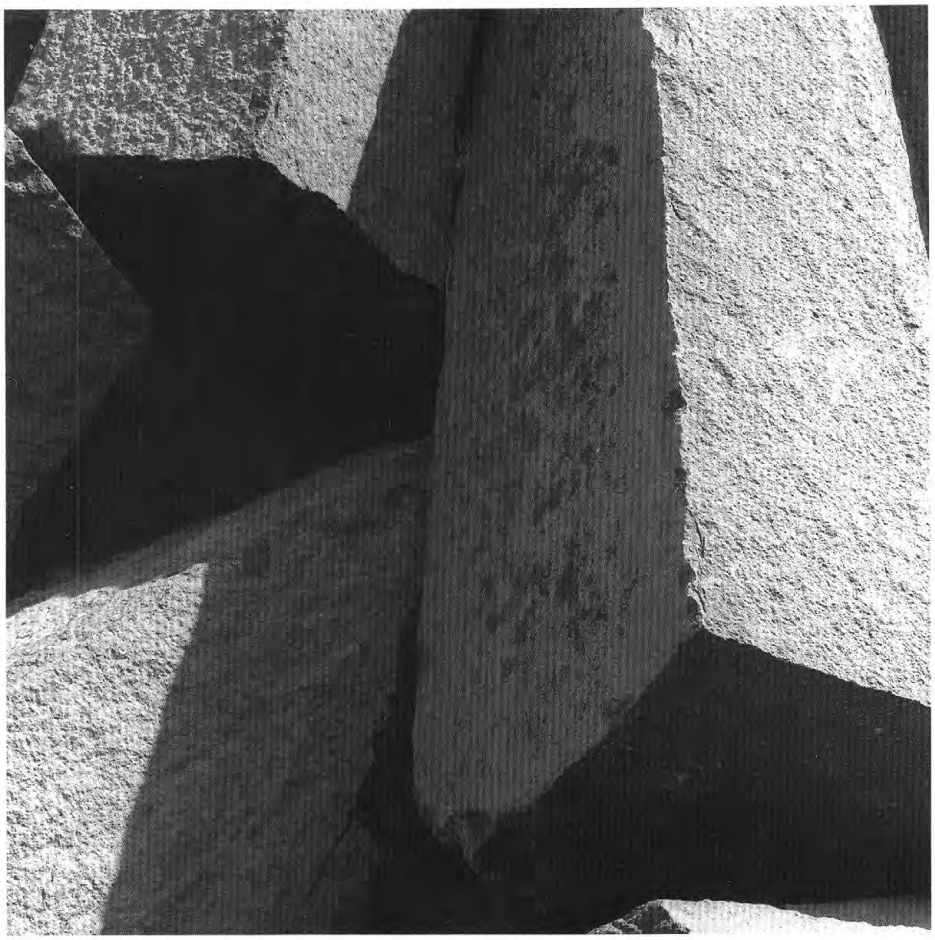


1992

U.S. GEOLOGICAL SURVEY

Front cover: Columnar jointing in Pleistocene basalt (age probably less than 100,000 years), Devils Postpile National Monument, Sierra Nevada, Calif. Use of cover photograph is courtesy of Paul Stone.

Back cover: Landsat imaging from USGS Geophysics Remote Sensing Laboratory, Denver, Colo.

U.S. GEOLOGICAL SURVEY YEARBOOK
FISCAL YEAR 1992
PARTNERSHIPS IN THE EARTH SCIENCES

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, *Secretary*

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, *Director*

Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government

United States Geological Survey Yearbook Fiscal Year 1992
ISSN 0892–3442

UNITED STATES GOVERNMENT PRINTING OFFICE: 1993

For sale by the U.S. Geological Survey, Map Distribution, Box 25286,
Bldg. 810, Federal Center, Denver, CO 80225

CONTENTS

v Message from the Director

1 Science and Cooperation after the Storms

11 People and Programs

37 Water Resources Investigations

55 Geologic Investigations

71 National Mapping Program

81 International Activities

93 Information Systems Activities

101 Administration

107 Organizational Chart

108 Budget Information

110 Guide to Information and Publications

111 U.S. Geological Survey Offices

116 Cooperators and Other Financial Contributors

DEDICATION

Thomas B. Nolan

1901–1992

The 1992 Yearbook is dedicated to the memory of Thomas B. Nolan, Director of the USGS from 1956 to 1965. Dr. Nolan died on August 2, 1992. Nolan was the ultimate scientist, administrator, and public servant. Perhaps most importantly, he was a good and kind human being, which was reflected in all he did. For this most of all, he will be missed. Nolan joined the USGS in 1931, and during the course of his 68-year career, he authored more than 90 publications and served under 12 presidents. He created the modern USGS and served as its director for 20 years. Highlights of his career include having been honored in 1961 by President Kennedy when he received the Rockefeller Public Service Award and in 1984 by President Reagan when he completed 60 years of active service. In addition to having mountains, minerals, and fossils named after him, he received international accolades too numerous to list. As President Reagan said in a letter to Nolan in honor of his 60 years of Federal service, "Tom set the highest of standards for all of us to pursue." His legacy to the USGS and to the worldwide community of earth scientists will never be forgotten.

Message from the Director

At its creation, the U.S. Geological Survey was given a daunting challenge: map the entire United States and catalog its natural resources. To help meet that challenge, the young USGS drew on the finest scientific talent the Nation had to offer, both from within its own ranks and from universities, State geological surveys, and industry. As the mission of the USGS has expanded and evolved, cooperative earth science ventures have become the firmly established tradition—a tradition that continues and flourishes today.

The strong working relations that we have built over the years with our colleagues in the State geological surveys, with other Federal agencies, and with the academic community stood us in particularly good stead when the Nation faced Hurricane Andrew—the most costly natural disaster in American history—and Hurricane Iniki and tropical storm Omar in the Pacific.

Relief efforts mounted by Federal, State, local, and private agencies relied on USGS maps. Map presses at the USGS ran around the clock to meet requests for literally hundreds of different maps of damaged areas that poured in from such agencies as the Federal Emergency Management Agency, the Defense Mapping Agency Combat Support Center, the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency.

USGS geologists at the Center for Coastal Geology and Regional Marine Studies, a cooperative undertaking with the University of South Florida in St. Petersburg, joined with scientists from the National Oceanic and Atmospheric Administration, the National Park Service, and the Florida Department of Natural Resources to assess the storm's effect on Florida's coast. USGS hydrologists worked with long-time cooperating State and local water management agencies to assess high-water marks and the hydrologic effects of Andrew's destructive path across Florida.

By the time Hurricane Andrew crashed into Louisiana at the end of August 1992, its fury was spent. But its destructive effects on the State's already-threatened coastline were tremendous. The USGS, along with several other Federal agencies and State and local agencies, had been working to establish the scientific reasons behind the loss and deterioration of the State's coastal wetlands and barrier islands to determine how to stem the loss of these valuable ecosystems. Because of strong existing partnerships among the USGS, the U.S. Fish and Wildlife Service's Wetland Research Center, the Louisiana Geological Survey, and the State's academic community, scientists were ready to respond when Hurricane Andrew hit. By using data gathered during earlier coastal studies and displayed in the recently published atlas of barrier island change, we were able to show exactly what happened when Andrew hit, why the barrier islands and wetlands reacted the way they did, and how the damage wrought by Andrew compares with other natural and human-caused impacts to coastal environments.

As the mission of the USGS has expanded and evolved, cooperative earth science ventures have become the firmly established tradition—a tradition that continues and flourishes today.

Our desire to document the effects of Hurricane Andrew on the environment also opened the door to humanitarian service. USGS hydrologists tracing the extent of the storm surge in Florida were sometimes the first visitors to devastated areas. They provided the first emergency food and water supplies to several neighborhoods that had been destroyed by the storm. Later, USGS employees and retirees banded together to provide thousands of dollars in disaster relief funds to aid their colleagues whose homes had been shattered by the storm.

In another disaster-related effort, we are paying closer attention to our own issues of disaster response and coordination in ensuring that telecommunications systems at USGS offices, particularly those in earthquake-prone California, are set up to work efficiently in the wake of a disaster and to ensure that we can continue to do our science and to communicate the information that is needed by community and State officials when an earthquake or other disaster happens. The message of preparedness is one that we all must heed.

These examples of collaboration following disasters are dramatic reminders of the value of partnerships. As important as our joint work in the face of disaster is, it represents only a small fraction of the cooperative efforts between the USGS and our counterparts around the Nation and around the world. Many of the areas in which we are laboring cooperatively in the name of good science may never be front-page news. Nevertheless, the continual exchange of information, expertise, and commitment helps the Nation to be ready to respond to the challenges of safeguarding our environment and ensuring sustainable economic development.

The National Geologic Mapping Act of 1992 is a good example. This landmark legislation will further the production of geologic maps, which are valuable environmental and economic decisionmaking tools. The passage of Public Law 102–285 was the product of cooperative work among State geological surveys and the USGS. Geologic maps are a public good—providing valuable information that can be used by many to deal with the challenging tasks of reinvesting in and reinvigorating the American infrastructure. As recent examples, the USGS, in cooperation with State and local agencies, has demonstrated that using high-quality geologic map information in siting landfills and planning transportation corridors can significantly reduce costs and safeguard public well-being. An effective partnership among all those involved in geologic mapping and in the use of geologic map information is paramount in ensuring that we meet the challenges of effective management and preservation of our resources and our environment.

Increased cooperation in geologic mapping represents only a portion of our efforts to promote partnerships in cartographic activities. The USGS chairs the Federal Geographic Data Committee (FGDC) on behalf of the Department of the Interior and the Federal Government. The FGDC is spear-

heading a governmentwide effort to standardize the collection and sharing of spatial data needed for geographic information systems and other advanced mapping technologies. In 1992, the FGDC adopted a new spatial data standard—the Spatial Data Transfer Standard (SDTS)—that is being employed throughout the Federal system. A proposed national geographic data base, linking all levels of government and the private sector, and slated for development by 2000, will be an essential bridge between producers and users of spatial data.

Partnerships have long been the way of doing business for USGS water resources programs. The nearly 100 years of successful cost-sharing coordination through the Federal-State Cooperative program have resulted in countless investigations that have served both Federal and State interests and have built a solid cooperative family of more than 1,000 agencies concerned about the health and welfare of the Nation's water resources. That model of cooperation is one of the essential building blocks of the ongoing National Water-Quality Assessment (NAWQA) program. Each NAWQA study unit (20 are currently underway with another 20 due to start in fiscal year 1994 and the final 20 in fiscal year 1997) has a local liaison committee. These liaison committees have representatives from pertinent Federal, State, and local agencies and other interested groups. These local sounding boards for the success of the NAWQA study function as a guiding force in ensuring that the assessment addresses the water resource issues of the area and as a check that the project is proceeding in a way that meets the needs of all who are involved.

The Glen Canyon environmental study that the USGS has undertaken with the Bureau of Reclamation (BOR) is an excellent example of "in-house" cooperation of two Interior bureaus pooling their specific expertise to meet a common goal. The information that the USGS is developing on the hydrology of the area will be used by the BOR to develop procedures for Glen Canyon Dam that will ensure that operation of the dam is both environmentally sensitive and economically reasonable. As another example of water resources cooperation, the new Water Information Coordination Program (WICP) unites representatives from Federal, State, and local governments, Indian tribes, and the private sector in cooperative water data-gathering efforts. Identifying opportunities to improve the effectiveness of water information activities—from the collection of basic data to the dissemination of interpretive information—will be a key component of the WICP effort.

Today, many of the most pressing problems in science, as well as critical issues in economic development, are global questions. Each day we are becoming more and more of a global community. To address these issues, USGS partnership arrangements extend well beyond the borders of the United States. USGS scientists apply the experience gained in cooperative mineral and energy resource assessments in foreign countries to assist in domestic minerals research and to help the U.S. minerals industry be more competitive in the world marketplace. Our efforts to help understand the ecology of water systems and in developing water supplies in foreign countries are useful in reexamining issues of water quality and water supply in our own country. Research links with such organizations as the United Nations Environment Programme aid scientists worldwide in their efforts to preserve the global environment. My official participation at the 29th International Geological Congress in Kyoto, Japan, in September 1992 was an exciting reminder of the cutting-edge, earth science research that is ongoing in every corner of the world. It is essential that we continue to promote the cause of good science as an effective means of diplomacy and good will. The opportunities that are evolving in areas such as Eastern Europe underscore the value of scientific cooperation as a first step in reestablishing effective economic and diplomatic relations. Through our science we can indeed be good ambassadors in the world community.

In areas of administration and information resources management, the USGS has been an effective partner as well. We have taken the lead in developing the computerized, state-of-the-art Federal Financial System (FFS), which has become the model for all Interior bureaus and has now also become a standard for many other Federal agencies. We are continually looking at new ways to share our information and to help our scientists network and interact online with other researchers to keep the flow of good science current and coordinated.

I am also ever mindful of the most important resource of this bureau—its people. We are constantly working to ensure that our people feel empowered as partners within the bureau. We have taken seriously the charges to improve employment opportunities for women, minorities, and persons with disabilities, to increase the use of volunteers, and to promote education in the earth sciences. The Volunteer for Science program has proved especially beneficial, providing opportunities for people of many ages and many walks of life to help the USGS and also providing much needed help to USGS employees, while saving the Federal Government significant money. In education, we not only encourage educational pursuits by our employees and provide graduate and postgraduate opportunities for young people to get a foot in the door with the Federal system, but we are also making significant contributions to precollege education. The students of today will be the employees and voters of tomorrow, and it is in our own best interest to ensure that students in our elementary, middle, and high schools have a good solid understanding of the earth sciences and the important role that science plays in each person's life every day.

The activities and investigations documented on the following pages would not have been possible without the contributions of many hundreds of partners with whom we work in other government agencies at the Federal, State, and local levels, in academic institutions, and in the private sector. These partnerships have implications that reach far beyond the world of earth science research. Because the earth sciences are intrinsic to so many policy and management decisions regarding the environment, natural resources, and the economy, they form the base on which the Nation can build. As the country seeks to restore the economy, rebuild the infrastructure, protect the environment, and contribute to international well-being, the USGS is proud of its contributions in providing "Earth Science in the Public Service."

Dallas L. Peck

Introduction

Few natural hazards can match the awesome destructive power of tropical cyclones. The devastating visits of Hurricane Andrew in Florida and along the Gulf Coast and of Hurricane Iniki and Typhoon Omar in the Pacific left vivid memories of the powerful force and potential destruction generated by these storms. And we can expect more devastation. Statistics compiled by the United Nations in 1989 show that by the year 2000, the surface of the Earth will experience several hundreds of earthquakes, landslides, floods, wildfires, and tornadoes, in addition to hundreds to several thousand tropical cyclones.

The 1990's have been declared the International Decade for Natural Disaster Reduction (IDNDR) to bring worldwide attention to the impacts of natural disasters and to develop programs to reduce the loss of life, economic impact, and human suffering resulting from these natural phenomena. The USGS shares responsibilities for earthquake, volcano, landslide, and flood hazards in the realm of natural disasters. As one of the Federal science and disaster-reduction agencies that are a part of the U.S. program for the IDNDR, the USGS is working with State and local agencies to develop hazard and risk assessments, preparedness and mitigation measures, predictions and warnings for natural hazards, and greater awareness and education for all sectors of society.

