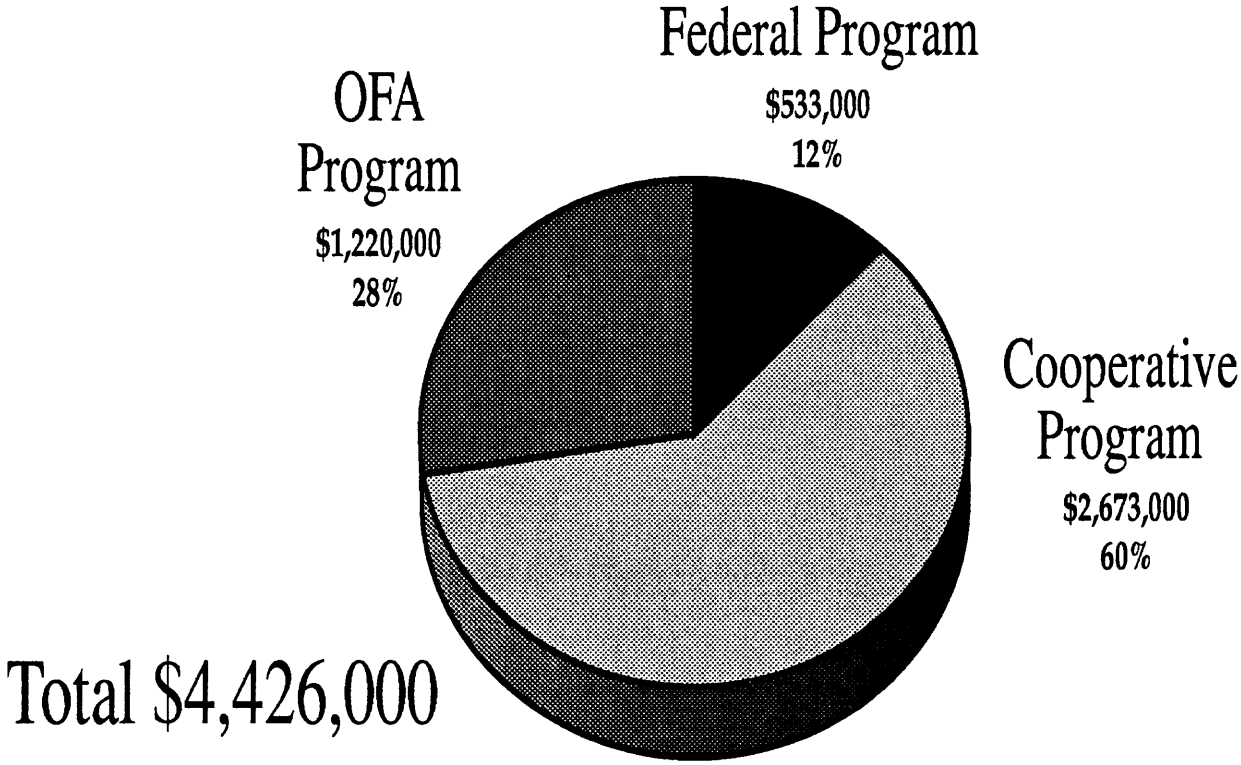
U.S. Geological Survey
Water Resources Division
82 North 100 East
P.O. Box 1066
Cedar City, Utah 84720

Moab Field Headquarters
(801) 259-5495

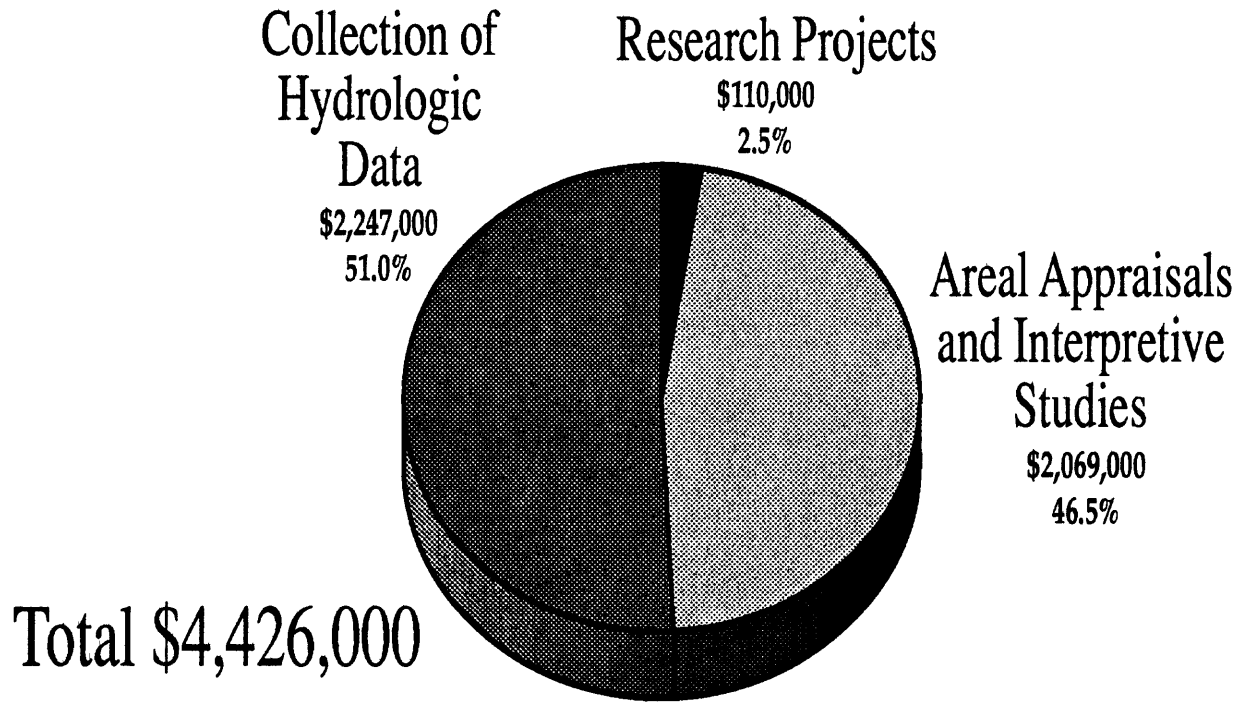
U.S. Geological Survey
Water Resources Division
50 East Center Street
P.O. Box 490
Moab, Utah 84532

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 1991, the total financial support from these programs for the Utah District was about $4.4 million. The distribution of funds among the three sources is shown below:



In fiscal year 1991, 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 51 percent of the program was for collection of hydrologic data, 46.5 percent was for interpretive studies and appraisals, and 2.5 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, 1990, to September 30, 1991, the cooperating agencies for District projects were:

State Agencies

Utah Department of Agriculture
Utah Department of Environmental Quality
    Division of Water Quality
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
Utah Department of Transportation

Local Agencies

Bear River Commission
Central Utah Water Conservancy District
City of Kanab
Kanab Area Water Association, Inc.
Kane County
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. Department of the Interior, Office of the Secretary
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, Cooperative Investigations Reports, and Water Circulars.

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, Water-Use Reports.

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

The following reports were published during October 1, 1990 to September 30, 1991:

Baskin, R.L., 1990, Selected factors related to the potential for contamination of the principal aquifer, Salt Lake Valley, Utah: U.S. Geological Survey Water-Resources Investigations Report 90-4110, 35 p.

Blanchard, P.J., 1990, Ground-water conditions in the Grand County area, Utah, with emphasis on the Mill Creek-Spanish Valley area: Utah Department of Natural Resources Technical Publication No. 100, 69 p.

Brothers, W.C., and Thiros, S.A., 1991, Infiltration of unconsumed irrigation water in Utah: Proceedings of the American Society of Civil Engineers Conference on Irrigation and Drainage, 9 p.

Gates, J.S., and Dragos, S.L., 1991, Water-resources activities in Utah by the U.S. Geological Survey, October 1, 1988, to September 30, 1989: U.S. Geological Survey Open-File Report 91-589, 55 p.