Natural hazards are severe manifestations of the natural processes of our environment, and we must learn to cope with them in the best manner possible. While great scientific strides have been made in predicting the course of hurricanes, for example, we cannot totally eliminate their devastating visits, although we can reduce their impacts through better building and land use practices.

There is much that can be done, particularly in assessing areas at greatest risk to particular hazards, in developing methods and plans to mitigate the effects of those hazards, and in educating officials and the public of the steps that are necessary to prepare for the inevitability of nature. Actions in these areas are the key elements in reducing the severity and number of human disasters that result from natural hazards.

Robert M. Hamilton
Chairman, Subcommittee on Natural Disaster Reduction
Committee on Earth and Environmental Sciences
Federal Coordinating Council on Science, Engineering and Technology

Hurricanes and Coastal Erosion—The Lessons of Andrew in Louisiana

By Asbury H. Sallenger, Jr., and S. Jeffress Williams

The coastal marshes and tidal wetlands of Louisiana's coast, and the barrier islands that protect them, form one of the world's most productive ecosystems. Louisiana has 25 percent of the vegetated wetlands in the 48 contiguous United States and 40 percent of the tidal wetlands. But the Gulf Coast of Louisiana is eroding faster than any other coastal area of the world. Every year, Louisiana loses as much as 100 square kilometers (39 square miles) of land—an area nearly the size of Washington, D.C. Some of this land loss can be traced to human activity, but much of it can also be traced to the forces of nature—including the large storms that strike the area about every 5 years.

Several Federal, State, and local agencies have been working together to establish the reasons behind this massive land loss and determine what can be done to stem this problem. Because of these cooperative studies, scientists were ready to respond when Hurricane Andrew carved a swath through the State's coastal areas. Andrew was the most destructive storm in the Nation's history in terms of insured losses. Strong partnerships between the USGS, the Louisiana Geological Survey (LGS), and the State's academic community enabled scientists to begin assessing

USGS-LOUISIANA GEOLOGICAL SURVEY

Hurricane Andrew continued—in a severe manner—an erosion process that has been going on for at least the past several hundred years on Whiskey Island, which is a part of the Isles Dernieres barrier island system. The Isle Derniere previously was a single island off Terrebonne Parish that supported forests and a resort community. An 1856 hurricane destroyed the resort, and continued erosion has since caused Isle Derniere to break up into four islands (Raccoon, Whiskey, Trinity, and East islands),—now renamed the plural Isles Dernieres. The dramatic effects of Andrew are shown in the "before" photograph (top), taken in July 1992, that shows Whiskey Island as nearly twice as long as in late August 1992 when the "after" photograph (bottom) was taken several days after Andrew. The west end of the island was washed away when Andrew's hurricane winds caused waters from the Gulf of Mexico to wash over the island. Some of the sand was deposited in the sandbars visible in the right center of the photograph.

Hurricane Andrew's effects only hours after the storm had passed on August 26, 1992.

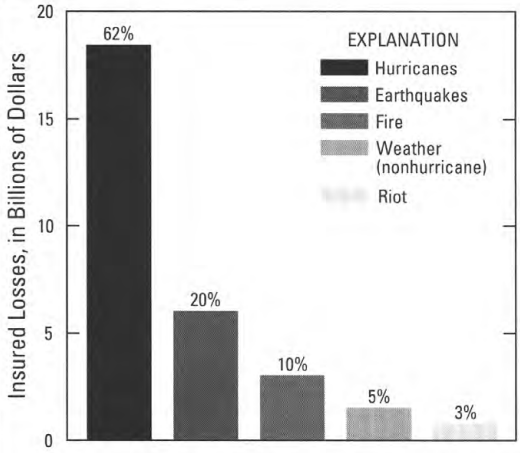
Earlier work by the USGS and LGS, which has been characterized by the State as a model of Federal-State interaction, produced an atlas of barrier island erosion and rapid land loss in Louisiana. This atlas, published in 1992, provided a baseline against which storm damage could be measured. Using the data gathered during the Barrier Island Erosion Study, joint efforts are underway to understand exactly what happened when Andrew hit, why the islands reacted the way they did, and how the damage wrought by Andrew compares with other natural and manmade challenges the islands have faced.

The barrier islands in Terrebonne and Lafourche parishes were hardest hit. Beaches were eroded more than 37 meters (120 feet) in 2 days. The Isles Dernieres and Timbalier Islands were completely inundated; storm action cut 15 major breaches in them and stripped away roughly 70 percent of their beach sand. Coastal wetlands behind these barrier islands also suffered severe damage. A blanket of mud about 46 centimeters (18 inches) thick was deposited over tens of thousands of acres of marsh and shallow bays. Although this mud will help nourish deteriorating wetlands, it also smothered extensive oyster reefs in the Barataria-Terrebonne National Estuary.

USGS studies, reported in the atlas prior to the storm, predicted that the Isles Dernieres barrier islands would likely disappear totally beneath the waves by 2020. As a result of Andrew, some of these islands may disappear before the turn of the century. And, once the barrier islands are gone, the productive wetlands that lie behind them will be fully exposed and vulnerable to wave action and storm flooding.

To prevent the loss of these vital barriers, several erosion control and shoreline restoration projects have begun along the Gulf Coast. The storm was a valuable lesson by providing scientists and land managers with information on how these efforts fared. As a result, the most effective ways to implement coastal restoration and mitigation measures are being identified.

The extreme erosion of the beaches and wetlands and the performance of the various coastal structures are providing insight into how to better manage Louisiana's coastal resources. All of the areas where protective seawalls had been built suffered severe erosion. Seawalls were somewhat effective, however, in protecting coastal oil and gas



Thirteen Most Costly Insured Catastrophes, in United States History

Year	Peril	Insured Loss (in Billions)
1992	Hurricane Andrew	$10.70
1906	San Francisco Earthquake	*$5.07
1989	Hurricane Hugo	$4.20
1871	Chicago Fire	*$1.83
1992	Hurricane Iniki	$1.60
1991	Oakland Fire	$1.20
1989	Loma Prieta Earthquake	$0.95
1983	Winter Storm/Freezing (41 States)	$0.88
1992	Los Angeles Riots	$0.78
1979	Hurricane Frederic	$0.75
1965	Hurricane Betsy	$0.52
1983	Hurricane Alicia	$0.68
1990	Wind/Hailstorm-Colorado	$0.63

*adjusted to 1990 dollars

Source: Property Claim Services Division, American Insurance Services Group; and Insurance Information Institute

facilities. Coastal protection and restoration projects that used sediment and vegetation also suffered damage during the storm, but they were far more successful than seawalls in protecting barrier island dune and marsh habitats. One of these efforts, known as the Isles Dernieres barrier island restoration project, demonstrated the importance of maintaining island elevation and width in order to prevent barrier islands from breaking up.

The legacy of Andrew lies in what the storm can tell us of the efficacy of human intervention in natural processes. Inherent in the most effective restoration actions is an understanding of the natural forces at work and an effort to develop mitigation measures that are in concert with nature's dynamic processes and its more capricious and destructive aspects.

Effects of Hurricane Andrew

Florida.—Mangrove coasts, both along the shores of Biscayne Bay and the Keys facing the Atlantic, were severely stripped and beaten by the wind. It is expected that severe wood damage to trees will prevent large areas of mangrove swamp from recovering rapidly. Dead mangrove forests required a decade to reestablish after Hurricane Donna tore through the Keys and Everglades in 1960, 30 miles (48 kilometers) south of Andrew's course. Curiously, a "green zone" of mangroves with leaves still intact extended a few feet above the water line on the eastern sides of the Keys and along the coast after Andrew's visit. Scientists speculate that these leaves were preserved because they were below water during the highest winds of the storm.

Louisiana.—Hurricane Andrew directly impacted the Mississippi River delta plain in Louisiana on August 26, 1992, with sustained winds of 140 miles per hour (225 kilometers per hour), gusting to 205 mph (330 kph). A storm surge of 15 feet (4.6 meters) accompanied landfall, inundating St. Mary's, Terrebonne, Lafourche, Jefferson, and Plaquemines parishes for more than 25 miles (40 kilometers) inland. The eastern eye wall of Hurricane Andrew cut a 30-mile (48-kilometer)-wide swath of destruction from Fourchon through Cocodrie and Morgan City to Baton Rouge.

Hydrology and Hurricane Andrew in Florida

By William B. Scott

The center of the eye of Hurricane Andrew made landfall near Florida City, 19 miles (31 kilometers) south of downtown Miami, Fla., at 5:30 a.m., on August 24, 1992, descending with winds at the eyewall of 140 miles per hour (225 kilometers per hour) and gusts up to 168 miles per hour (270 kilometers per hour). The eyewall of the storm cut a swath 20 miles (32 kilometers) wide as it passed south of Miami. Andrew then roared across the southern tip of the State and swept into the Gulf of Mexico leaving a devastating trail of destruction. Damages were mostly wind related and estimated to be greater than $20 billion. The infrastructure of roads, power lines, water and sewer services, and communications was severely and extensively damaged, with the greatest destruction occurring in South Dade County in the vicinity

WILLIAM J. HAIRE

Home of USGS employee that was totally destroyed by Hurricane Andrew at 111th St. in Miami.

E. CAROLYN PRICE

View of destruction on 259th Street in Homestead.

of Homestead and Florida City. A total of 15 lives were reported lost in South Florida. Had the storm veered less than a degree of latitude north, the disaster from this natural hazard would have been even greater.

Hurricane Andrew, described as the greatest natural disaster ever to strike the United States, did not discriminate in its devastation. Five people from the USGS Miami Subdistrict Office had their homes completely destroyed, while homes of seven other employees suffered severe damage. Fortunately, no injuries occurred to personnel or their immediate families. The office, located northwest of the Miami International Airport, was not damaged but was without power until the morning of August 26. Damage, however, was extensive to the network of USGS hydrologic stations located throughout south Dade County.

In accordance with the USGS mission to develop information on water-related natural hazards, hydrologists worked cooperatively with other Federal, State, and local agencies to document the magnitude and extent of Hurricane Andrew's tidal surge and flooding. USGS hydrologic data-collection activities related to Hurricane Andrew were coordinated with the National Oceanic and Atmospheric Administration, the Florida Department of Natural Resources, Division of Beaches and Shores, and the U.S. Army Corps of Engineers Waterway Experiment Station, Coastal Engineering Research Center.

On the day following the storm (August 25), USGS personnel began fieldwork to collect pertinent data to document the hydrologic impact of Hurricane Andrew in southeastern and southwestern Florida and to assess and begin repairing damage to the hydrologic network. Reported damages to the USGS network included 27 instrument stations destroyed, 7 ancillary structures destroyed, and 16 satellite data-collection platforms damaged or destroyed. Cost to repair or replace damaged hydrologic equipment and structures was estimated at $778,000. As human and financial resources became available, continual progress was made on repairing damaged network stations in the months following the storm.

The Federal Emergency Management Agency (FEMA) asked the USGS to locate and describe high-water marks in areas affected by the hurricane and to field survey these marks to determine the actual elevation and maximum extent of the tidal surge. USGS hydrologists and geologists worked together to determine the height of the storm surge in the Miami area. The flagging and surveying of recoverable high-water marks along the eastern and western coastlines of South Florida were completed by September 15. Large portions of the Florida Keys between Key Biscayne and the northern tip of Key Largo, a distance of 28 miles (45 kilometers), were submerged by a 6- to 8-foot (1.8- to 2.4-meter) surge across the islands. Biscayne Bay, 8 miles (12.9 kilometers) wide and only 12 feet (3.7 meters) deep, was roiled by the storm, but major sediment deposits and grass beds appeared unaltered during overflights of the affected area. The shallow water amplified the storm surge so that, as Andrew crossed Biscayne Bay, the tide rose from 12 to 16 feet (3.7–4.9 meters) above normal by the time it reached the western shore. Although Andrew was not a particularly wet hurricane, western

Biscayne Bay was decidedly brackish after the storm. Freshwater extended several hundred yards from the shore, and the salinity was 11 parts per thousand (compared with a typical 34 parts per thousand) up to 1.5 miles (2.4 kilometers) out. Much of this effect may have been due to the precautionary actions of State water management agencies, which lowered the level of Lake Okeechobee in anticipation of the storm. The network of salinity monitoring wells for the Biscayne aquifer (a sole source aquifer) was sampled within a week after the hurricane to determine if salinity conditions had been changed by the tidal surge. Results of sampling showed no significant increase in salinity when compared with data from previously collected samples.

Preliminary evaluation of data shows the highest recorded elevation for high-water marks surveyed on the east coast to be 16.88 feet (5.15 meters) above sea level at the Burger King Corporate Headquarters near SW. 184 Street in south Dade County. Elevations of high-water marks diminished from this point both north at Broad Causeway where it reached 5.17 feet (1.58 meters) and south at Key Largo and reached 5.49 feet (1.67 meters) on the west side of Key Largo near Sunset Cove. On the west coast of Florida, high-water marks ranged in elevation from 4.38 feet (1.34 meters) at Everglades City to 6.85 feet (2.09 meters) at west Goodland. The farthest landward extent of the tidal surge was detected about 3 miles (5 kilometers) from the eastern coastline near SW. 224 Street east of the Florida Turnpike. The north-south inland extent spanned about 33 miles (53 kilometers) along the eastern coastal area.

The severe damage brought by Hurricane Andrew, as well as the emotional effects, will not be resolved in a few days, weeks, or even months. Recovery and rebuilding for the USGS, its employees, and their families, however, have begun. This catastrophe may have shattered homes and destroyed property, but it has also reinforced the bond of community that unites the USGS family.

WILLIAM J. HAIRE

Boat in photograph was docked at Cutler Ridge, just north of Homestead Air Force Base, near the area of maximum storm surge, and was moved about 300 feet (91 meters) inland by Andrew.

Hurricane Iniki: Effects on the Coast of Kauai

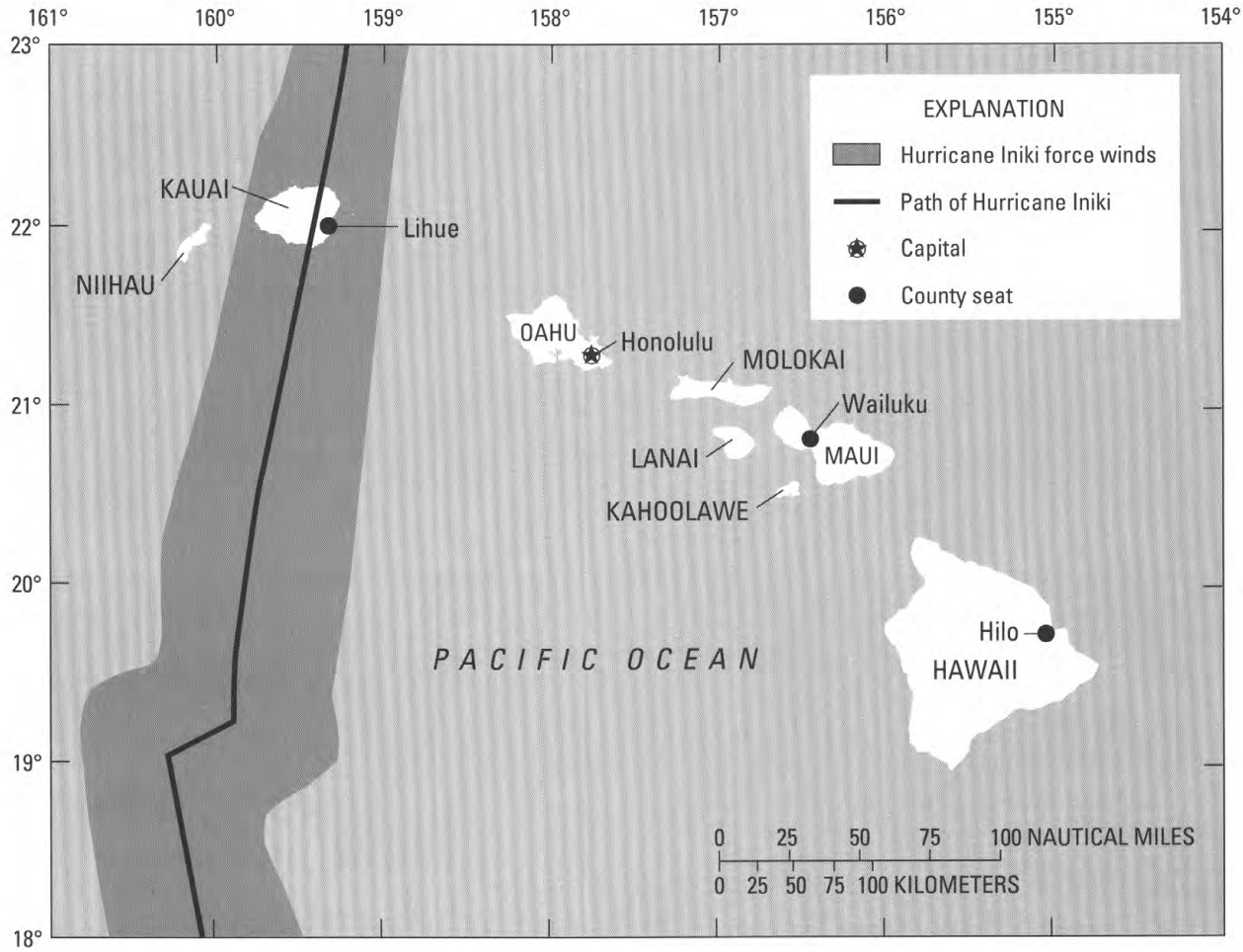
By Bruce M. Richmond and Monty A. Hampton

Hurricane Iniki struck Hawaii on September 11, 1992, causing extensive damage to property and natural coastal systems; it was the most powerful hurricane to strike the Hawaiian Islands this century. The island of Kauai, battered by sustained winds of about 225 kilometers per hour (140 miles per hour), was the most extensively damaged. Overwash, which is the combination of wave setup, wave runup, and storm surge, extended inland to distances of nearly 300 meters (985 feet) and reached elevations above mean sea level of nearly 9 meters (30 feet).

The effects of Hurricane Iniki varied depending on the orientation of the coast in relation to the eye wall, which is the zone of strongest winds. The south coast of Kauai, for example, experienced a combination of high overwash and strong winds, whereas the north coast underwent little overwash but suffered severe wind damage. The elevation

Oblique aerial photograph of Poipu Beach Park, southern Kauai, showing turbid sediment plumes in the nearshore, erosion and channelization on the beachface, and overwash debris in the backshore.

MONTY HAMPTON



Path of Hurricane Iniki and extent of hurricane force winds.

and extent of overwash depended strongly on local conditions. Overwash height increased with steeper offshore slopes, narrower reef widths, or both.

Geologic effects on the coast of Kauai included erosion of the beachface and formation of scarps. Although accretion occurred in some of the natural beaches of the island, generally there was a loss or lowering of the foreshore profile of the beaches. Turbid plumes of suspended sediment persisted in the nearshore for weeks after the event.

USGS scientists and others observed that the natural, undeveloped beaches underwent less erosion than beaches where engineered structures such as seawalls existed.

Poipu Beach area, southern Kauai, showing damage to revetments and coastal road from Hurricane Iniki overwash.

BRUCE RICHMOND

Meeting Demand for Maps in Storm's Wake

By Harry L. Zohn

As Hurricane Andrew approached the Florida coast, USGS customer service personnel were already pulling thousands of maps of Florida and nearby Gulf Coast States to meet the inevitable demands in the wake of such a devastating storm. Within hours of the storm's initial impact, USGS maps of south Florida had been provided to Federal disaster assistance authorities. More than 12,000 copies of 1,000 different maps of the affected areas were distributed quickly to the Federal Emergency Management Agency, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, and numerous State and local agencies.

When existing supplies were exhausted, USGS map printing presses, which can produce 5,000 maps an hour, ran around the clock, printing maps of Florida and Louisiana. An emergency printing of 24 topographic maps of the area most affected by the storm was underway within hours of the hurricane's devastating sweep across Florida. By September 4, more than 200,000 maps had been printed to replenish depleted stock and to meet the continuing demand by Federal, State, and local organizations.

The USGS Earth Science Information Centers in Washington, D.C., and Reston, Va., assembled sets of maps to meet the demand, including 1:100,000 scale maps and 7.5-minute topographic quadrangle maps of the area south of 27 degrees latitude in Florida and between New Orleans and Galveston on the Gulf Coast. The USGS Distribution Center in Denver, Colo., filled hundreds of orders directly received from various Federal and State agencies.

USGS technicians at the EROS Data Center in Sioux Falls., S. Dak., produced sets of daily images from NOAA satellite AVHRR (Advanced Very High Resolution Radiometer) data to show the track of the storm as it swept across the Gulf. Prehurricane coverage of the Gulf Coast from the USGS National Aerial Photography Program was helpful in various analysis efforts.

The USGS also helped assemble and organize a team of image interpreters to analyze damage from the storm. By registering high-altitude imagery to USGS maps of regional terrain, technical personnel were able to outline widely scattered damage sites along the storm's track.

DAVID USHER

USGS customer service personnel pull maps of Florida and Gulf Coast States from shelves at the Earth Science Information Center in Reston, Va., to support disaster assistance efforts.

Employees Lend Helping Hand

In response to a general call for aid and assistance in the wake of Hurricane Andrew, USGS employees around the country and many retired employees joined together in lending a helping hand to their fellow employees. Director Dallas Peck sent the following memorandum to all employees:

To: All Employees — Dated: Nov. 6, 1992
From: Director
Subject: Support for Hurricane Andrew Victims

I would like to share with you the contents of a memorandum dated November 4, 1992, I received from William B. Scott, Water Resources Division Subdistrict Chief, Miami, Florida, regarding the support many of you provided in the aftermath of Hurricane Andrew:

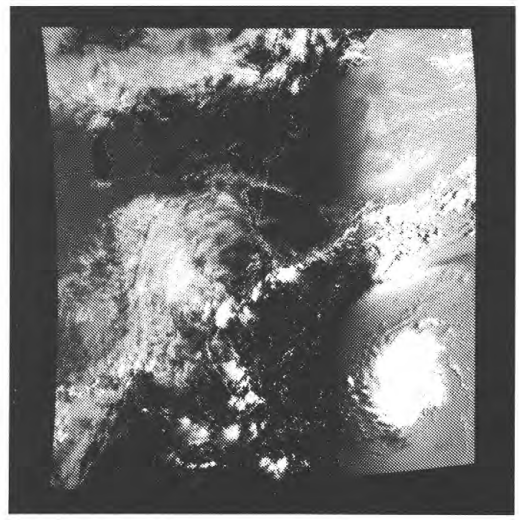
> On behalf of the entire staff of the Miami Subdistrict Office, I would like to express our sincerest thanks to U.S. Geological Survey employees past and present for their outpouring of generosity in the wake of Hurricane Andrew. Your extraordinary support in the form of money, food, provisions, and heartfelt expressions of concern has touched us deeply. Your contributions to the USGS Disaster Relief Fund have served to feed, clothe, and ease the suffering of your fellow employees, some having lost nearly everything.
>
> Although battered, rebuilding and the putting of lives back together have begun, this calamity may have shattered homes and destroyed property, but it has also reinforced the bond of community that unites the USGS family. A thousand thanks from all of us to everyone who helped.

I can only add to Mr. Scott's thoughts by expressing my sincerest thanks to those of you who supported this most worthy cause.

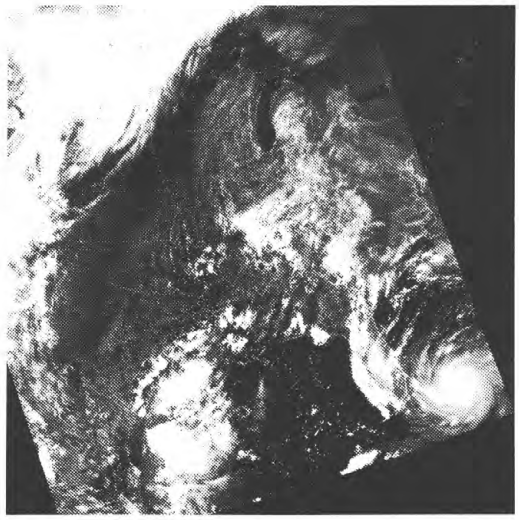
(Signed)

Dallas L. Peck

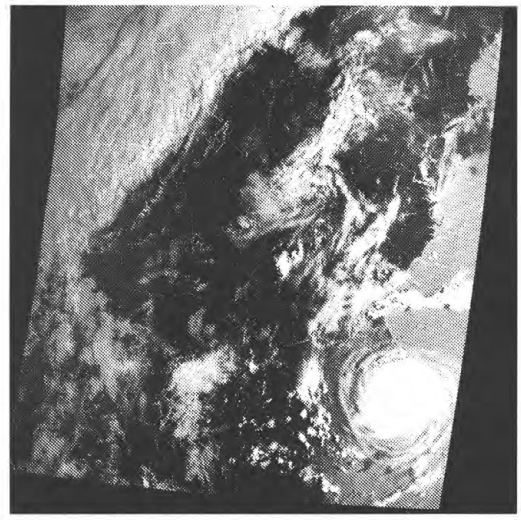
Generalized location map. Numbers 1 through 8 refer to reproductions of color images that were produced from NOAA satellite AVHRR data showing the track of Hurricane Andrew as it swept across the Gulf.



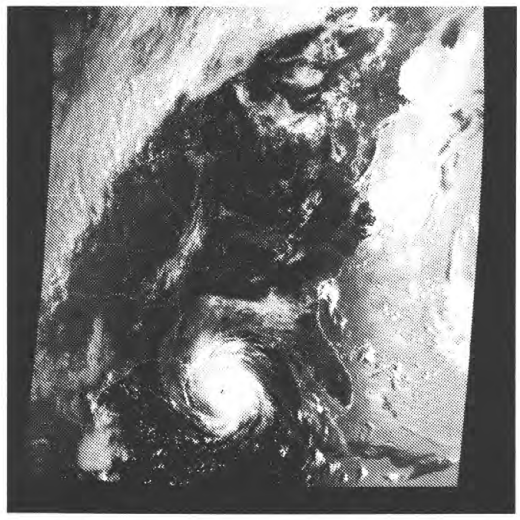
1 August 22, 1992, 8:53 a.m. e.s.t.



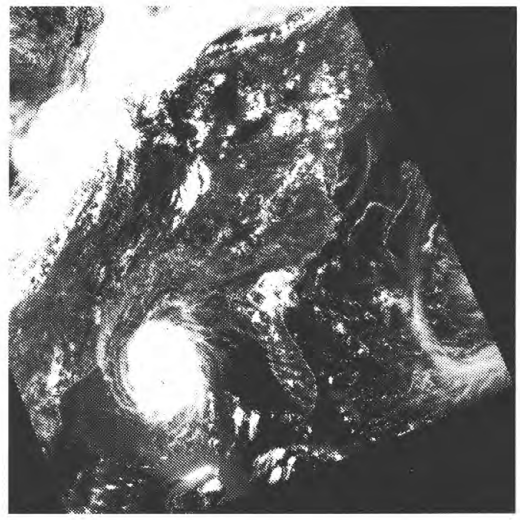
3 August 23, 1992, 4:53 p.m. e.s.t.



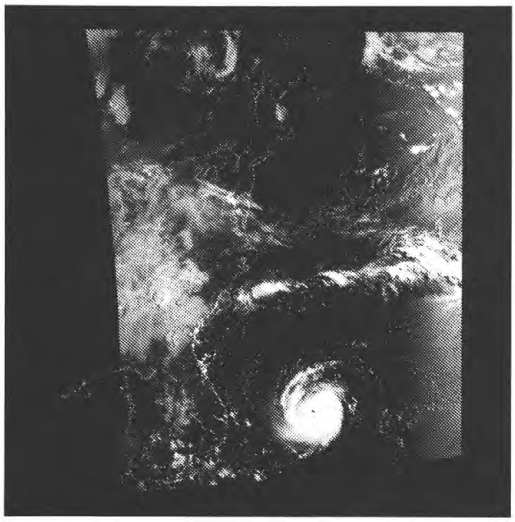
4 August 24, 1992, 9:49 a.m. e.s.t.



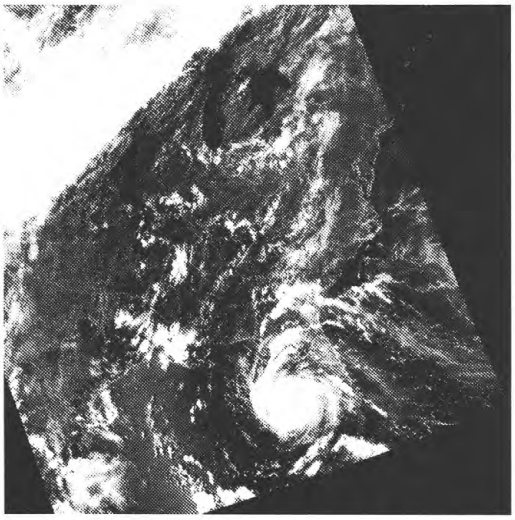
6 August 25, 1992, 9:28 a.m. e.s.t.



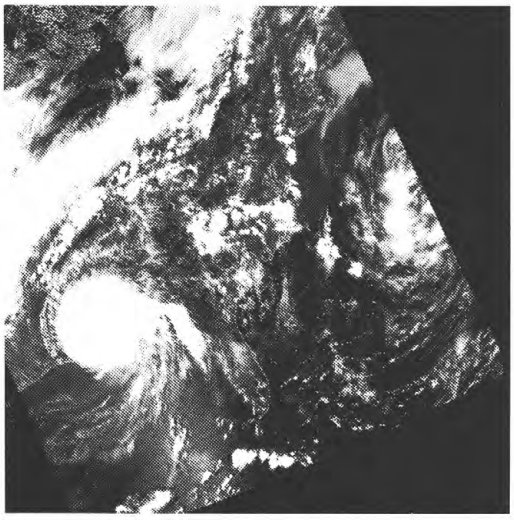
7 August 25, 1992, 4:29 p.m. e.s.t.