Herbert, L.R., Gates, J.S., and others, 1991, Ground-water conditions in Utah, spring 1991: Utah Department of Natural Resources Cooperative Investigations Report Number 31, 92 p.

Holmes, W.F., and Thiros, S.A., 1990, Ground-water hydrology of Pahvant Valley and adjacent areas, Utah: Utah Department of Natural Resources Technical Publication No. 98, 64 p.

Howells, Lewis, 1990, Base of the moderately saline ground water in San Juan County, Utah: Utah Department of Natural Resources Technical Publication No. 94, 35 p.

ReMillard, M.D., and others, 1990, Water-resources data, Utah, water year 1990: U.S. Geological Survey Water-Data Report UT-90-1, 383 p.

Roark, D.M., Holmes, W.F., and Shlosar, H.K., 1991, Hydrology of Heber and Round Valleys, Wasatch County, Utah, with emphasis on simulation of ground-water flow in Heber Valley: Utah Department of Natural Resources Technical Publication No. 101, 93 p.

Stephens, D.W., and Waddell, Bruce, 1992, Selenium contamination of waterfowl areas in Utah and options for management, in Aquatic ecosystems in semi-arid regions, Implications for resource management: National Hydrology Research Institute, Symposium No. 7, Environment Canada, Saskatoon, p. 301-311.

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. Bureau of Land Management; 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, warning of hazards, operation, and management of Utah's surface-water resources. Such information is used in water-related fields such as water supply, hydroelectric power, 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, reservoir contents, and lake stage 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 183 streamflow-gaging stations and contents and stage records for 23 lakes and reservoirs continued during the year. In addition, periodic measurements were made of water flow 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 given in the series of reports "Water resources data for Utah", U.S. Geological Survey Water-Data Reports. The stations are classified as follows:

	Number of stations
Discharge	
Current use	125
Hydrologic data for planning and design	47
Benchmark for long-term trends	11
Contents of lakes and reservoirs	21
Stage of Great Salt Lake	2

One gaging station was discontinued. This station was:

Grouse Creek near Vernal

Gaging stations established were:

Bullfrog Creek near Bullfrog
Mud Creek below Winter Quarters Canyon, near Scofield
Price River near Heiner
Uinta River below Powerplant Diversion, near Neola
McLeod Creek near Park City

Seepage studies:

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

Plans for Next Year: Continue operation of network. Prepare 1992 water-year records for publication. Complete report on floods in the Great Basin during 1983-84, and on the flood resulting from the Quail Creek Reservoir dike failure. Continue monitoring flow through the breach in the Great Salt Lake causeway. Complete report on surface-water reconnaissance of the Sevier River basin above Sevier Bridge Reservoir.

Reports:

ReMillard, M.D., and others, 1991, Water resources data for Utah, water year 1990: U.S Geological Survey Water–Data Report UT-90-1.

U.S. Geological Survey, 1990, National Water Summary 1987–88—Floods and Droughts: U.S. Geological Survey Water-Supply Paper 2350, p. 491–498.

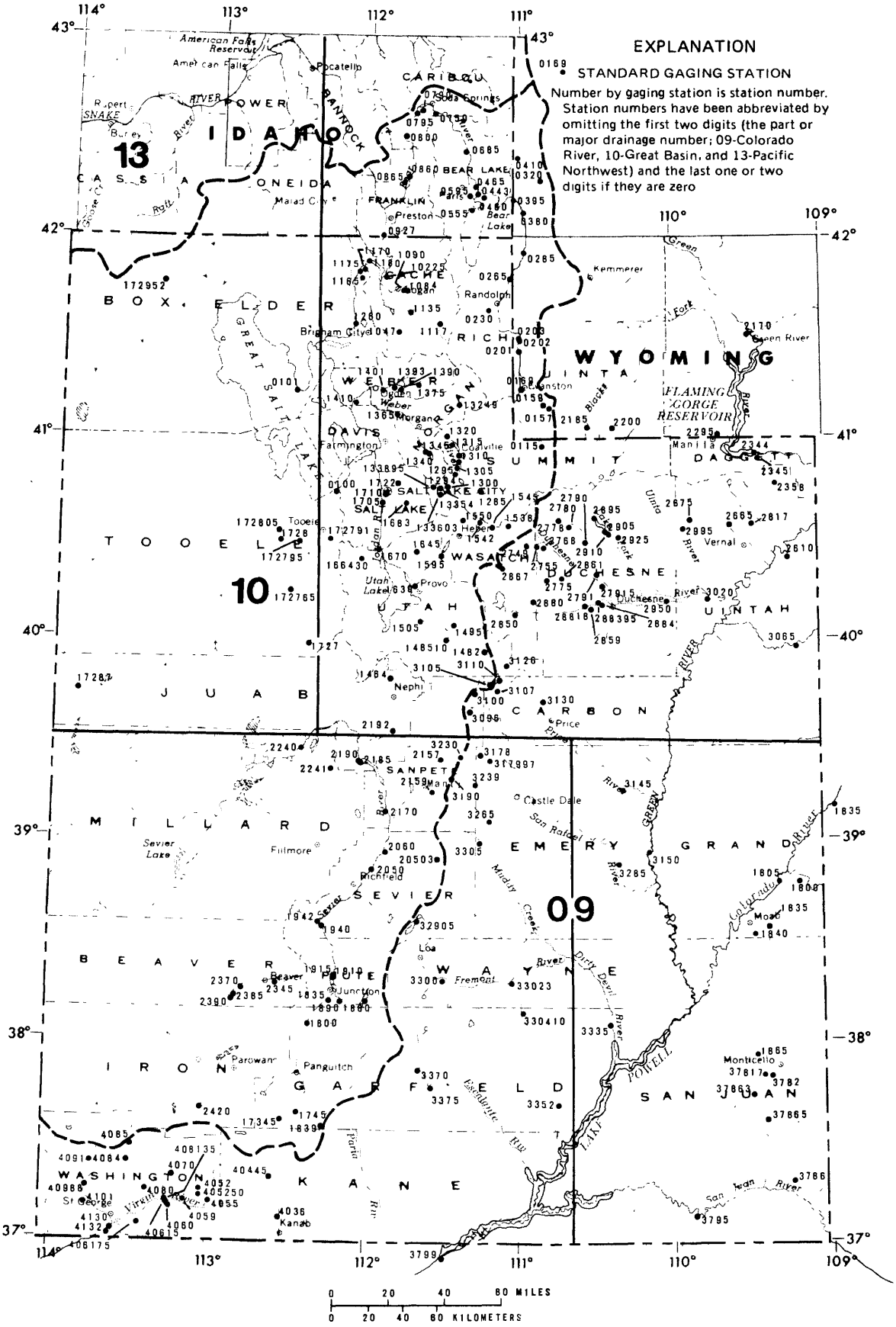


Figure 2.--Location of gaging stations.

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; Utah Department of Transportation

Staff: L.R. Herbert, Hydrologic Technician, Project Chief 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-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. 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. Water levels in about 600 of these wells were measured in September, and water levels in 34 wells were measured monthly. Continuous water-level recorders were maintained on 31 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 of about 50 wells was measured during the irrigation season. Number and diameters of wells drilled during the

past year were determined. The twenty-eighth in the series of annual reports on ground-water conditions in Utah was completed.

Plans for Next Year: Continue collecting, recording, and publishing data on water levels, ground-water withdrawals, and wells drilled. The twenty-ninth in the series of annual ground-water reports will be compiled.

Reports:

Herbert, L.R., Gates, J.S., and others, 1991, Ground-water conditions in Utah, spring of 1991: Utah Division of Water Resources Cooperative Investigations Report 31.

ReMillard, M.D., and others, 1991, Water resources data for Utah, water year 1990: U.S. Geological Survey Water–Data Report UT-90-1.