2 August 23, 1992, 8:31 a.m. e.s.t.



5 August 24, 1992, 4:41 p.m. e.s.t.



8 August 26, 1992, 4:17 p.m. e.s.t.

U.S. Department of the Interior

STEWARDSHIP after the STORM.....

Stewardship After the Storm

By Trudy P. Harlow

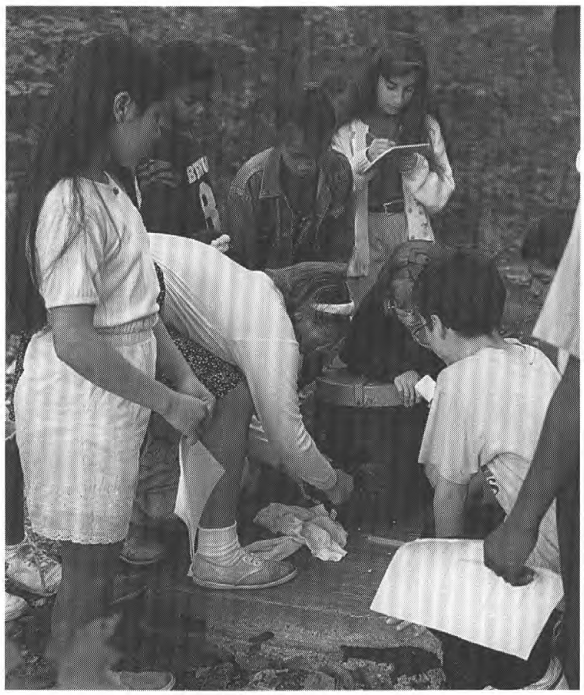
In order to highlight Interior's resource-management and scientific efforts following natural disasters, the USGS, on behalf of the Department of the Interior, produced a newsletter, "Stewardship after the Storm." The newsletter provided information from all of the Interior Department bureaus that have responsibilities in the areas affected by Hurricanes Andrew and Iniki.

In addition to reports on coastal erosion, disruption to water resources monitoring activities in Florida, and emergency map distribution efforts by the USGS, the newsletter told the story of other bureaus' efforts and how their operations were affected. Hurricane Andrew caused extensive damage, for example, to Everglades and Biscayne National Parks, which are located to the west and east of Homestead, the most heavily damaged area. Over half of the 3,852 offshore drilling structures located in the Gulf of Mexico were exposed to the hurricane-force winds, which significantly damaged 166 production platforms and toppled 34. The Minerals Management Service, which is responsible for regulating the Nation's offshore drilling, swiftly moved in response teams to contain damage to offshore rigs and wells. National wildlife refuges survived Hurricane Andrew with only minor damage. As a result of Hurricane Andrew, the U.S. Fish and Wildlife Service is developing proposals to monitor hurricane damage to local wildlife species.

The resource and scientific information highlighted in the newsletter's two issues helped to evaluate the damage to Federal public resources and to provide scientific assessments of the impacts of these natural disasters that will guide immediate and long-range management decisions at Federal, State, and local levels.

Department of the Interior employees were at the forefront of many relief efforts. They were among the first to volunteer by coming forward with donations and offers of assistance, giving special meaning to the expression, "The Interior Family."

PEOPLE AND PROGRAMS



MISSION

As the Nation's largest earth science research and information agency, the USGS maintains a long tradition of providing "Earth Science in the Public Service."

The USGS, a bureau of the U.S. Department of the Interior, was established to provide a permanent Federal agency to conduct the systematic and scientific "classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain."

As a Nation we face serious questions concerning our global environment. How can we ensure an adequate supply of critical water, energy, and mineral resources in the future? In what ways are we irreversibly altering our natural environment when we use these resources? How has the global environment changed over geologic time, and what can the past tell us about the future? Will we have adequate supplies of quality water available for national needs? How can we predict, prevent, and mitigate the effects of natural hazards?

Collecting, analyzing, and disseminating the scientific information needed to answer these questions are the primary mission of the USGS. This information is provided to the public in many forms, such as reports, maps, and data bases, that provide descriptions and analyses of the water, energy, and mineral resources, the land surface, the underlying geologic structure, and the dynamic processes of the Earth.

from more than 3,000 authorized commercial map dealers nationwide.

Water Resources Division

The headquarters office of the Water Resources Division is located in Reston, Va. The Chief Hydrologist, the Associate Chief Hydrologist, and five Assistant Chief Hydrologists are responsible for the overall direction of the Division. National water-research programs are developed at Division headquarters under the direction of the Assistant Chief Hydrologist for Research and External Coordination.

General direction of the Division's field programs is conducted through four Regional Hydrologists, located in Reston, Va.; Norcross, Ga.; Denver, Colo.; and Menlo Park, Calif. Forty-eight District Offices conduct the water-resources investigations and data-collection programs of the Division in all 50 States, Puerto Rico, the Virgin Islands, and the Territory of Guam.

National Water-Quality Assessment.—The National Water-Quality Assessment (NAWQA) program seeks to provide nationally consistent descriptions of current water-quality conditions and trends for a large, representative part of the Nation's streams and ground-water resources and to provide explanations of the major natural and human factors influencing water quality. Information from the assessment is being used to monitor, manage, and regulate water resources. In fiscal year 1992, 20 study unit investigations developed assessment plans, began analyzing available water-quality information, and conducted reconnaissance-level field studies.

National Water Summary.—The National Water Summary program provides water information on a State-by-State and national basis to aid policymakers in the analysis and development of water policies, legislation, and management actions. Changing patterns in availability, quantity, quality, and use of water resources are summarized for use by government officials, natural-resources managers, and the public.

The principal products of the program are National Water Summary reports that describe hydrologic events and water conditions for individual water years and provide a State-by-State overview of specific water-related issues. In fiscal year 1992, the 1988–89 report on floods and droughts (Water-Supply Paper 2375) was distributed.

Hazardous Waste Hydrology.—The USGS conducts research and investigations into the disposal of hazardous chemical and radioactive wastes. This information is useful in alleviating the effects of waste on the Nation's water resources. The USGS evaluates the existing and potential effects on water resources of hazardous-waste disposal and provides baseline data on the chemical contamination of surface and ground water to assist the Department of Energy in developing procedures and guidelines for identifying suitable waste-disposal sites.

Radioactive-waste studies are conducted in the Nuclear Waste Hydrology program, the principal emphasis of which is a better understanding of radionuclide transport in ground-water systems.

Nonradioactive wastes are the focus of the Toxic Substances Hydrology program, which provides data to mitigate existing and potential contamination problems.

Regional Aquifer-System Analysis.—The Regional Aquifer-System Analysis (RASA) program is a systematic study of a number of regional ground-water systems that represent a significant part of the Nation's water supply. The program includes assessment of discharge-recharge dynamics, hydrogeologic and chemical controls governing response of aquifer systems to stress, and development of computer simulation models. As of fiscal year 1992, more than 800 RASA reports and maps have been produced.

Acid Rain.—The USGS provides information needed to improve the scientific understanding of the occurrence and effects of acid rain, so that judgments can be made about effective measures for controlling or alleviating the problem. Components of the acid rain research and monitoring program include determination of the effects of acid deposition on lakes, streams, aquifers, and building stones and operation of the National Trends Network for monitoring precipitation chemistry. The program is coordinated through the Interagency Task Force on Acid Precipitation. In fiscal year 1991, program objectives were revised to emphasize evaluation of the effectiveness of the Clean Air Act Amendments of 1990.

Hydrologic Data Collection.—The Hydrologic Data-Collection program provides information on the quantity, quality, location, and use of the Nation's surface and ground water to support the needs of Federal, State, and local governments. Data-collection stations are maintained at selected locations to provide records on streamflow, reservoir and lake storage, ground-water levels, and the quality of surface and ground water. These data form an information base that supports national and regional assessments of water resources. In fiscal year 1992, the USGS operated more than 7,300 continuous streamflow stations; collected stage and (or) discharge data at about 5,200 other stream, lake, and reservoir sites; determined ground-water levels in about 31,000 wells; and collected water-

USGS Programs

Scientific programs are administered through the Geologic, Water Resources, and National Mapping Divisions and supported by the Information Systems and Administrative Divisions. The National Center of the USGS is located in Reston, Va., near Washington, D.C. Research and investigations are carried out through an extensive organization of regional and field offices located throughout the 50 States, Puerto Rico, the Virgin Islands, and the Territory of Guam.

National Mapping Division

The headquarters office of the National Mapping Division is located in Reston, Va., and is composed of five primary organizational units: Program, Budget and Administration; Coordination and Requirements; Production Operations; Research; and Information Services. Four mapping centers (Reston, Va.; Rolla, Mo.; Denver, Colo.; and Menlo Park, Calif.) and the EROS (Earth Resources Observation Systems) Data Center (Sioux Falls, S. Dak.) perform operational mapping, remote sensing, printing, product distribution, and data dissemination activities.

Mapping Coordination.—The USGS annually coordinates requirements for maps and digital cartographic data of Federal agencies under authority of Office of Management and Budget (OMB) Circular A–16. In October 1990, OMB revised Circular A–16 to broaden the scope of Federal spatial data activities to be coordinated. Under the new circular, the USGS also coordinates requirements of State and local agencies for maps and map-related products. In the area of digital cartography, the USGS chairs both the Interior Geographic Data Committee (a departmental committee) and the Federal Geographic Data Committee (a multiagency committee) established under the new Circular A–16. The USGS provides leadership in the use of spatial data and in the development of digital data exchange standards. The USGS also provides staff support to the U.S. Board on Geographic Names, an interdepartmental board that determines the choice, form, spelling, and application of official geographic place names for Federal use.

Map and Digital Data Production.—The USGS prepares base maps, image map products, digital cartographic and geographic data, and selected thematic maps of the Nation that are used extensively for land planning, land and resource management, and recreation purposes. Of rapidly increasing importance is the production of digital geographic data in various electronic media. Reproductions of aerial photographs and satellite images also are available. Digital data are available from the National Digital Cartographic Data Base as digital line graphs or digital elevation models.

Primary topographic maps, including 7.5-minute maps mostly at 1:24,000 scale for all areas of the lower 49 States and 15-minute maps of Alaska at 1:63,360 scale, are especially useful where detailed information is needed for all types of land and resource management. These detailed maps are periodically inspected and revised to maintain data currentness.

Also available are smaller scale topographic maps, such as the intermediate-scale maps prepared at 1:100,000 scale and the 1:250,000-scale map series. These map series are widely used by Federal and State agencies and the private sector for preparing their own special-purpose maps and depicting their unique data. Other maps available include 1:500,000-scale State base maps and smaller scale U.S. base maps.

The land use and land cover maps, primarily at a scale of 1:250,000 and of 1:100,000 for selected areas, provide the only systematic nationwide inventory of land use and land cover data. The USGS also prepares special-purpose map products, such as orthophotoquads, small-scale image maps, U.S. National Park maps, and thematic maps.

Research and Technology.—The USGS has pioneered investigations that have led to significant developments and changes in surveying and mapping. Mapping research activities, which are centered primarily on the geographic and cartographic disciplines, currently emphasize spatial data analysis, applications of remote sensing and geographic information systems, and advanced techniques for producing digital cartographic data.

The Division has embarked on a major research and development plan to move from manual to digital production and revision of map products. The goals of the map modernization effort are to implement the advanced cartographic systems and procedures required to automate map production and to provide digital cartographic data required by Federal and State agencies for computer-based analysis of spatial data.

Information Services.—The USGS disseminates much of the Nation's earth science information through its Earth Science Information Centers (ESIC), 64 State ESIC-affiliated offices, the Tennessee Valley Authority, and the Library of Congress. Information about products is provided in many forms ranging from maps and books to computer-readable magnetic tapes and compact discs. About 130,000 different maps, books, and reports and about 9.5 million aerial and space images are available for purchase. USGS maps are also available

quality data from about 3,700 surface-water and 7,700 ground-water sites.

Federal-State Cooperative Program.—The Federal-State Cooperative program, which constitutes more than 40 percent of overall Division activity, is a partnership for water-resources investigations involving 50–50 cost sharing between the USGS and more than 1,000 State or local government agencies. One of the program's unique characteristics is that the USGS conducts most of the work on behalf of the cooperators. Hydrologic data-collection activities as well as water-resources investigations and research are included in the program. In fiscal year 1992, water issues of highest priority included ground-water quality; water supply and demand; stream quality; wetlands, lakes, and estuaries; hydrologic hazards; hydrology of global climate change; nonpoint source pollution; and hydrologic data collection.

National Research Program.—Basic research in the Water Resources Division focuses on increasing understanding of the fundamental hydrologic processes of the Nation's ground- and surface-water systems. Knowledge and techniques derived from these efforts are directed at solving current problems and anticipating future problems. Research studies are concentrated in surface-water hydrology and chemistry, ground-water hydrology and chemistry, sediment transport and geomorphology, and ecology.

State Research Institutes.—The State Water Resources Research Institutes program, the costs for which are shared by Federal and State governments, supports 54 Water Research Institutes at land-grant colleges or universities in the 50 States, the District of Columbia, Puerto Rico, the Virgin Islands, and Guam. Research projects at the institutes are conducted in all water-related fields including engineering and the physical, biological, and social sciences.

Research Grants.—The Water Resources Research Grants program supports research as defined in the Water Resources Research Act of 1984. Competitive grants are awarded on a dollar-for-dollar matching basis to qualified educational institutions, foundations, private firms, individuals, or agencies of local or State governments. Research is supported on water-resources-related problems of national interest.

Water Data Activities Coordination.—The Office of Water Data Coordination is responsible for providing governmentwide leadership to coordinate water-information activities as required by the OMB memorandum No. M–92–01, which established the Water Information Coordination program (WICP). The goal of the WICP, administered by the USGS, is to establish and maintain an active partnership among Federal, State, and local agencies and the private sector to meet the Nation's water-resources information requirements effectively and economically (see article, p. 51).

Geologic Division

The headquarters office of the Geologic Division is located in Reston, Va., and consists of the Office of the Chief Geologist and six subordinate offices: Earthquakes, Volcanoes, and Engineering; Regional Geology; Mineral Resources; Energy and Marine Geology; International Geology; and Scientific Publications. Assistant Chief Geologists in the Eastern, Central, and Western Regions act for the Chief Geologist in carrying out general objectives, policies, and procedures for the Division. Project operations are conducted by personnel located principally in regional centers at Reston, Va.; Denver, Colo.; and Menlo Park, Calif.; at field offices in Flagstaff and Tucson, Ariz.; Anchorage, Alaska; Woods Hole, Mass.; Hawaii National Park, Hawaii; Pasadena, Calif.; Albuquerque, N. Mex.; Reno, Nev.; Seattle, Spokane, and Vancouver, Wash.; and San Juan, P.R.; and at the Center for Coastal and Regional Marine Studies in St. Petersburg, Fla.

Geologic Hazards Surveys.—The Earthquake Hazards Reduction Program is a national research effort conducted to reduce hazards and risks from future earthquakes in the United States. Specific tasks include evaluation of earthquake potential for seismically active areas of the United States and operation of global seismic networks. Specific regions of emphasis include the central United States, Pacific Northwest, Alaska, and California. In fiscal year 1992, the Earthquake Hazards Reduction Program provided support to several dozen scientists studying the Landers and Big Bear earthquakes, the largest earthquakes to hit California in the past several decades; the ramifications of those earthquakes in the near future are being studied.

The Volcano Hazards Program conducts research on volcanic processes to help reduce the loss of life, property, and natural resources that can result from volcanic eruptions and related hydrologic events. The Hawaiian Volcano Observatory on the Island of Hawaii, the Cascades Volcano Observatory in Vancouver, Wash., and the Alaska Volcano Observatory in Anchorage are the program's principal field research centers. Volcano eruptions in Alaska during fiscal year 1992 were predicted in advance, and appropriate alerts were provided to private, State, military, and other Federal agencies. Ongoing monitoring of Mt. Pinatubo by USGS and Philippine

scientists has helped save thousands of lives and prevent major equipment losses.

The Landslide Hazards Program emphasizes field and laboratory research on the earth processes that result in ground failures such as landslides, mudflows, subsidence, liquefaction, and debris flows. A study of landslides in Hawaii, nearing completion in fiscal year 1992, will help the State of Hawaii to design mitigative techniques to reduce the risk from future slides. The USGS also helped to assess the immediate landslide threat from the Oakland Hills wildfire in California.

Geologic Framework and Processes.—The National Geologic Mapping Program conducts basic geologic research to acquire fundamental data on the Nation's geologic structure and the environmental and dynamic processes that have shaped it. Geologic mapping, geophysical research on the properties of Earth materials, age determinations of rocks, and modernization of mapping techniques through the development of digital geologic cartographic techniques are the main components of the program. Geologic maps provide the data required to address many societal and environmental issues, such as water-quality and toxic-waste issues; earthquake, volcano, and landslide hazards; and potential ground-water contamination by agrichemicals. The National Geologic Mapping Act of 1992 authorizes a program that includes not only the research described above but also geologic mapping conducted by State geological surveys. Under the enacted legislation, the USGS is responsible for managing and coordinating all components of the National Geologic Mapping Program. Plans for implementing the national cooperative program were developed during 1992 (see article, p. 66).

The Deep Continental Studies Program conducts research to obtain information on the composition, structure, formation, and evolution of the middle and lower crust and upper mantle of the Earth and on how dynamics of the deeper crust affect life at the surface.

The Geomagnetism Program measures and interprets changes in the strength and direction of the Earth's magnetic field. Eleven global geomagnetic observatories provide data for continually updating navigational charts and maps produced by Federal agencies for use by Federal, military, and industrial entities. Efforts were expanded in fiscal year 1992 to integrate a global network of stations for monitoring geomagnetism in realtime.

The Coastal and Wetlands Program conducts research on the geologic processes involved in coastal issues, such as coastal erosion, wetland loss, and pollution. Information from the program is used by land use managers to make decisions on multiple use of coastal lands. The Southern Lake Michigan Coastal Erosion Study was completed in fiscal year 1992 (see article, p. 55).

Global Change Research.—The Global Change and Climate History Program conducts research on the natural variability of past climate, including the mechanisms and rates of past change, and on the impacts of global change on ecosystems and lands in support of the U.S. Global Change Research Program, in which all USGS divisions participate. Major field operations completed in fiscal year 1992 are designed to obtain long records of past global change in northern and central California, along the California coast, and in the Arctic off the North Slope of Alaska.

Offshore Surveys.—The Offshore Geologic Framework Program conducts scientific investigations to understand geologic and geophysical characteristics of the continental margins, adjacent slope and deep-ocean areas, and the U.S. Exclusive Economic Zone. Results of these studies and analysis of new information are essential for energy and mineral-resource evaluation and assessment. During fiscal year 1992, researchers created a model of how the Mississippi Fan off Louisiana and the Monterey Fan off California evolved, which will aid in understanding the distribution of oil and gas reservoir rocks.

Mineral-Resource Surveys.—The National Mineral Resource Assessment Program conducts research to identify and delineate tracts of land that have potential for the occurrence of undiscovered mineral resources and to estimate the probable amounts of these resources. It provides useful, timely, and credible mineral-resource information and assessments for planning and managing the use of the Nation's lands and resources. Recent developments include a quantitative assessment of mineral resources in the East Mojave National Scenic Area, California (estimated gross-in-place value of metallic resources is $6.2 billion) and preliminary mineral-resource assessments of the following areas: West Mojave Management Area and San Bernardino National Forest, California; Butte and Dillon quadrangles, Idaho and Montana; Coronado National Forest, Arizona; International Falls 1:250,000 quadrangle, Minnesota; and West Virginia.

The Strategic and Critical Minerals Program provides a continuing, accurate analysis of global mineral resources and a network for dissemination of comprehensive information on minerals that are essential to a strong national economy and security. In fiscal year 1992, the program (1) completed a mineral-resource assessment of the Guayana Shield in Venezuela and trained Venezuelan scientists; (2) installed or expanded the USGS Mineral Resources Data System (MRDS) data base in

13 Latin American countries and increased the total number of MRDS records worldwide to more than 91,000; and (3) published, with the U.S. Bureau of Mines, a report on the resources and future production of phosphate rock in the United States.

The Development of Assessment Techniques Program is continually developing new tools that can identify undiscovered mineral deposits. Recent developments include (1) a backpack-transportable electrical-geochemical method to move indicator elements out of the earth to collection electrodes, where they can be analyzed by chemical means; (2) an airborne remote-sensing procedure that allows remote mapping of variations in rock composition of some geologic units, which indirectly can be used to define potentially mineralized areas; and (3) regional studies that reveal the importance of geologic shear and fault zones for the localization of gold deposits in the Southeastern United States.

Energy Surveys.—The Evolution of Sedimentary Basins Program conducts multidisciplinary research to define the evolution of and the energy and mineral commodities located in sedimentary basins in the United States. In fiscal year 1992, construction of the National Ice Core Repository was begun with funding from the National Science Foundation (NSF) to the Institute of Arctic and Alpine Research of the University of Colorado. This repository, located at the USGS Central Region Headquarters in Denver, Colo., will be used to store ice cores acquired by NSF's Division of Polar Programs and by the USGS Global Change and Climate History Program; the repository is a joint effort of the USGS, NSF, and the University of Colorado.

The Coal Investigations Program conducts geologic, geophysical, and geochemical research to develop scientifically based assessments of the quality, quantity, and availability of the Nation's coal resources. During fiscal year 1992, coal availability studies were completed on six quadrangles—two in the central Appalachians, three in the northern Appalachians, and one in the Illinois Basin—covering a total of about 350 square miles (900 square kilometers).

The Oil and Gas Investigations Program conducts petroleum and natural gas research to provide reliable assessments of the oil and gas resources of the Nation that are critical to the development and implementation of national energy policies and strategies. Fiscal year 1992 saw the initiation of a new assessment of the Nation's oil and gas resources (see article, p. 61).

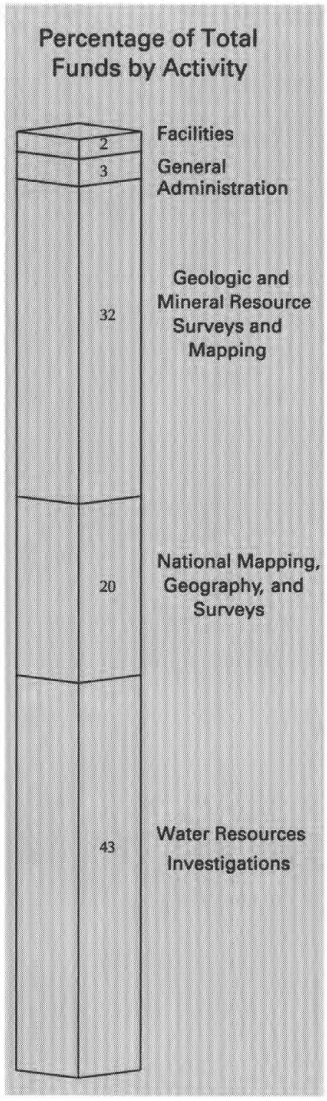
The Oil Shale Investigations Program conducts research to assess the Nation's oil shale resources, including investigation of the structure and chemistry of oil shale deposits and identification of oil-shale deposits suitable for exploitation under current environmental and technological constraints. More than 22,000 feet (6,700 meters) of oil-shale core was processed for permanent archival at the USGS Core Research Center during fiscal year 1992. This work, performed in cooperation with the Department of Energy, will lead to preservation of a world-class collection of oil-shale cores that will be available for future research on oil-shale deposits.

The Uranium and Radon Investigations Program conducts basic research to determine the nature and distribution of uranium and thorium resources and byproducts, such as radon, that may be health hazards. Through continuing cooperative agreements between the USGS, the Department of Energy, and the Environmental Protection Agency, scientists are investigating the sources and geological conditions that control the distribution of radon gas. Techniques developed by the USGS through these cooperative studies have been applied in indoor radon assessments; USGS-developed methodologies are being adopted by other Federal and State agencies.

The Geothermal Investigations Program conducts basic research to determine the nature, distribution, and potential of the Nation's geothermal resources. In fiscal year 1992, program scientists worked closely with private industry, the National Park Service, and the Department of Energy to define the geothermal resources associated with national parks in Hawaii, Alaska, California, and Wyoming and to assess the potential impact on these resources by development adjacent to the parks.

Steam rising from Roaring Mountain in Yellowstone National Park, Wyo., hints at the geothermal energy resources of the area.

JOHN R. KEITH



The World Energy Resources Assessment Program provides information on worldwide energy resources (principally oil and gas) for use by other agencies in the development of national-energy, international-trade, and foreign policies. During fiscal year 1992, researchers completed a study of the oil and gas resources of Southeast Asia.

International Activities

The USGS has conducted earth science studies in foreign countries for nearly 50 years. Authorization is provided under the Organic Act, as revised, and the Foreign Assistance Act and related legislation when such studies are deemed by the U.S. Departments of the Interior and State to be in the interest of the U.S. Government.

Current international program efforts focus on technical-assistance programs in developing countries and scientific cooperation and research through agreements with other countries as an extension and enhancement of USGS domestic programs. Cooperative research activities range from informal communications among scientists, through formal, jointly staffed projects, to multinationally staffed coordinated programs focused on particular problems or topics.

Related activities that are integral to the international programs include institutional development, exchange of scientists, training of foreign nationals, and representation of the USGS or the U.S. Government in international organizations and at international conferences and meetings.

In fiscal year 1992, a comprehensive study of the mineral resources of the Altiplano of Bolivia was completed and published (see article, p. 86).

Information Systems Division

The Information Systems Division headquarters office is in Reston, Va. The Division is composed of five offices: Assistant Director, Computer and Communications Services, Customer Services, Field Services, and Management Services. Service centers in Reston, Va.; Menlo Park, Calif.; Denver, Colo.; and Flagstaff, Ariz., provide a complete range of services to users.

The Assistant Director for Information Systems is the Division Chief and chairs the USGS Information Systems Council, which recommends technology-related policies to the Director, coordinates computer science research and technology, and provides guidelines for USGS information management programs.

Significant accomplishments in information systems management in fiscal year 1992 included evaluation of a commercial mass storage software system as part of expanded mainframe services. In the area of electronic mail systems, numerous mail systems were linked together, and now over 8,000 addresses are maintained on the bureauwide system. Other activities included upgrading network access to the mainframe computer and automation of general-purpose computer data center operations, such as job scheduling and reports distribution.

Administrative Division

The headquarters office of the Administrative Division is located in Reston, Va. The Assistant Director for Administration is the Division Chief. Under his leadership, the Division provides administrative direction and coordination to support the scientific and technical programs of the USGS.

The Division is composed of five headquarters offices: Financial Management and Systems Management are centralized headquarters functions. Facilities and Management Services, Personnel, and Procurement and Contracts provide operational support at headquarters and at USGS field units through Regional Management Offices in Denver, Colo., and Menlo Park, Calif.

The Division also manages the development, maintenance, and operation of the financial management system for the entire U.S. Department of the Interior through a sixth component, the Washington Administrative Service Center. As of fiscal year 1992, 7 of the 10 DOI bureaus are now using the Federal Financial System (see article, p. 102).

In building on its success with the Federal Financial System for DOI, the USGS is leading the effort to acquire and implement a standard procurement system for the Department.

Cooperative Agreements Initiated in Fiscal Year 1992

Counterpart Organization(s)	Description
U.S. Environmental Protection Agency	Cooperation on the implementation of the National Water-Quality Assessment Program as it concerns pesticide-related water-quality issues.
National Geographic Society	Coordination of water resource research activities. (See below.)
Defense Mapping Agency	Sale of Defense Mapping Agency standard digital and topographic products by the USGS to the general public.
Bureau of Land Management National Park Service U.S. Forest Service, Department of Agriculture	Management of fossils on public lands.
National Center for Health Statistics	Collaboration in support of research, data collection, and joint studies to integrate data and information to help reveal relations between human health and earth science factors.
U.S. Environmental Protection Agency	Cooperation in the conduct of water-quality monitoring and assessment activities.
U.S. Forest Service, Department of Agriculture	Coordination of the production, exchange, and dissemination of cartographic products and services.
Woods Hole Research Center Woods Hole Oceanographic Institution	Cooperative research in the use of remote sensing technology for assessment of global change.
Office of Medical Services, Department of State	Provide medical services to USGS employees who travel overseas on official temporary duty.
Pacific Gas and Electric Company San Francisco, California	Cooperative research and development agreement to demonstrate a prototype broadcast earthquake information service in the San Francisco Bay region.
Washington State University Pullman, Washington	Cooperation in sharing facilities on the Pullman campus.
Soil Conservation Service U.S. Forest Service Agricultural Research Service	Establishment of the Cooperative Interagency Terrestrial Ecosystem Regional Research and Analysis (TERRA) laboratory in Colorado.
Haskell Indian Junior College Lawrence, Kansas	Support recruitment, training, and employment of Native Americans into the earth science career areas.
Bureau of Indian Affairs	Indian water rights claims.

Budget

Cooperative agreements with more than 1,000 Federal, State, and local agencies and the academic community support a large share of research and investigations. In fiscal year 1992, the USGS had obligational authority for $852 million, $586.7 million of which came from direct appropriations, $7.6 million from estimated receipts from map sales, and $257.7 million from reimbursements. The USGS was reimbursed for work performed for other Federal, State, and local agencies whose needs for earth science expertise complement USGS program objectives. Work for State, county, and municipal agencies is most often conducted on a cost-sharing basis (see p. 109).