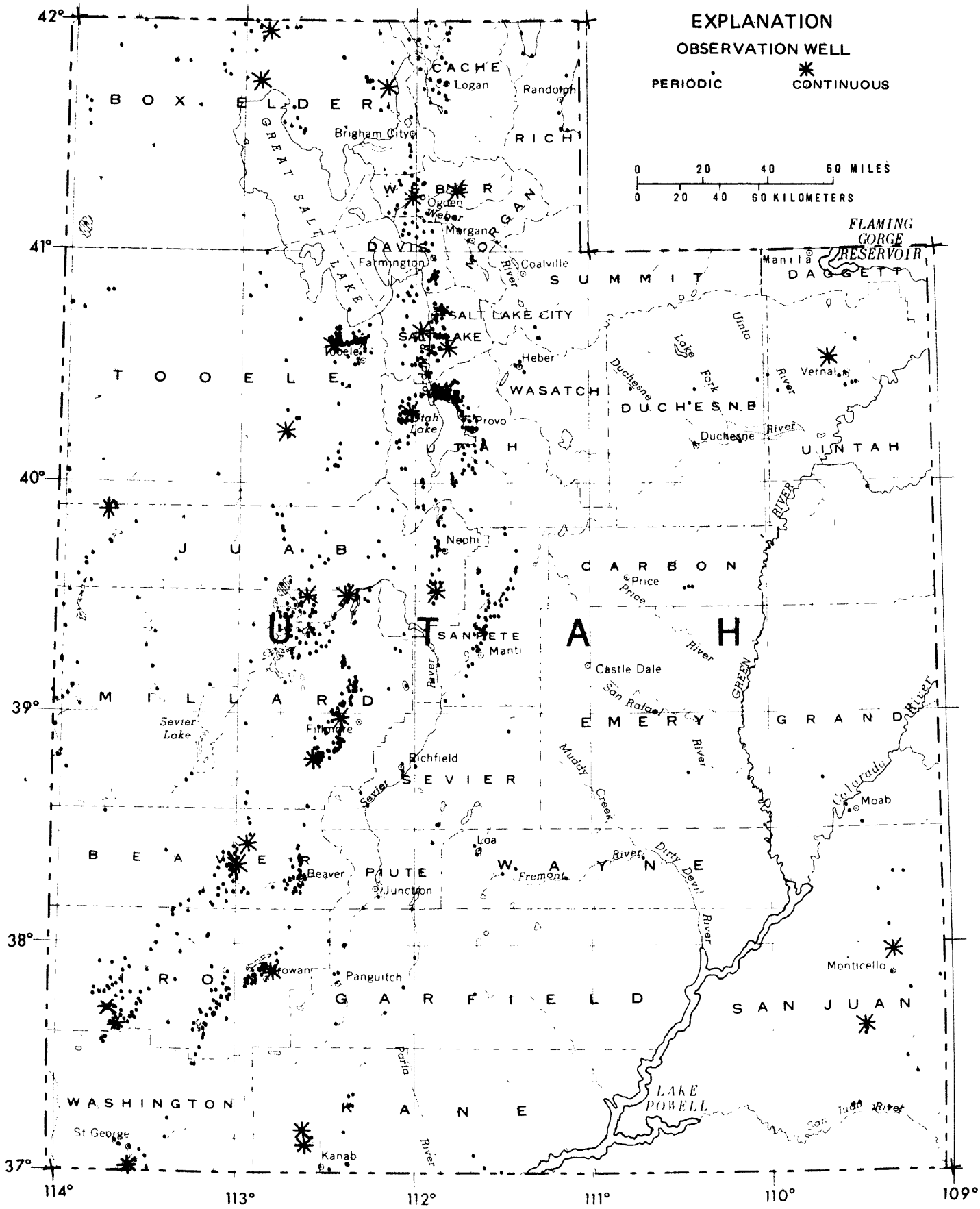


Figure 3.--Location of observation wells in which water levels were measured.

Water-Quality and Fluvial-Sediment Data

Number: UT–00–003; UT–00–004

Cooperating Agencies: Utah Department of Agriculture; Utah Division of Water Resources; Utah Division of Water Rights; Utah Geological Survey; U.S. Bureau of Land Management; 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 in various 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 (about 8 times per year) at 17 stream sites (fig. 4). In addition, water temperature and specific-conductance data were obtained daily at four of these stream sites. Water temperature and specific-conductance data also were obtained periodically at an additional 143 stream sites. About 200 wells are in the ground-water-quality monitoring program (fig. 5); water-quality data were collected at about 150 of these wells. Sixteen other wells were sampled for pesticide contamination of ground water. Water-quality data were collected from West Pond for the Great Salt Lake pumping project. Drafts of three reports pertaining to the water-quality monitoring program and water and salt balance at West Pond have been completed. Water quality in nine observation wells near the dikes of West Pond was monitored. Temperature and specific gravity at various depths of Great Salt Lake were monitored. Sediment data were obtained daily at 4 sites and periodically at an additional 11 sites (fig. 4).

Plans for Next Year: Continue collecting and processing data and preparing records for publication.

Reports:

ReMillard, M.D., and others, 1991, Water resources data for Utah, water year 1990: U.S. Geological Survey Water-Data Report UT–90–1.

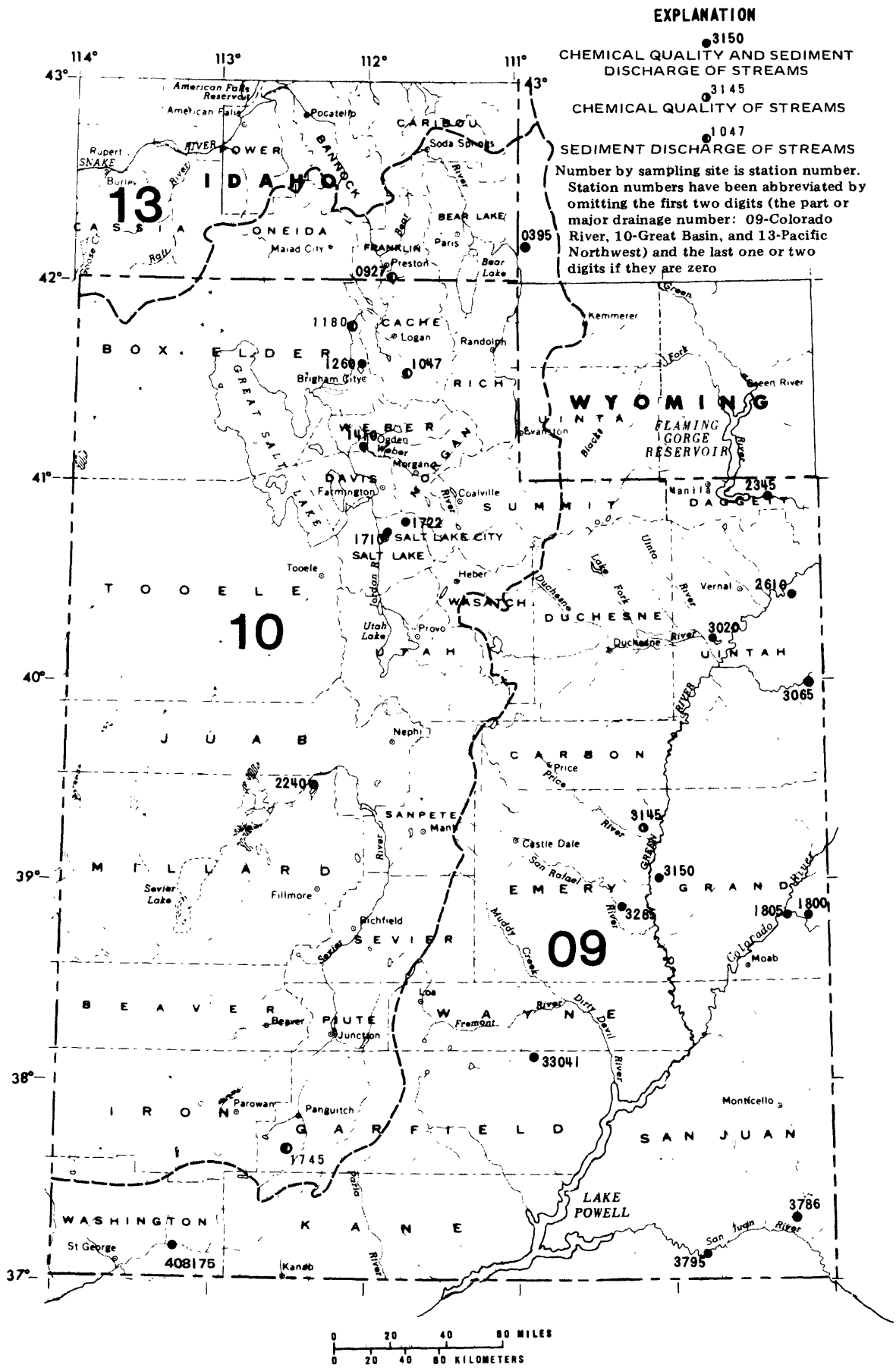


Figure 4.--Location of surface-water-quality stations.