USGS Signs Water Agreement with National Geographic Society

In June 1992, the National Geographic Society and the USGS launched a collaborative effort to increase public understanding of the Nation's freshwater resources. The multiyear project will encompass a variety of activities including collaborating on scientific research and translating results of that research into outreach and educational products. Some of the projects that are underway are teacher workshops, instruction kits, and jointly written scientific reports.

Open House—Earth Science Takes You Everywhere

Real-Live Lessons in Earth Science

By Kathryn D. Gunderson and Wendy R. Hassibe

In its continuing effort to reach out to the public with a series of events to better acquaint people with the USGS, the National Center in Reston, Va., was the site for the 1992 Open House. More than 400 USGS employees were involved in the planning and hosting of this successful outreach to the local community.

Visitors to the Saturday, April 25, 1992, Open House got a live-action lesson in realtime geology when a magnitude 6.9 earthquake in northern California registered on a seismograph as they looked on. A USGS employee and Reston resident had just begun demonstrating how the seismograph operates when the seisomograph needle began to move, recording the earthquake that occurred about 35 miles (56 kilometers) south of Eureka, Calif.

The real-live earthquake was an unexpected addition to the more than 85 exhibits, presentations, and demonstrations that highlighted the theme of the Open House, "Earth Science Takes You Everywhere."

More than 12,000 visitors made their way through the exhibits and had a chance to interact one-on-one with dozens of USGS scientists. The Earth Science Information Center was open throughout the Open House, affording visitors a chance to purchase USGS maps and book reports. The Hands-On Room, adjacent to the Visitors Center, was inaugurated during the Open House and was a beehive of activity with children using the interactive video display to learn about volcanoes and plate tectonics and donning hip-waders to stand in the portable water flume and measure streamflow, just like a real hydrologist. A special tent was set aside for an activity made popular at previous open houses—Ask the Scientist—where USGS scientists were available to answer questions about the earth sciences and to identify rocks. Particularly popular with the children, this activity also allowed adults to try to "stump" the scientists. Children also had a chance to learn to be rock detectives and solve various mysteries about rocks and minerals.

Gold panning, dinosaur tracks (and a special exhibit on what dinosaurs ate), the deepest lake in the world, the mystery of vanishing barrier islands, and the stories that tree rings tell were all features of the third Open House that has been held in Reston. The Western Region headquarters in Menlo Park, Calif., has hosted three open houses as well, the last in 1991. The Central Region headquarters in Denver, Colo., will host its first open house in May 1993. The USGS has developed a rotational schedule for open houses. Menlo Park will again hold an open house in 1994 and the National Center in 1995.

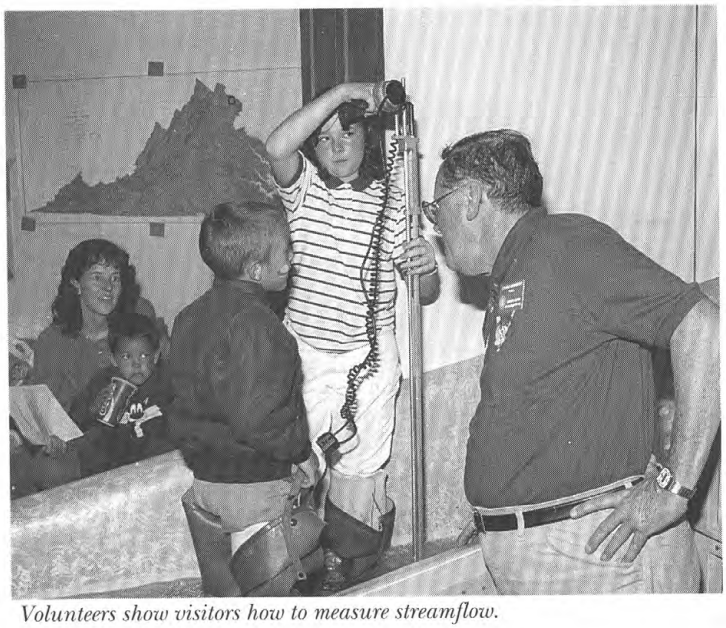
These open house events provide a fun opportunity for people to learn more about the earth sciences and for USGS employees to tell visitors about what they do and how it affects daily life. As Director Dallas Peck said, "the Open House is an opportunity for the local community to come and spend some time with us, learn a little more about the earth sciences, and get a first-hand look at some of our exciting and important scientific research and investigations."

Visitors start their adventure.

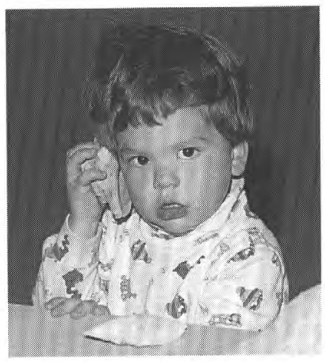
Breaking News—earthquake registers under watchful eyes.

The latest technology assists in the earth sciences.

Acid rain can dissolve building stones.

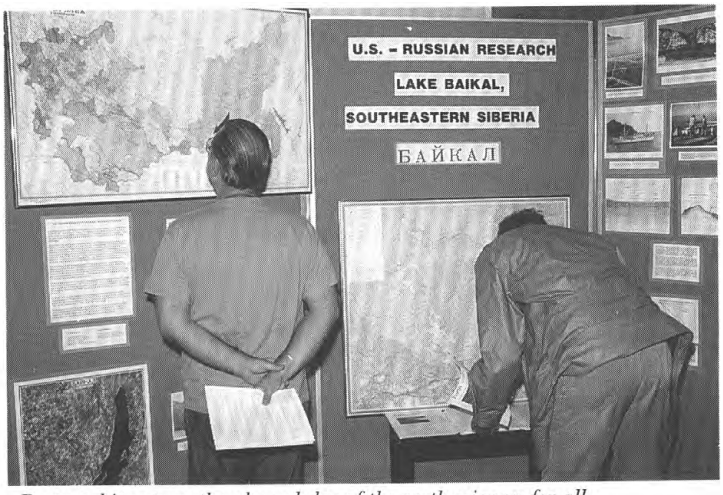


Volunteers show visitors how to measure streamflow.



Curiosity about the earth sciences has no age limits.

Everyday items are made from minerals.

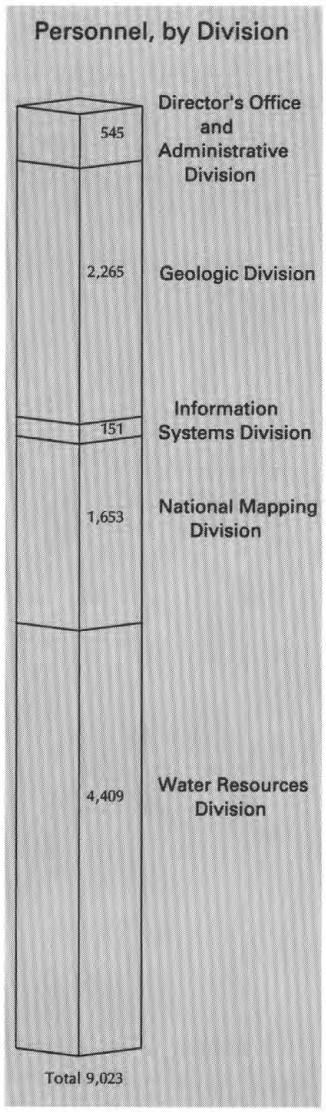


Partnerships strengthen knowledge of the earth sciences for all.

Posters, maps, and first-hand advice are available to visitors.

Gold fever strikes again.

Sediment cores show what's under our feet.



People

At the end of fiscal year 1992, the USGS had 9,023 permanent full-time employees. The diversified earth science research programs and services of the bureau are reflected in the workforce, about half of which possess a bachelor's or higher level degree.

Permanent employees are supported by the 2,036 other-than-full-time permanent employees, including many university students and faculty members. This relation with the academic community has made the expertise of many eminent scientists available to the USGS. Students have proved valuable during times of increased workload, especially during the field season. Academic institutions have provided a means of recruiting qualified young professionals for permanent full-time positions upon completion of their studies. The USGS has several innovative programs that provide opportunities for graduate students. Other programs promote interest in the earth sciences at historically black colleges and universities, at Hispanic-serving institutions, and at colleges with Native American students.

Outreach and Information Dissemination

In its continuing commitment to meet the earth science needs of the Nation, the USGS collects, analyzes, interprets, publishes, and disseminates earth science information. The results of USGS investigations are published in scientific reports and in topographic, geologic, and hydrologic maps. About 150,000 different maps, books, and reports are available for purchase. A series of general-interest publications is available to inform the public about USGS activities. Research results and investigations are also published in journals of technical and scientific organizations and in publications of cooperating Federal and State agencies. News releases, realtime information on earthquakes in the United States and around the world, and news conferences on reports and events of current interest are other important means by which the USGS provides earth science information to the public.

During fiscal year 1992, the USGS produced 1,500 new or revised topographic, geologic, and hydrologic maps, bringing the total number of maps available to 88,500. Of these, more than 7.1 million copies were distributed. The number of reports approved for publication in fiscal year 1992 was 4,571, 73 percent of which were designated for publication in outside professional journals and monographs and the remainder for publication by the USGS.

More than 125,000 copies of technical reports were distributed. Also, 900 new reports were released as open files, making the total more than 30,000 open-file reports available. More than one million copies of general-interest publications were distributed in response to inquiries from the public. Of the approximately 9.9 million aerial and space images available for sale, about 200,000 copies are sold annually.

Adventures in Earth Science—Public Lecture Series

By Mark V. Bonito

The last Thursday of each month has become an important outreach opportunity for the USGS Western Region Center. Since May of 1990, on the 10th anniversary of the eruption of Mount St. Helens, the center in Menlo Park, Calif., has hosted a monthly public lecture series to expand the public's understanding of the diverse mission of the USGS. The inaugural program featured an overview of 10 years of volcano research at Mount St. Helens in Washington.

Scientists who present the talks are encouraged to use nontechnical language to communicate their research accomplishments and share personal experiences of their study of the Earth, its resources, and its complex processes. The informal atmosphere of the public lecture setting allows the public to interact with the scientists as individuals. It also gives the scientists a more relaxed format in which to present their research than the typical professional meetings.

The lecture series has become a popular local event, well advertised in newspapers and on radio and television. Generally, more than 100 people attend the lectures, and attendance is sometimes over 200. Lecture-goers range from professors and schoolteachers to realtors, outdoor enthusiasts, and those who just want to learn more about the earth sciences. The topic of each lecture is featured on large display panels and short video segments at the USGS Earth Science Information Center in Menlo Park, where maps and books are sold. Word-of-mouth enthusiasm has become the best form of advertising, as the series has grown in popularity. The lectures are videotaped and archived in the USGS library.

Topics in the lecture series have ranged from droughts and climate change on Earth to water and the possibility of life on Mars. One popular lecture in 1992 explained how the present topography, climate, and soil in the Napa Valley, which are so conducive to growing wine grapes, are the result of geologic events and processes that began eons ago and continue today. Other topics in 1992 included the challenge of geologic mapping in the last frontier of Alaska; the explosive volcanic eruption of Mount Mazama that created the crater of Crater Lake National Park in southwest Oregon; and a "Journey to the Center of the Earth" on the composition of the Earth's interior and the techniques scientists use to explore it. Sometimes, timing is everything—a planned lecture on volcanology in June 1991 was given to a standing-room-only crowd when Mt. Pinatubo in the Philippines erupted hours before the lecture was scheduled to begin.

The USGS plans to continue its popular lecture series in 1993. These public presentations foster a greater appreciation of the multidisciplinary role of government scientists and of the wide-ranging mission and activities of the USGS. The scientists appreciate the opportunity to share directly with taxpayers the personal rewards and societal benefits of their ongoing adventures in earth science.

Awards and Honors

Each year USGS employees receive awards and honors that range from certificates of excellence and monetary awards to recognition of their achievements by election to membership or office in professional societies.

Presidential Rank

Presidential Rank Awards are presented annually by the Office of Personnel Management on behalf of the President, to career members of the Senior Executive Service, for exceptional service. Presidential Rank Awards, the highest civilian honor awarded to Federal executives, are given at two levels: Distinguished and Meritorious. In 1992, four USGS executives received Meritorious Rank awards:

Peter F. Bermel, for his efforts to balance the demand for USGS information and products with the need to support Federal deficit reduction and to maximize the productivity of the scientific, technical, and administrative staff of the USGS.

Gary W. Hill, for providing exceptional leadership in USGS offshore programs. He set targets and directions that have been critical to the successful development of a national oil and gas assessment, mapping of the U.S. Exclusive Economic Zone, and a new national coastal geology program.

David W. Moody, for developing the National Water Summary (NWS), one of the most successful vehicles in the Nation's history for the dissemination of water-resources information. NWS reports provide a focus for communicating the results of USGS water-resources investigations to those who might benefit from them.

Allen H. Watkins, for providing oversight to the Advanced Cartographic Systems modernization program, including a restructuring of the system development approach. He helped establish the USGS as an international leader in remote sensing and advanced information-systems research, development, and operations.

Distinguished Service

The highest honor given by the Department of the Interior to its employees is the Distinguished Service Award. Symbolized by a gold medal, this award for outstanding achievement was presented to 15 USGS employees in 1992.

Edith B. Chase, for exceptional contributions to scientific programs through excellence in the writing, editing, and design of technical reports.

James F. Daniel, for exceptional contributions to the science of hydrology and to the management of water-resources programs.

John R. Filson, for outstanding leadership of earthquake and seismologic research.

William F. Gossman, Jr., for outstanding contributions in directing facilities and management programs and in administrative management.

Donald E. Hillier, (retired) for exceptional contributions to the production and improvement of water-resources reports.

Edgar A. Imhoff (retired), for numerous accomplishments in water-resources management throughout the United States.

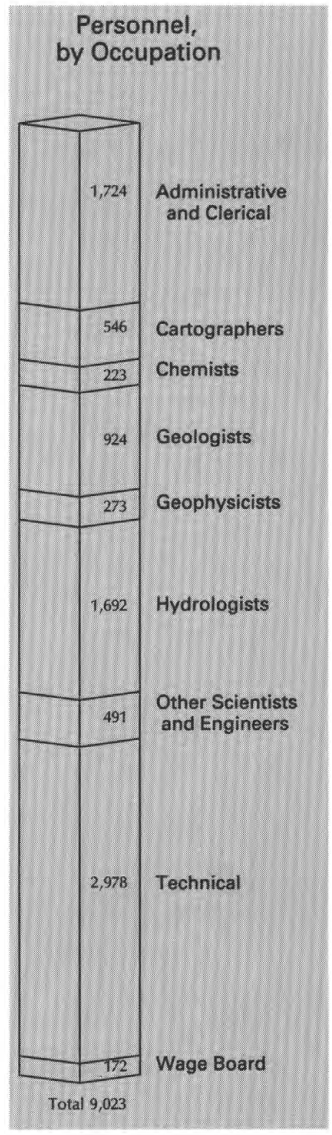
Samuel N. Luoma, for creative research in biochemistry and geochemistry.

Richard F. Mast, for outstanding contributions to petroleum geology and to the administration and leadership of major petroleum research programs within the USGS.

John C. Reed, Jr., in recognition of outstanding contributions to Precambrian geology and leadership of scientific programs of the USGS.

Kathleen B. Rutledge, for outstanding contributions to human-resources management in the USGS.

Verne R. Schneider, for exceptional contributions to the water-science community as a technical program manager, including execu-



tive direction for the USGS National Water-Quality Assessment program.

Ren Jen Sun, for his outstanding career with the USGS, particularly his significant contributions in the field of ground-water hydrology and the understanding of the Nation's regional aquifer system.

Paul K. Theobald, Jr., in recognition of outstanding contributions to exploration geochemistry research, leadership in the international scientific community, and career-long dedication to earth science education.

Edwin W. Tooker, for accomplishments in the field of economic geology and as an administrator of USGS mineral deposits research programs.

Harry A. Tourtelot, for outstanding contributions to geology and for distinguished leadership and administration of geologic programs.

Meritorious Service

The Meritorious Service Award is the second highest award granted by the Department of the Interior and is given for significant contributions to the earth sciences and to management and administration of USGS scientific programs. Recipients in 1992 were

R. Ernest Anderson, Charles A. Appel, Paul R. Beauchemin, Bruce L. Beaudin, John C. Behrendt, Betty B. Brodes, Ernest D. Cobb, Gary D. Cobb, Richard M. Comerford, Tyler B. Coplen II, William P. Dillon, Paul V. Dresler, Harold E. Fiebelman, Bette T. Goodrich, Larry C. Harms, Maxine Chavis Jefferson, Marshall Jennings, Richard D. Krushensky, Lyman Ladner, Donald L. Light, Stuart W. McKenzie, Wanda C. Meeks, Alan Mikuni, William D. Miles, John W. Morgan, C. Wylie Poag, Stephen F. Pousardien, David A. Rickert, Wayne G. Rohde, Lawrence F. Rooney, Hedy J. Rossmeissl, Norman E. Schmidt, Jr., Wayne C. Shanks III, Robert J. Shedlock, Darlene R. Sira, Craig D. Skalet, Michael T. Tobin, Kenneth L. Wahl, William G. Wilber, Helen P. Willingham, Joe R. Willmon, Valentine E. Zadnik.

Superior Service

The Superior Service Award is the third highest award granted by the Department of the Interior and is given for significant acts, services, or achievements that materially aid the accomplishment of the Survey's mission. Recipients in 1992 were

James C. Adams, Don P. Adkins, Ellen P. Antholis, Mark A. Ayers, James H. Barks, Lynda B. Bellisime, Kenneth E. Bencala, Curtis S. Bennett III, Rick D. Benson, William A. Braddock, Maurice G. Brumm, Allan W. Burns, Dorothy I. Burns, Jacqueline Burns, Scott C. Christensen, Timothy S. Collett, Billy E. Colson, Jerold D. Combs, Alan K. Cooper, Robert A. Crovelli, Robert S. Cupp, Kathryn Czernowski, Robert E. Davis, Donald L. Dunn, Mark L. Faye, Lori Ghequiere, Edward J. Gilroy, Kirstie Lea Ginnodo, George D. Glysson, Herman C. Gunter, Richard R. Hansell, Ronald L. Hanson, Sherry A. Hathaway, John S. Havens, Joan E. Helmrich, William J. Herb, David C. Hooper, Rick T. Iwatsubo, Emanuel P. James, F. Paul Kapinos, Stanley W. Kirkendall, Gary W. Kramer, Richard L. Krause, Mark S. Kutsko, Terrance E. Lamb, Kenneth J. Lanfear, Marjorie F. Lanier, Melinda M. Lanza, Michael P. Lee, Ronald Lofton, Derek R. Lovley, Harold C. Mattraw, Jr., James B. McConnell, Norwood B. Melcher, Beverly A. Mercilliott, Timothy L. Miller, Joan G. Nadeau, Charles D. Nethaway, Wendy E. Norton, David A. Page, Bruce Parks, Glenn C. Patterson, Richard A. Pearsall, John D. Peper, Kathy D. Peter, Carol E. Peters, James G. Peters, Margaret B. Pillera, J. Elton Porter, Jeanice I. Powell, Gerald T. Pruett, LeRoy C. Rauschenbach, Joseph F. Rinella, Gilpin R. Robinson, Jr., Curtis L. Sanders, Jr., William E. Schinkel, James C. Schornick, Jr., Jonathon C. Scott, Allen M. Shapiro, James O. Shearman, Nancy Jean Short, John Skelton, Judell C. Spoering, Geraldine R. Stallworth, John K. Stamer, Jo Anne M. Stapleton, Elaine M. Stout, Robert R. Sybert, Jr., Janet T. Thomas, William A. Thomas, W. Jane Timmins, Priscilla G.Utterback, Gary R. Vanderhaven, Larry M. Vandiver, James N. VanDriel, Frank C. Wells, Maurice D. Winner, Jr., Thomas H. Yorke, Jr.

USGS Unit Award for Excellence of Service

The Women's Advisory Committee—Geologic Division—was recognized for its efforts to promote communication with Division management on issues related to the professional development of all women employees, to improve the working environment for women, and to recruit qualified women for positions at all levels. Members of the committee have also worked to identify and implement plans to enhance productivity, improve working conditions, and provide numerous educational programs on women's issues for all employees in the Geologic Division.

The USGS Joint Education Initiative (JEdI) Team was recognized for its spirit,

dedication, expertise, and teamwork in developing the JEdI CD-ROM's (compact disc, read-only memory) with accompanying activities for teachers to use in the classroom—a model for curriculum materials for the 21st century. The JEdI program was developed in cooperation with the National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, numerous educational communities, and the private sector.

National Medal of Science

Eugene M. Shoemaker was presented the National Medal of Science by President Bush, in a ceremony in the Rose Garden of the White House, on June 23, 1992. In presenting the award to Shoemaker, President Bush cited his "pioneering research and inspiring leadership in the geological exploration of the solar system, his entrepreneurial creation and direction of the Branch of Astrogeology of the USGS, and his research on Earth-approaching asteroids and comets and their potential impact effects."

Awards and Honors Received by USGS Employees in 1992

William J. Campbell was awarded the Nansen Polar Bear Award of Norway for outstanding research in remote sensing and polar geophysics (Dec. 5, 1991). Campbell died Nov. 20, 1992.

William F. Cannon was awarded the 1992 Goldrich Medal, presented annually by the Institute on Lake Superior Geology, for excellence in research on the geology of the Lake Superior region.

Edward C.T. Chao received the 1992 Barringer Medal of the Meteoritical Society, in honor of his discovery of high-pressure forms of quartz that are evidence of terrestrial impact craters, and other contributions to the study of meteorite impact craters.

Edward Clifton was granted honorary membership in the Society for Sedimentary Geology, in recognition of his contributions to the society and to the field of sedimentary geology.

Billy E. Colson received the Meritorious Service Award from the Federal Emergency Management Agency (FEMA), in honor of his work in preparing FEMA's report to the U.S. Congress on flood plain management.

James E. Constantz received a patent and a cash award for developing a process for desalinating water and a drip irrigation system that uses solar energy to purify water and distribute it for irrigating crops or recharging ground water.

Eugene M. Shoemaker (right) with former Presidential Science Advisor Allan D. Bromley (left) and President Bush at National Medal of Science awards ceremony in the Rose Garden of the White House. (Photograph by David Valdez, The White House.)

George E. Ericksen received the Medal for Meritorious Service to Mining, from the Government of Bolivia, in recognition of his scientific investigations of Salar de Uyuni and other salt flats in southern Bolivia. Ericksen was also inducted into the Chilean Academy of Sciences in August 1992, in recognition of his contributions to science in Chile.

Robert Fournier was presented the 1991 Bowen Award of the Volcanology, Geochemistry, and Petrology section of the American Geophysical Union for his innovative research on the chemistry of hydrothermal fluids.

Harold J. Gluskoter received the 1992 Gordon H. Wood, Jr., Memorial Award of the Energy Minerals Division of the American Association of Petroleum Geologists, in recognition of his significant contributions to the field of coal geology.

Walter W. Hays received the Annual Leadership Award of the Central United States Earthquake Consortium for his support of earthquake preparedness in the central United States and for his work in promoting earthquake hazard-reduction measures nationwide.

John D. Hem received a special award from the International Association of Geochemistry and Cosmochemistry for his pioneering contributions to developing an understanding of the geochemistry of aluminum, iron, and manganese.

Derek R. Lovley was a Grand Winner in the Best of What's New awards for 1992 by Popular Science magazine, for his research in the field of organic remediation of water-quality problems.

Bernard Malo received the Max Hecht Award of the American Society for Testing and Materials Committee D-19 on Water, for out-

Federal Design Achievement Awards

Federal Design Achievement Awards were presented to the USGS by the National Endowment for the Arts, for a poster-leaflet entitled "Map Projections," and for the prototype of an electronic "science journal" known as the Arctic Data InterActive. Award recipients for the poster-leaflet were Nancy B. Faries, Annette Kulyk, and Gary W. North; for Arctic Data InterActive, Kevin Laurent, Gerry Lebing, and Denise Wiltshire.

On-The-Spot Awards

On-the-Spot awards provide immediate recognition to employees for noteworthy performance and accomplishments that might go unrecognized under normal incentive award procedures. Since the first award was presented Oct. 31, 1991, the USGS has presented 1,205 on-the-spot awards. **Jane Wallace**, received the first On-the-Spot Award for writing an ethics handbook for employees on USGS policies and procedures regarding ethics and outside activities.

standing service in the advancement of water studies.

Colleen C. Maurer was elected 1992–93 president of the American Society for Photogrammetry and Remote Sensing, Northern California Region.

Jill McCarthy received the 1992 World of Today and Tomorrow Award from the Girl Scouts of America. The award is presented annually to an individual or group that increases the skills and awareness of young women in the fields of math, science, engineering, and computers.

Alan M. Mikuni was appointed to the executive committee of the American Society of Civil Engineers, Surveying and Engineering Division.

Joel L. Morrison was awarded an Honorary Fellowship by the International Cartographic Association, in recognition of his outstanding contributions to leadership of the ICA and for his contributions to the science of cartography.

Christopher E. Neuzil received the O.E. Meinzer Award of the Geological Society of America, given for papers judged to have significantly advanced the field of hydrogeology or a related field.

Gary W. North was elected chairman of the Geography and Map Section of the International Federation of Library Associations.

James A. Peterson was awarded the Distinguished Service Award of the American Association of Petroleum Geologists, for his service to the association and to the profession of geology in applying geology to exploration, educating students, and publications.

David J. Roddy received the Interior Department's Award of Excellence for 15 years of accident-free flying.

Robert O. Rye received the Silver Medal of the Society of Economic Geologists, in recognition of his pioneering research in the application of stable isotopes and hydrothermal geochemistry to the understanding of ore-forming processes, fluid-rock interaction, and the geochemistry of hydrothermal ore-forming systems. The Society also chose Rye as their 1992 Distinguished Lecturer.

Holly Stein was the recipient of the first Outstanding Woman Alumna Award from Western Illinois University.

Robert Tilling was elected Vice-President for 1991–95 of the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI). Tilling is the only U.S. member of the IAVCEI Executive Committee.

Donald E. Vaupel received the Peter Homack Award of the American Water Resources Association for outstanding contributions toward multidisciplinary understanding and management of water resources in New Jersey.

Jane Wallace (left) is awarded the Smith College Medal by Mary Maples Dunn, President of Smith College. (Photography by Jim Gipe, copyright 1992, reprinted by permission.)

John Vecchioli received the Keith E. Anderson Award of the Association of Ground Water Scientists and Engineers—a division of the National Water Well Association—for his many years of dedicated service to the association.

Jane Wallace was elected a Fellow of the Geological Society of America. Wallace was also awarded the Smith College Medal for outstanding career achievements.

Stephen M. Wessells received an Emmy from the Television Academy of Arts and Sciences, in the category of student education videos, for "Oceanfloor Legacy: A Critical Juncture."

Donald E. White received a special award from the International Association of Geochemistry and Cosmochemistry for his pioneering contributions to the understanding of water-rock interactions in geothermal and hydrothermal systems.

Brenda Williams received an Interior Department "Point of Light" award for her years of work with the annual Colorado Special Olympics Winter Games and for supervising local Special Olympic Races at ski areas in the State of Colorado.

Paul Woods was presented the Dedicated Public Service Award by the Clark Fork-Pend Oreille Coalition, for his study of nutrient enrichment of Pend Oreille Lake, Idaho.

Sherman S.C. Wu was chosen as the 1992 recipient of the Photogrammetric (Fairchild) Award of the American Society for Photogrammetry and Remote Sensing in honor of his contributions to planetary topographic mapping.

Allen L. Zack was named Engineer of the Year for the USGS, Department of the

Interior, by the National Society of Professional Engineers.

Public Service Recognition

Special awards were presented by the USGS to nine employees in 1992 for their outstanding contributions as public servants. These awards were part of the celebration of Public Service Recognition Week activities, to celebrate the indispensable and diverse contributions of the millions of women and men who make up the public workforce. Those receiving Public Service Recognition Awards were

Gale K. Fullerton, for creative problem solving in providing employee relations support and for the development of excellent training programs and a successful voluntary leave donation program.
Charlotte de S.L. Garvin, for providing strong employee support in processing personnel actions and for ensuring that all personnel records are current.
Barbara J. Gunderson, for performing her work in a most professional and productive manner and for setting high standards for peers and junior support staff.
Doris M. Johnson, for dedication and commitment to excellence in every aspect of her work.
Timothy H. Lee, for designing, implementing, and managing the local area network and for outstanding contributions to the data communications environment of the USGS.
John E. Owen, for his commitment to the success of computer systems administration and management of water-resources programs.
William H. Raymond, for time-consuming technical assistance to many facets of the Federal government and the Nation.
Laurie F. Rinker, for her career-long dedication to making Federal service a career in which public interests are met with concern and excellence.
Willie C. Rivers, for analyzing thousands of rock samples and for maintaining responsibility for accuracy and reproducibility of results.

Productivity Enhancement Award

Michael T. Meyer received the Secretary of the Interior's Productivity Enhancement Award for contributions to laboratory safety and automated methods development.

John Wesley Powell Awards

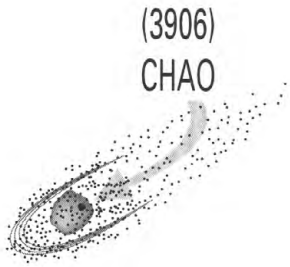
Each year the USGS presents the John Wesley Powell Awards to persons or groups outside the Federal Government for voluntary actions that result in significant gains or improvements in the efforts of the USGS to provide "Earth Science in the Public Service."

Charlotte Garvin, honored for exemplary personnel support.

Willie Rivers, honored for career-long geologic data analysis and data management.