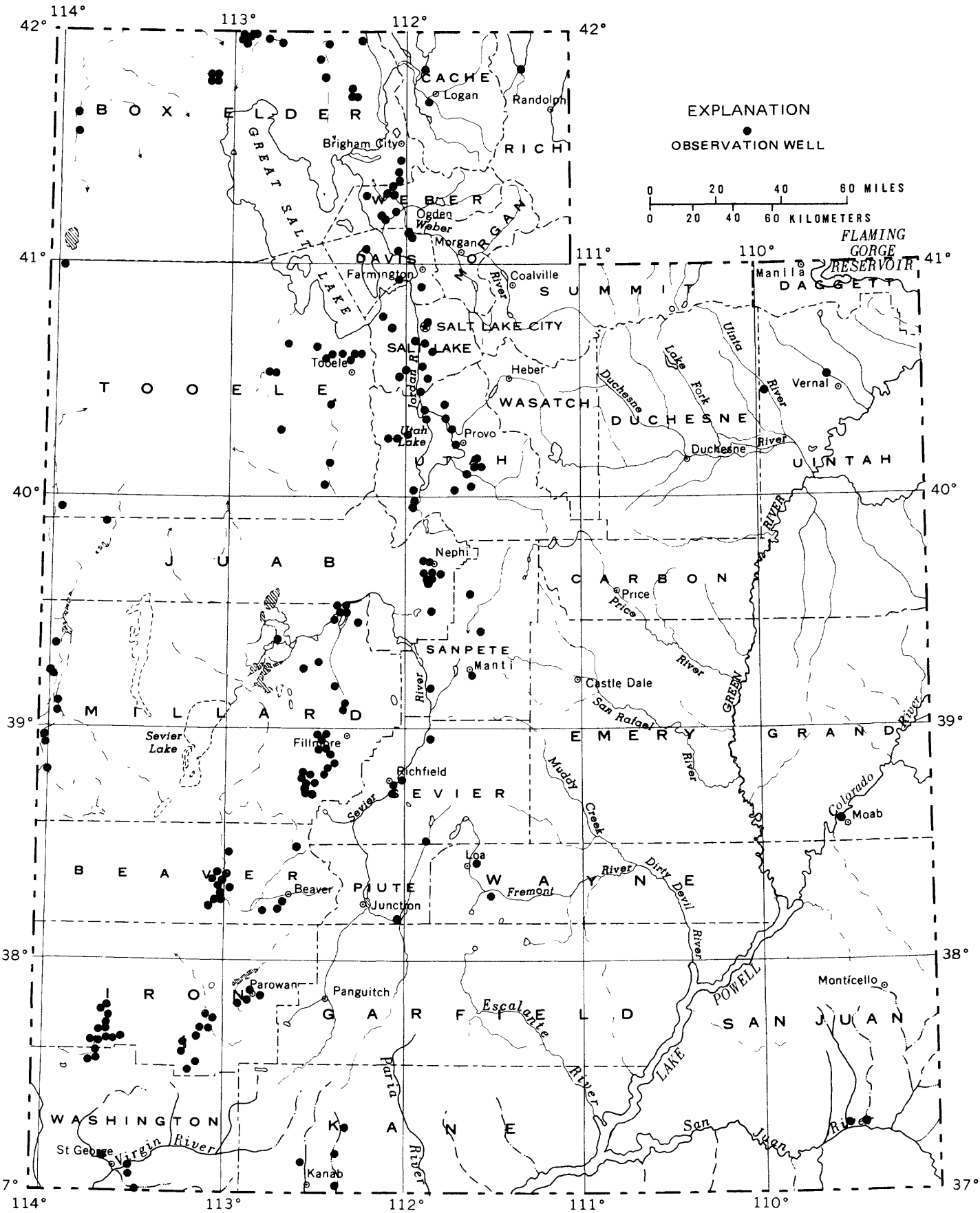


Figure 5.--Location of observation wells where water samples were collected for monitoring water quality.

Interpretive Studies

Location 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. Shlosar, Hydrologic Technician, Project Chief
G.E. Pyper, Hydrologist (part time)
K. K. Wilson, Hydrologic Technician (part time)
W.H. Smart, Engineer, Utah Division of Water Rights
Other State and District personnel as assigned

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 various 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 various 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. Collection, verification, and calculations were completed for the report "Estimated Use of Water in the United States in 1990". Utah's data were put in the Aggregated Water Use Data System, and quality-control procedures were completed. The data were sent to the Regional office of the Water Resources Division, U.S. Geological Survey.

Plans For Next Year: Continue the collection of irrigation water-use data in conjunction with the land-use surveys of the Utah Division of Water Resources. Complete a one-page water fact sheet with graphics showing Utah's 1990 water use. Complete a report with graphics summarizing and comparing 1985 and 1990 water-use data for Utah.

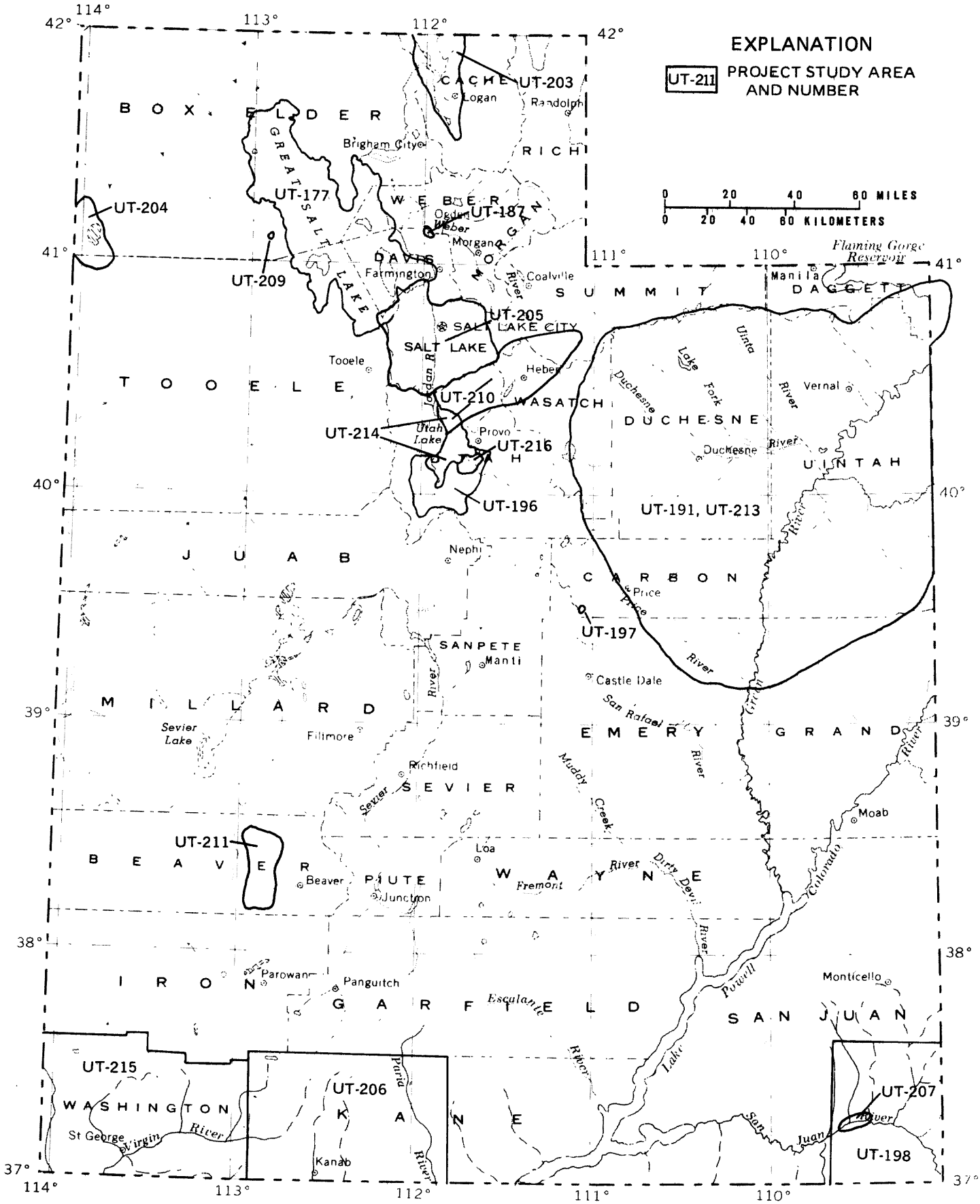


Figure 6.--Location of interpretive studies.

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 predicting 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 constraints originally defined for the model.

Objective: To update the existing model of the water and salt balance of Great Salt Lake so that it can be used to predict 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 in 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 calculating 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: Developed interpolation methods and equations to estimate flows through the causeway fill for use in the causeway model. The flows were computed for a variety of boundary conditions by the two-constituent solute-transport model of Sanford and Konikow (1985). Began calibration of overall model and draft of report.

Plans for Next Year: Complete calibration of overall model, determine effects of various parameters on stratification, and complete draft and review of report.

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
L.J. Gerner, Hydrologist
C.B. Slaughter, Hydrologist (part time)
J.L. Mason, Hydrologist (part time)
P.L. Haraden, 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 United States 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 the proper safety equipment will 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 Remedial Investigation report was reviewed by U.S. Geological Survey and Hill Air Force Base reviewers and is being revised. The draft of the report on the computer model (an addendum to the Remedial Investigation report) is being revised because of changes in the water budget for the model. The calibration of the model is nearing completion.

Plans for next year: Complete review and revision of Remedial Investigation and ground-water model reports, drill additional wells, and conduct geochemical investigation to better define the source and location of contaminants. Prepare draft of an addendum report describing the results of additional drilling and geochemical study.

Detailed Assessment of Effects of Irrigation Drainage on Water Quality in the Middle Green River Basin, Utah

Number: UT–88–191

Cooperating Agency: U.S. Department of the Interior, Office of the Secretary

Staff: D.W. Stephens, Hydrologist, Project Chief
Period of Project: October 1988 to September 1991

Problem: Stewart Lake Waterfowl Management Area and Ouray National Wildlife Refuge were identified as sites with gross contamination due to selenium in a 1986-87 Department of the Interior irrigation-drainage study. Concentrations of selenium in drainwater entering Stewart Lake exceeded 100 µg/L, and concentrations in biological tissue collected at Stewart Lake exceeded 30 µg/L. At Ouray National Wildlife Refuge, water from the Roadside Ponds contained in excess of 100 µg/L of selenium, and several deformed bird embryos were found. This resulted in closure of part of the refuge for a short period in 1987.

Objectives: (1) To define the extent and severity of existing water-quality problems induced by irrigation drainage or the potential for future problems, and (2) to provide the scientific understanding needed for development of alternatives to mitigate or resolve identified problems. The areas that received detailed study were: Stewart Lake and associated marsh 4720, lower Ashley Creek, and Ouray National Wildlife Refuge. Reconnaissance was extended at Pariette Wetlands to include upstream agricultural areas in Pleasant Valley.

Approach: Sample drainwater to determine the relative quantity of chemical loading from each of the drains that provide water to Stewart Lake. Identify major contributing reaches, collect and analyze soil cores, and determine the potential for continued release of selenium if irrigation is continued, using sequential extractions. Analyze samples of shallow ground water to determine selenium speciation in the drainwater and compare with selenium speciation. Analyze samples of shallow ground water collected in the Jensen area to provide information on vertical and horizontal gradients, direction of flow, and concentration of dissolved constituents in the water from existing and new wells. Drill shallow wells north of Stewart Lake and install piezometers that will be monitored periodically for water levels. Analyze well water to determine the concentration of selenium in the water.

Determine the degree to which the water has been concentrated by evaporation using hydrogen and oxygen isotopes as described by Deverel and Fujii (1988). Date the shallow ground water using tritium. Collect water samples at several locations for analysis of oxygen-18/oxygen-16 ratios, deuterium/protium ratios, and tritium. Identify processes involved in precipitation of selenium, incorporation by sediments, and uptake by plants; and quantify by transect sampling and analysis of water, sediments, and plants.

Sample Ashley Creek from Vernal to its confluence with the Green River by synoptic methods. Collect samples from all inflowing water and from existing wells and analyze to determine quantities of selenium and total salts entering Ashley Creek.

Continue reconnaissance of water supplied to marsh 4720 to determine if seasonal patterns exist in selenium content of the irrigation-drainage water. Determine the relation of water delivery in the Ruppe drain, Naples drain, and the oilfield canal to selenium entering the marsh.

Sample the outflow from Pelican Lake and Ouray Park Irrigation Company drainage (inflow to the Ouray National Wildlife Refuge) three times during the summer and analyze for selenium and major ions. Make a complete search of well records prior to test-well drilling to determine if existing wells could be used for monitoring. Sample by synoptic methods to identify stream reaches where the selenium input into ground water is greatest. Determine the distribution of selenium in bottom sediments of Roadside Ponds and Sheppard pond S5.

Progress: All data collection completed. Data report in editorial review. Draft and colleague review of final report completed and final corrections currently underway by U.S. Geological Survey and U.S. Fish and Wildlife authors. Under phase 4, remediation planning has begun for areas at Stewart Lake, Ouray National Wildlife Refuge, and Ashley Creek.

Plans for Next Year: Submit final report for editorial review, revise, and forward to Region for approval. Phase 4 of the Irrigation Drainage Study to begin under U.S. Bureau of Reclamation supervision. The U.S. Geological Survey part of this work will be done under a new project number, UT-213.

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 (part time)
J.E. Dishart, Hydrologic Technician (part time)

Period of Project: October 1988 to September 1992

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 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 predict effects of proposed changes in water use on the system;. (6) prepare a basic-data report and an interpretive report for publication by the Utah Department of Natural Resources.

Progress: Analyzed data from seepage runs made on perennial streams and major canals during a previous study to determine the quantity of ground-water recharge from leaky streams and canals and the quantity of ground-water discharge to streams and canals. Conducted seepage runs on two short stream reaches that were not included in the previous study. Estimated ground-water recharge from ephemeral and intermittent streams. Collected irrigation records to determine the location and volume of applied surface water. Determined the quantity of ground water used for irrigation. Analyzed land-use data to determine the consumptive use of water by crops throughout the valley,

and determined recharge to the ground-water system from applied irrigation water and precipitation. Measured the discharge of springs, natural drains, and seeps. Determined discharge from wells for municipal and industrial use. Estimated flowing-well discharge. Estimated evapotranspiration from crops and phreatophytes. Collected and analyzed waste-water-treatment records to estimate the volume of ground-water discharge to municipal waste-water systems. Developed a ground-water budget. Measured water levels in 195 wells in early March 1991. Constructed and began calibrating a steady-state ground-water model.

Plans for Next Year: Estimate the volume of ground-water inflow from consolidated rock and the volume of ground-water outflow to Utah Lake on the basis of Darcy's law using measured water levels and estimated transmissivity values. Calibrate the ground-water model to steady-state and transient conditions. Prepare a basic-data report for publication and an interpretive report for colleague review.

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)

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 various impacts 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 effect 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 Middle 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: A preliminary report outlining short-term effects of mining-induced subsidence on ground- and surface-water systems has been written and reviewed by the cooperating agency and the Cyprus Plateau Mine geologist. The report includes interpretation of data collected prior to and during mining of the Wattis coal seam through July 1990. Additional water-level, water-quality, and streamflow data were compiled and added to tables in the preliminary report.

Plans for Next Year: Data collection will be completed. The preliminary report will be updated with data on water levels and chemical analyses of water samples from wells, springs, mine inflows, and the North Fork of the Right Fork of Miller Creek collected during the mining of the Middle seam. The report will be submitted for review and 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

Staff: L.E. Spangler, Hydrologist, Project Chief

Period of Project: October 1988 to September 1993, suspended in December 1989

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 25 years, salinity levels have increased in several water wells completed in the Navajo aquifer. The most substantial increase is near the town of Aneth. This increase may have resulted from the injection of oil-production water rather than upward migration of brines from underlying salts. 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 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: Considerably more geochemical, hydrochemical, geologic, and hydrologic information are needed to determine the source of the saline water, its direction and rate of movement, and its areal extent. The investigation will be pursued in four phases: (1) collect and compile new and existing geologic, geochemical, and hydrologic information, (2) collect and compile hydrochemical data, (3) analyze all data and begin development of a variable-density model to calculate possible flow directions for fluids of variable salinity, and (4) develop and test final variable-density-flow and solute-transport models.

Progress: Project was reactivated from suspended status in July 1991. The U.S. Environmental Protection Agency funded preparation of an interim report with minimal interpretation that will document ground-water and water-quality data collected during the project. Compilation of data began for inclusion in the report.

Plans for Next Year: The U.S. Environmental Protection Agency, U.S. Bureau of Land Management, U.S. Bureau of Reclamation, U.S. Bureau of Indian Affairs, and the Utah Division of Oil, Gas, and Mining decided to fund reactivation of the full project in FY 92. The interim data report will be completed and published, plans for completion of project sampling will be prepared, and sampling will begin. Plans for geophysical surveys to define the occurrence of saline water will be prepared.

Ground Water and Ground-Water/Surface-Water Relations in Cache Valley, Cache County, Utah, and Adjacent Parts 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
F.R. Hayes succeeded by K.M. Hanson, Hydrologic Technician

Period of Project: September 1989 to September 1992

Problem: Cache Valley is a north-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 various patterns of ground-water development would affect water levels, streamflow, spring discharge, water quality, and evapotranspiration.

Objectives: (1) To assess current ground-water conditions, especially in terms of 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 by 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, if possible, to define ground-water/surface-water relations and estimate recharge from and discharge to streams. Prepare a map of the potentiometric surface, and, if possible, prepare maps showing aquifer thickness and distribution of water quality. 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 various parts of the valley would 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: All field work, including water-level measurements, well inventory, stream seepage studies, canal seepage studies, spring discharge measurements, flowing-well discharge measurements, pumpage inventory, a recovery test on one of the Logan city wells, and installation of monitoring wells, has been completed with the exception of slug testing of selected wells and possibly an additional aquifer test or tests. New data from

this study have been compiled and have been included in a basic-data report that is in preparation. New and existing data have been compiled for input into the digital model of the ground-water system.

Plans for Next Year: Complete and publish the data report. Write interpretive sections of the final report. Compile the 1990 potentiometric-surface map and a map of change in water levels between 1969 and 1990. Calibrate a steady-state version of the ground-water digital model on the basis of data representing conditions in 1969. Run simulations of the ground-water system for each year from 1982 to 1990 to reproduce water-level rises due to greater-than-average recharge related to high levels of precipitation and streamflow in 1983-84, and water-level declines from 1985 to 1990. Write sections of the interpretive report describing the digital model, and submit draft report for colleague review and final approval.

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.C. Brothers, Hydrologist
Hydrologist, Vacant, 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 future 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 impacts 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 (USBLM) and the Technical Review committee formed by USBLM. (2) Define formation and movement of ponds using LANDSAT data and available aerial photography of the salt-flats area. (3) Develop a preliminary three-dimensional solute-transport model. (4) Compile data collected or available since the Lines (1979) study, including brine-withdrawal, water-level, chemical-analysis, 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 (or 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 constitu-

ents. The model will be used to simulate future water levels and ground-water chemistry using alternative scenarios. (11) Prepare reports documenting the results of the study.

Progress: The scope of work for fiscal year 1991 was reduced because the project was not fully funded. Work included final revisions to the project proposal/plan of study and the initial stages of data collection. The USBLM cadastral survey unit completed surveys to determine altitude and location control of existing wells. Vibration-time-totalizing meters (VTTs) were installed on five wells completed in alluvial fans southwest of the salt crust; discharge from these wells was periodically measured with a Hoff meter. A VTT was installed on the booster pump on the ditch that transports brine from Federal leases. Eleven additional observation wells were completed in the shallow brine aquifer. Three of the shallow wells, each completed at a different depth, are at a central location on the salt flats. A recorder was installed to continually measure water levels in the 9-foot well. A 23-foot well was completed to measure vertical head gradient. A second recorder was installed on an observation well near the brine-collection ditch.

Plans for Next Year: Prepare project planning document. Measure water levels in observation wells and collect samples for brine-chemistry analysis. Measure discharge and collect brine samples on a continuing basis to determine the quantity of salt being transported by the brine-transport ditch. Contract for installation of three weather stations. Drill five deep observation wells in alluvial-fan and basin-fill aquifers, each having multiple completion intervals. Cores will be collected during drilling of one well on an alluvial fan to determine the hydraulic properties of various types of alluvial deposits. Conduct aquifer test using alluvial-fan production well and nested observation wells. Begin analysis of LANDSAT data and aerial photography and collect data for the analysis of salt transport by wind-driven ponds. Drill observation wells and begin ground-water monitoring in Pilot Valley. Continue developing solute-transport models.

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)
J.W. Christensen, 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 in developing ground-water resources in the 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 ground-water-/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 the 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 water 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 aquifer and confining-unit properties 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 simulations using the model to increase knowledge about the source and movement of water of various degrees of salinity in specific parts of the system; (5) develop multiple solute-transport simulations to better understand the hydrochemical system in the valley; and (6) synthesize collected information and prepare reports.

Progress: From March to May 1991, 14 test wells were drilled. Cores of the confining layers were collected and analyzed for a variety of properties. All of the drilled wells were developed; most were slug tested. Three multiple-well aquifer tests were done to estimate vertical hydraulic conductivity of the confining layer. Water levels are being monitored monthly. Water samples were collected and analyzed for common constituents, metals, organic compounds, and isotopes.

The horizontal and vertical fluid-density distribution in the ground-water system was estimated based on available water-quality data. Output from the existing ground-water-flow model was used to define horizontal and vertical hydraulic gradients. Areas where the effects of variable-density fluids on fluid movement may be substantial were then determined by comparing the hydraulic pressure-driven component of flow with a representation of the density-related gravity-driven component of flow at selected sites in the valley.

Work is well underway on updating and refining the existing ground-water-flow model. Grid spacing, layering, definition of boundary conditions, and internal hydrologic properties are all being updated with newly acquired information.

Plans for Next Year: Conduct additional slug tests and aquifer tests on monitoring wells. Finish updating and recalibrating the existing flow model as new data become available. Start particle-tracking analysis. Develop sectional variable-density and solute-transport models. A basic-data report on the drilling phase of the project will be completed, and preparation will begin on an interpretive report on the aquifer testing and water-quality aspects of the study.

Definition of Recharge Areas, Physical Extent, and Quality of Water in the Principal Aquifers in Western Kane County, Utah

Number: UT-90-206

Cooperating Agencies: Utah Division of Water Quality; Kane County; the City of Kanab; and the Kanab Area Water Association, Inc., through the Five County Association of Governments.

Staff: L.E. Spangler, Hydrologist, Project Chief (part time)

Period of Project: March 1990 through February 1991

Problem: The residents of Kane County, Utah, and the Utah Division of Water Quality would like to define and classify major aquifers in western Kane County and identify the aquifer recharge areas so that future plans for development in the County could provide for the protection of its ground-water resources. Kane County contains large reserves of coal, the mining of which might substantially impact the area's ground-water resources by changing the quality and quantity of the water that recharges the aquifers, or by physically changing aquifer properties or geometry via mining practices.

The State and County, as part of their ground-water-protection strategy, would like to identify the principal aquifers, their recharge areas, and their boundaries so that future development, be it mining, agriculture, stock grazing, or residential, could be planned to minimize ground-water contamination and aquifer alterations. The information could be used by the State and County when reviewing plans for development to minimize detrimental effects to aquifers and their recharge areas.

Objectives: (1) To define and describe the physical boundaries of the principal aquifers in western Kane County, including their variability in thickness and their upper, lower, and lateral extents; (2) to identify aquifer recharge areas and the relative quantity of recharge provided by each of these areas; and (3) to provide the maps necessary for preliminary classification of water in these aquifers using the State's aquifer-classification system, which is based on chemical quality of water.

Approach: Because of limited funding, field work will be restricted to the collection of six to eight water samples. Remaining information necessary to complete the project will be obtained from available reports and data in the files of the U.S. Geological Survey and State agencies. The basic approach will be as follows: (1) Compile and review geologic reports to identify lateral and vertical extent and lithologic character of formations. This will lead to a preliminary categorization of aquifers and confining layers within 2,000 feet of land surface. (2) Compile drillers' and geophysical logs and water-quality information from the files of the U.S. Geological Survey, the Utah Division of Water Rights, and Petroleum Information, Inc., to identify aquifers and their extent and to initially determine depth to water and relative quality of ground water. (3) Use information from existing digital models and from available aquifer tests, specific-capacity tests, water-level measurements, and drill-stem tests to compile hydrologic data needed to estimate ground-water-flow velocity between recharge and discharge areas. (4) Use geographic information system techniques to portray and characterize aquifers, confining layers, and re-

charge areas, and to determine how they spatially relate to each other. (5) Prepare maps showing: (a) lateral extent of principal aquifers that occur within 2,000 feet of land surface, (b) thickness of principal aquifers, (c) location of recharge areas for the principal aquifers, and (d) summary of chemical quality of water in the principal aquifers from previously collected water-quality data. (6) Select and sample six to eight wells completed in the area's primary aquifer (the Navajo Sandstone) and analyze for major chemical constituents, trace metals, organic chemicals, and radionuclides. These analyses will serve as baseline data for comparison with future samples collected during further development of water from the Navajo aquifer.

Progress: From October to December 1991, three water samples were collected from wells discharging from the Navajo aquifer; samples were analyzed in the laboratory for common ions, trace metals, organic compounds, and gross alpha activity. Temperature, specific conductance, and pH were measured in the field. Analyses of all of the samples have been completed and results have been compiled. In addition to the base map, maps showing outcrops of Navajo Sandstone and surrounding geologic units; the areal extent and thickness of the principal aquifers; areas of potential recharge to the Navajo Sandstone, including areas of unconsolidated deposits overlying the Navajo; and dissolved-solids concentration in ground water have been prepared. A draft of the final report has been written and received colleague review. Post-review revisions have begun.

Plans for Next Year: Following revision, the report will be submitted for editorial review about November 30, 1991, revised, and forwarded for Regional review and Headquarters approval. Delivery of published report to the cooperating agency is anticipated during 1992.

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 Bureau of Indian Affairs and the Navajo Tribe 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 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: Completed digitizing location, at selected points in time, of the San Juan River near Bluff from aerial photography. Reviewed records in U.S. Bureau of Indian Affairs files. Completed literature search for pertinent articles in newspaper and agency files. Obtained copies of photography documenting the location of the San Juan River near Bluff, Utah. Completed rough draft of figures, tables, and sections of report.

Plans for Next Year: Complete draft of Administrative Report, submit for review, revise, and submit for approval.

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: C.B. Slaughter, Hydrologist, Project Chief
L.J. Gerner, Hydrologist (part time)
Other District personnel as assigned

Period of Project: October 1990 to December 1992

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 (if any) 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 core-sample analyses and aquifer tests. Ground-water samples will be collected for chemical analysis to determine if leachates from the landfills have reached the principal aquifer.

Progress: Landfill records were reviewed and personnel were interviewed to gain information on types of material buried in the landfills and the location of landfill boundaries. A final Work Plan that included a Health and Safety Plan and a Quality Assurance Plan was submitted to the Air Force. Shallow boreholes were augered at each of the three monitoring-well locations. Sediment samples were collected from undisturbed cores for on-site lithologic logging, gas chromatograph analysis, and laboratory geotechnical and chemical analyses. Mud-rotary drilling began at the first location but was stopped because of circulation and borehole-stabilization difficulties. The site was secured until a drill rig equipped with a casing-advancement system and/or a top-head drive could be scheduled.

Plans For Next Year: Three monitoring wells will be drilled into the principal aquifer. Undisturbed sediment cores 2 feet in length will be collected at 5-foot intervals during drilling. Samples of each core will be analyzed with a portable gas chromatograph; the remainder will be used for lithologic logging. Selected cores will be used for laboratory geotechnical and chemical analyses. Borehole-geophysical logs will be made of the monitoring wells, the monitoring wells will be completed, and dedicated submersible pumps and pressure transducers with data-storage modules will be installed. Ground-water

samples will be collected for chemical analysis. If conditions permit, an aquifer test or tests will be done .

Review of Water Demand and 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

Number: UT-91-210

Staff: K.M. Waddell, Project Chief (part time)
G.W. Freethey, Hydrologist (part time)
D.D. Susong, Hydrologist (part time)
G.E. Pyper, Hydrologist (part time)
E.B. Johnson, Hydrologist (part time)

Period of Project: March 1991 to December 1991

Problem: Questions have been raised concerning the adequacy of available water to provide for storage, exchanges, diversions, and instream flows pursuant to existing water rights in the Provo River drainage basin part of the Bonneville Unit. Also, concern exists about the potential for seepage of water from Jordanelle Reservoir to underground metal mines in the adjacent Park City mining district. The Utah Congressional Delegation requested the U.S. Geological Survey to review the results of analyses done by and for the U.S. Bureau of Reclamation and to address the concerns.

Objectives: Review hydrologic data, techniques, and the model used by the U.S. Bureau of Reclamation in their analyses of the Provo River drainage basin. Review data, techniques, and the results of a study of the potential for seepage from the Jordanelle Reservoir to underground mines.

Approach: The U.S. Geological Survey reviewed the three principal water-utilization studies done by the U.S. Bureau of Reclamation: the Provo River Project Operation Study, the Provo River Surplus Flow Study, and the Jordanelle Reservoir Operation Study. The reviewers examined texts, water-supply accounting tables, and water-accounting model programming found in several published and unpublished U.S. Bureau of Reclamation documents.

Progress: Completed review and began preparation of report.

Plans For Next Year: Publish an open-file report describing the review and its conclusions.

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 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 will 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.

Objectives: The proposed study will 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. Models of infiltration and downward flow at each site will be developed using the VS2D unsaturated-flow model.

Progress: Proposals and workplans have been prepared.

Plans for Next Year: The study sites will be selected and instrumented. Neutron-moisture tubes, weirs, flow meters, tensiometers, and the weather station will be installed and data collection begun. Well logs and water-level data will be compiled, and geographic information system coverages will be created for mapping recharge areas.

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 1993

Problem: Selenium concentrations of water in drains discharging to Stewart Lake Waterfowl Management Area in the middle Green River basin ranged from 27 to 92 µg/L, and selenium concentrations in samples of water from a pond at Ouray National Wildlife Refuge, along the Green River, were 28 and 92 µg/L. Selenium concentrations in Ashley Creek, which drains to the Green River near Stewart Lake, have ranged from 25 to 96 µg/L and have been as large as 16,000 µg/L in seepage entering the creek. Concentrations in fish and waterfowl are so large in these areas that a health advisory has been issued. Contamination is from the dissolution of selenium in the Mancos Shale and drainage from irrigated lands, which contaminate Ashley Creek, nearby Stewart Lake, and part of Ouray National Wildlife Refuge, and may create problems in the Green River. 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: Define the local hydrologic system for Ashley Creek, identify the major sources of selenium, and determine movement of selenium through the hydrologic system. Design and implement a monitoring program for selenium contamination at Stewart Lake, Ouray National Wildlife Refuge, and in the Green River that will provide data to evaluate any remedial actions implemented by the U.S. Bureau of Reclamation.

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 National Wildlife Refuge and Stewart Lake; and (3) design a monitoring program to assess changes in the aquatic systems with time and in response to remedial actions in the middle Green River basin.

Progress: Water and sediment sampling were done in 1991; water sampling is almost complete; sediment sampling is complete. A water-quality monitoring program was established. A team from the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and U.S. Geological Survey was formed to screen potential remedial actions.

Plans for Next Year: Prepare workplan and complete seepage studies on Ashley Creek.

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)
A. Andrews, Hydrologic Technician (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 freshwater 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 lakebed topography at Bird Island and Lincoln Point to help define geologic conditions related to spring locations; (4) conduct 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; use measurements to

develop a relation between thermal anomalies and discharge that can be used to estimate the discharge of other springs; and (4) sample representative springs for chemical analyses, including selected isotope analyses.

Progress: A. Topographic and bathymetric surveys of Bird Island - Lincoln Point area—All preliminary planning for the surveys is complete, and surveys are scheduled for early FY 1992.

B. Aquifer/interference test in Lincoln Point area—An interference test was completed in the Lincoln Point area by pumping an existing well. Effects of pumping were observed in a nearby well, on a staff gage installed in a spring-fed pond, and in four flumes installed to measure spring discharge. Discharge of the pumped well and pH, temperature, and conductivity of the water from the pumped well were measured during the test. Rough graphs of the water levels and discharge have been plotted, and results of the test are currently being evaluated.

C. Geophysical Survey of Bird Island - Lincoln Point area—A marine-seismic survey has been completed in the area between Lincoln Point and Bird Island. Thirteen seismic sections were shot. The geophysical data have been plotted on maps and are currently being evaluated.

D. Thermal Survey—Thermal data from NASA's Thermal Infrared Multispectral Scanner have been collected for the entire lake and the data are being evaluated and interpreted.

E. Flow Measurement—Springs above lake level in the Lincoln Point area were measured, and two submarine springs near Bird Island have been identified and measured.

F. Water-Quality Parameters—Temperature, pH, and specific conductance of all springs with substantial discharge that were above the current (1991) lake level were measured. Three of the larger springs and three wells in the Lincoln Point area were sampled for major constituent and stable isotope (oxygen/deuterium) analysis. One of the large springs was sampled for tritium analysis. Temperature, pH, and specific conductance of water from two submarine springs at Bird Island were measured, and samples were collected for major constituent analysis. In addition, temperature, pH, and specific conductance of a cold-water spring at Bird Island were measured.

Plans for Next Year: Complete bathymetric- and topographic-surveys and process data, process thermal data and select thermal anomalies to be investigated, determine source of thermal anomalies by field verification, and sample springs identified by thermal imaging. Evaluate geophysical-, bathymetric-, and topographic-survey results. Write an interpretive report on initial data collected, and a second interpretive report on the thermal-imaging survey. Complete journal articles, and prepare Miscellaneous Investigations Map in cooperation with NASA.

Definition of Recharge Areas, Physical Extent, and Quality of Water in the Navajo Aquifer in Washington County, Utah

Number: UT-91-215

Cooperating Agency: Utah Division of Water Quality

Staff: G.W. Freethey, Hydrologist, Project Chief

Period of Project: May 1991 to September 1992

Problem: The Utah Division of Water Quality would like to define the Navajo aquifer in Washington County and be able to classify water in the Navajo aquifer according to the State's Ground-Water Protection Standards. Washington County is experiencing the largest rate of population increase in the State, and the Navajo aquifer likely will be the primary source of ground water to support this increase. Establishing the limits of this water supply in terms of quantity and quality will likely become an important need of residents of the County in the next five years. The State and County need to define the recharge area, extent of the aquifer, and the existing quality of water in the Navajo aquifer so that future development can be planned to minimize the possibility of ground-water contamination or overuse.

Objectives: The project will focus on defining the recharge area, extent of the aquifer, and quality of water in the Navajo aquifer. Specifically, the objectives are to: (1) Define and describe the boundaries of the Navajo aquifer in western Washington County. This will include describing the variability in thickness and defining the upper, lower, and lateral extents, including definition of the parts of the Navajo Sandstone that are unsaturated; (2) identify recharge areas for the Navajo aquifer and the potential for recharge in those areas; and (3) provide information to the Utah Division of Water Quality that would enable them to classify water in the Navajo aquifer using the State's ground-water classification system. This information will consist of a compilation of water-quality parameters such as common constituents, trace metals, organic chemicals, and radionuclides.

Approach: The approach will be to: (1) Compile and review geologic reports to identify lateral and vertical extent and lithologic character of formations. (2) Compile drillers' and geophysical logs and water-quality information to identify the dimensions of the Navajo aquifer and to initially determine depth to and relative quality of the ground water. (3) Select and sample six to eight wells or springs discharging water from the Navajo aquifer and analyze the samples for major chemical constituents, trace metals, organic chemicals, and radionuclides. (4) Use geographic information system techniques to define and characterize the Navajo aquifer and its recharge areas. (5) Prepare maps showing: lateral extent of those parts of the Navajo aquifer that occur within 2,000 feet of land surface; thickness of the Navajo aquifer (saturated thickness of Navajo Sandstone); location of recharge areas for the Navajo aquifer and relative potential for recharge in those areas; and a summary of chemical quality of water in the Navajo aquifer from previously collected water-quality data and analyses done for this study. (6) If additional funding becomes available, complete the same work for the unconsolidated alluvial aquifer in Washington County.

Progress: Plans for sampling were made, and eight sites were selected. Information was given to the Utah Division of Water Quality for review. Sampling trips were scheduled. Geographic, geologic, and hydrologic information was digitized.

Plans for Next Year: Complete sampling, tabulate data, and finish map report.

The Movement of Pesticides in Ground Water in the Lower Spanish Fork Area of Southern Utah Valley, Utah County, Utah

Number: UT-91-216

Cooperator: Utah Department of Agriculture

Staff: R.W. Puchta, Hydrologist, Project Chief
M.E. Enright, Hydrologic Technician (part time)

Period of Project: July 1991 to September 1994

Problem: The lower Spanish Fork area has a high potential for pesticide contamination of ground water resulting from large quantities of pesticides being applied over an area of shallow ground water. The Utah Department of Agriculture needs additional information on actual movement of pesticides and the potential for movement of primarily triazene herbicides, chlorophenoxy-acid herbicides, and nitrates from areas of application through a thin unsaturated zone, into the shallow ground-water system, and then to domestic wells, drains, canals, streams, Utah Lake, or wells completed in deeper zones.

Objectives: The objectives of the study are to: (1) Describe the ground-water system in terms of sources and areas of recharge, directions of movement in deep and shallow zones, types and points or areas of discharge, and hydraulic properties; (2) document the history, areas, types, and quantities of pesticide application; (3) determine the areal and vertical distribution of selected pesticides in the shallow water table and deeper zones and explain the distribution; and (4) identify the potential flow paths along which pesticides could migrate to wells or surface-water sources.

Approach: The approach is to: (1) Compile information on the ground-water system and on pesticide application from previous studies and from government agencies, private companies, and individuals; (2) determine additional data needed (partly with the use of a geographic information system); (3) collect additional data by water sampling, aquifer testing, test drilling, measuring water levels, and measuring well, spring, drain, canal, and stream discharge; (4) if possible, develop maps showing the distribution of the concentration of pesticides in ground water in the study area; and (5) describe the potential flow paths for pesticide migration.

Progress: Immunoassay-testing methods and equipment for analyzing pesticides were investigated, and equipment and testing kits were ordered. Several shallow and deep wells in the study area were visited to determine their suitability as future sampling wells, and their water levels were measured.

Plans for Next Year: Locate all shallow wells in the area and measure their water levels. Collect water-quality samples from shallow wells and from some deep wells, canals, drains, springs, and streams. Incorporate data into a geographic information system. Measure discharge of selected drains, springs, canals, and streams.

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