The Powell Award is named in honor of the second USGS director (1881–84). Powell, a geologist, Civil War hero, and Indian ethnographer, led pioneer explorations of the Colorado River. Powell Award recipients for 1992 were

A. Ivan Johnson, of Arvada, Colo., received the Powell Award in the Citizen's Achievement category. A retired USGS hydrologist, Johnson has contributed over 45 years to the establishment of standards for earth sciences terminology, measurements, test methods, and practices. Over the past decade, he has served as a consultant, advisor, and coordinator for many national and international scientific societies and organizations. Through these professional activities, Johnson has helped to bring the scientific results of the USGS to the attention of the public and the professional community.
Carl Kisslinger, Professor of Geology at the University of Colorado, received the Powell Award for Achievement in an Educational Institution. Kisslinger was cited for his career-long commitment to developing and nurturing USGS programs, particularly in the areas of seismology and earthquake research. A distinguished scholar and teacher, Kisslinger has



Asteroid number 3906 has been named in honor of Edward C.T. Chao, USGS geologist and pioneer in the study of meteorite impact structures on Earth and rocks brought back from the Moon by U.S. astronauts. Chao, a 42-year veteran of the USGS, has devoted his career to the study of planetary geology, with emphasis on tektites, a special kind of natural glass. He has advanced key theories that tektites are the product of meteorite impacts.

"(3906) Chao" was discovered in 1987 and may be an extinct comet. It is large, with an estimated diameter of about 25 miles (40 kilometers) and is now orbiting in the outer part of the asteroid belt between the orbits of Jupiter and Mars.

The asteroid name has been endorsed by the International Astronomical Union.

participated in many panels and committees that have provided guidance to the USGS, such as the National Academy of Sciences Committee on Specifications for a World-Wide Network of Standard Seismographs, and the USGS Advisory Panel on Earthquake Studies and its successor, the Earthquake Studies Subcommittee of the National Research Council.

Ray A. Miller, Chief of Technical Services at the Idaho Department of Lands, received the Powell Award for Achievement in State and Local Government. Miller was cited for his leadership of the Idaho State Mapping Advisory Committee and the Idaho Geographic Information Advisory Committee in mapping the entire State. Miller was cited in particular for his foresight in creating locally produced and managed data as part of the USGS national map revision program.

Stewardship Awards

To recognize employees who play active roles in the preservation, conservation, and development of natural resources, then Secretary of the Interior Manuel Lujan, Jr., presented Stewardship Awards to three USGS employees. Recipients were

Stephen J. Vandas accepted the Stewardship Award for Education on behalf of the Water Resources Education Initiative for efforts to increase student awareness of the importance of water resources. In cooperation with other Federal agencies, the American Water Resources Association, and the National Science Teachers Association, the Initiative is producing a series of posters for classroom use (see p. 29).

Eleanora I. Robbins received the Stewardship Award for Education for her outstanding contributions and unfailing dedication to the education of children of all ages and especially for minority and underprivileged children. Robbins has been conducting annual summer field geology courses for inner city minority children in the Washington, D.C., area since 1988. She was instrumental in the development of the publication, "What's Under Your Feet," an earth science activity book.

Mary F. Orzech received the Stewardship Award for Volunteerism for her outstanding leadership and contributions to volunteer programs at the USGS. Orzech compiled a handbook of rules for supervisors of volunteers.

Safety Management Awards

Safety Management Awards are presented to employees who have made a significant contribution toward making the workplace safer by reducing or eliminating hazardous conditions or through safety awareness and education programs. Recipients in 1992 were

Eleanora I. Robbins receives the Secretary's Stewardship Award for Education from former Secretary Lujan (center). Also present (left to right) were then Assistant Secretary for Water and Science John Sayre, Chief Geologist Ben Morgan, and Associate Director Doyle Frederick. (Photograph by Tami A. Heilemann, DOI.)

Isabelle K. Brownfield, Ronald D. Gist, Ronald V. James, Edward A. Johnson, William R. Normark, Roger P. Rumenik, John S. Stuckless, Jackie M. Williams.

Special Programs and Initiatives

During fiscal year 1992, the USGS continued its support of Secretarial initiatives in volunteerism, education, and women, minorities, and persons with disabilities. The following are highlights of activities in these special program areas.

Volunteers for Science

By Maxine C. Jefferson

In fiscal year 1992, more than 1,000 volunteers donated their time and talent to the USGS under the Volunteer for Science program. Since the program began in June 1986, nearly 4,000 volunteers have served more than 700,000 hours—an estimated $8 million contribution to the USGS. The program has grown each year since its inception. The USGS experienced a 24 percent increase in volunteer activity in 1992 over that in 1991.

The growth in the number of volunteers coming on board in 1992 can be partly attributed to an aggressive recruitment program. Leaflets, posters, pencils, and the annual "Volunteer/Intern/Teacher Opportunities" handbook were distributed at college recruitment fairs, volunteer conferences, the National Science Teachers Association Convention, the USGS Open House at the National Center (see p. 18), high schools,

service clubs, and the annual meeting of the Geological Society of America.

In conjunction with National Volunteer Week in April, public service announcements were printed in the newspapers circulated in the USGS National Center and regional offices. The Volunteer for Science Program gained nationwide exposure through an article, "Probing an Iceberg Barrier," and subsequent references to volunteer opportunities, in "Earth" magazine. The article detailed a research project undertaken by a team of USGS scientists and volunteers at the Bering Glacier in Alaska. The response to this publicity was overwhelming: hundreds of prospective volunteers requested additional information.

The Volunteer for Science program continued to be a valuable asset to the USGS and to the volunteers as well. The program's versatility in meeting vocational, educational, programmatic, and altruistic needs was demonstrated over and over. Fifty high school students completed internships as research assistants to fulfill the requirements of a science fair project; classes of young students in Virginia and South Carolina learned the practical nature of scientific research and the value of public service by gathering hydrologic data; homemakers reentering the job market gained proficiency in an automated office setting; professionals between jobs stayed active in their career field and learned new skills; and many USGS retirees, concerned with passing their personal and professional store of knowledge to the next generations, served as docents, researchers, and historians.

Volunteer recognition ceremonies, in Menlo Park in May and in Reston in August, gave the USGS an official opportunity to recognize and thank the more than 200 volunteers at each site who had served during the previous 12 months. The volunteers were commended for sharing their successful lives with the USGS and for investing themselves in their country. These events marked the first time that volunteers received special honorary awards based on their hours of service. Those who had donated 200 or more hours received a patch, bearing the Volunteer for Science logo, and those who donated 500 or more hours received a similar lapel pin. Volunteers who served 1,000 or more hours received a personalized plaque bearing the logo. Every volunteer received a special certificate.

From sixth grader to scientist emeritus, the Volunteer for Science program offered energetic, curious, dedicated people a unique opportunity to be a public servant by joining the USGS in its work.

Volunteers Help Keep PACE

By Jill McCarthy

In February 1992, the USGS completed the fourth and final phase of a refraction transect in the southwestern United States. The goal of the program, called PACE (Pacific to Arizona Crustal Experiment), was to study the geologic history and tectonic evolution across a broad zone of continental rifting. The combined transect ranges from the unbroken and elevated Colorado Plateau in northeastern Arizona to the highly faulted and extended Basin and Range province in southeastern California. The 1992 refraction experiment focused on the southwestern part of this transect, in the Imperial Valley and Salton Sea regions of California, to determine the thickness of the crust, the locations of major faults below the surface, the composition of the lower crust, and the geologic processes controlling rifting in the Salton Sea.

Of the 30 participants in the 10-day-long refraction experiment, 6 were volunteers. Two of the volunteers were graduate students in geophysics—one from Pennsylvania State University and the other from the University of California at Santa Cruz. One volunteer was a retired Army officer, who teaches accounting and business law at a junior college in Kansas, and three were seismologists from the Geological Survey of Canada.

These volunteers participated in all aspects of the experiment. They were responsible for programming the instruments to turn on at the predetermined shot times, for deploying the instruments in the field, and for transferring the data from the instruments to the field computers. The volunteers worked from helicopters and four-wheel drive vehicles in rugged terrain and assisted USGS experts in firing the seismic shots (holes 100–200 feet (30–60 meters) deep, filled with chemical explosives), which produced the critical seismic energy to be measured. Without the hard work and competent help of these volunteers, the PACE experiment would not have succeeded.

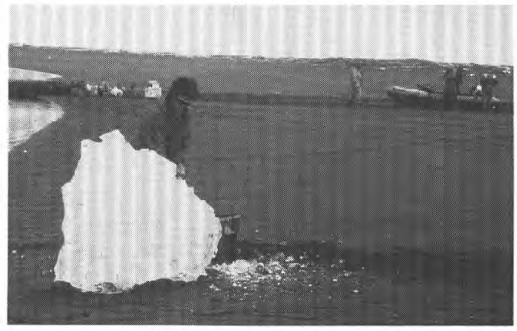
Volunteers at Bering Glacier, Alaska

By Mary F. Orzech

Scientists know that the largest and longest glacier in North America, the Bering Glacier, is retreating. But why? What will be the environmental consequences? Will the glacier produce icebergs that could threaten the safety of vessels in the Gulf of Alaska and Prince William Sound?

These questions and others are studied each year by a team of scientists and volunteers from the USGS. Since 1989, the Bering Glacier Research Project has sent 11 scientists and 22 volunteers to Alaskan public land about 100 kilometers (62 miles) east of Prince William Sound. The volunteers represent diverse professions, including an explosives expert, a professor, scientists from various disciplines, students, a magazine writer, a photographer, a fisherman, a piano teacher, an art restorer, and a law enforcement officer.

In 1992, more than 4,000 volunteer hours were spent in project preparation and actual fieldwork. Volunteers assessed iceberg production, performed seismic surveys, measured beach erosion and glacier thickness, studied water quality, and examined the new land surface exposed by the retreating glacier. They also documented an increase in the number and size of icebergs entering the open sea. Future volunteer efforts will focus on continued scientific observations to document potential threats to vessels off the coast of Alaska.



ELISABETH BROUWERS

Volunteer chops ice to be used for drinking water; in the background, volunteers prepare to haul an inflatable boat into the water.

USGS scientist and volunteer prepare a current meter, which will measure current velocity and allow them to determine the discharge of the Seal River.

LAURIE ORTIZ (VOLUNTEER)

Volunteers use global-positioning system technology to survey a base station. Using these and other data, they will be able to measure the river discharge and its bathymetric profile and determine the size of the largest iceberg that could float out into the Gulf of Alaska.

Partnerships in Education

By Susan Wells

Like an African proverb that says, "It takes a whole village to educate a child," the USGS is joining teachers and parents throughout the country in the challenging task of educating America's younger citizens for the scientific and technological world of the 21st century. Through formal Partnerships in Education agreements, the USGS is channeling its people and other resources into an effective force for promoting overall scholarship, science education, and personal achievement among students.

In 1992, the USGS Partnerships in Education program grew to six formal agreements between the USGS and educational institutions. Partnerships have now been established with Dogwood Elementary School in Reston, Va.; Cole Elementary in Cheyenne, Wyo.; Watkins Elementary School in Jackson, Miss.; Horace Mann Middle School in Denver, Colo.; the Grandview Heights Public School District in Columbus, Ohio; and Lincoln University in Jefferson City, Mo. USGS employees in these locations serve as tutors, science fair judges, coaches, project assistants, lecturers, and mentors and role models. Opportunities to support partner schools are available to all employees—scientist, secretary, technician, and manager. Maps, posters, brochures, career information, rock collections, and other displays and materials are made available to the schools for use in guiding students in pursuing scientific careers or in enriching the school curricula in science, mathematics, geography, and social studies.

The USGS benefits, too, from these partnerships. Students provide art displays and music concerts for employees at USGS offices, teachers offer lectures on education and child development topics, and both students and teachers often serve as USGS volunteers. Through formal education agreements, the USGS is not only opening students' eyes to the wonders and possibilities of the earth sciences but also demonstrating the value of neighbor helping neighbor.

With Bucket and Broom.—Sixth grade students from Dogwood Elementary School in Reston, Va., engaged in a unique, hands-on learning project during the 1991–92 school year, called "With Bucket and Broom." Each Wednesday, Thursday, and Friday morning, these budding scientists trekked the short

distance to the USGS to study the hydrology of the 105-acre (42-hectare) National Center.

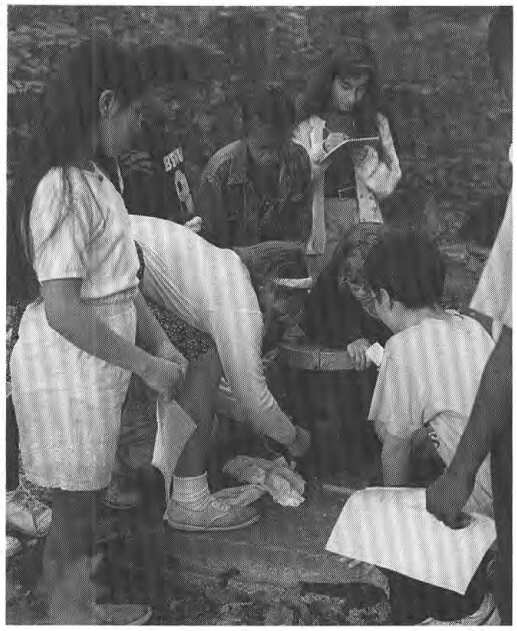
The students worked in teams of 10 to 12, with each student visiting the site three times each school quarter to observe changes in a runoff pond and two ground-water observation wells. Each of the 98 students measured and recorded the air temperature and the corresponding water temperature in the pond. They visually estimated the water level and used a pocket-sized electronic pH meter to measure changes in the acidity of the water. To help students appreciate the environmental effects of the natural cycles of water, they were encouraged to record weather conditions and changes in vegetation and animal life.

The students learned that scientific discovery does not always need "high-tech" equipment. The project earned its name from the plastic mop bucket, attached to a broom handle, that was used to carry equipment. Emphasizing a "low-tech" approach to scientific discovery, the students were given a metal tape measure and blue carpenter's chalk to measure the water level in the ground-water wells. This technique has been used for over 100 years. The chalk turns dark in color when it hits the water. Students were, therefore, able to compare their measurements with those recorded at a nearby automated station that displays a digital reading of water depth and also tracks water-level changes by markings on graph paper.

The "With Bucket and Broom" project not only tied in with science units on liquids and weather but also supported math concepts taught throughout the year. When the students first learned to measure the level of well water, they estimated the difference between the amount of tape dropped down the well and the water mark on the chalk. Later in the year, when the digital readout on the automated station failed to function, the students used their knowledge of decimals to interpolate the values on the graph paper.

The USGS and the teachers at Dogwood Elementary School hope this experience will heighten the students' interest in science in coming years. They also hope that stereotypes of scientists in white laboratory coats with frizzled Einstein-like hair will be forever dispelled and be replaced with the image of themselves and their classmates.

The data collected by the students have been given to the USGS and will be entered into a special data base. Because of their significant voluntary contribution to the hydrologic research of the USGS, each of the students and their teachers were officially recognized and honored through the USGS Volunteer for Science program.



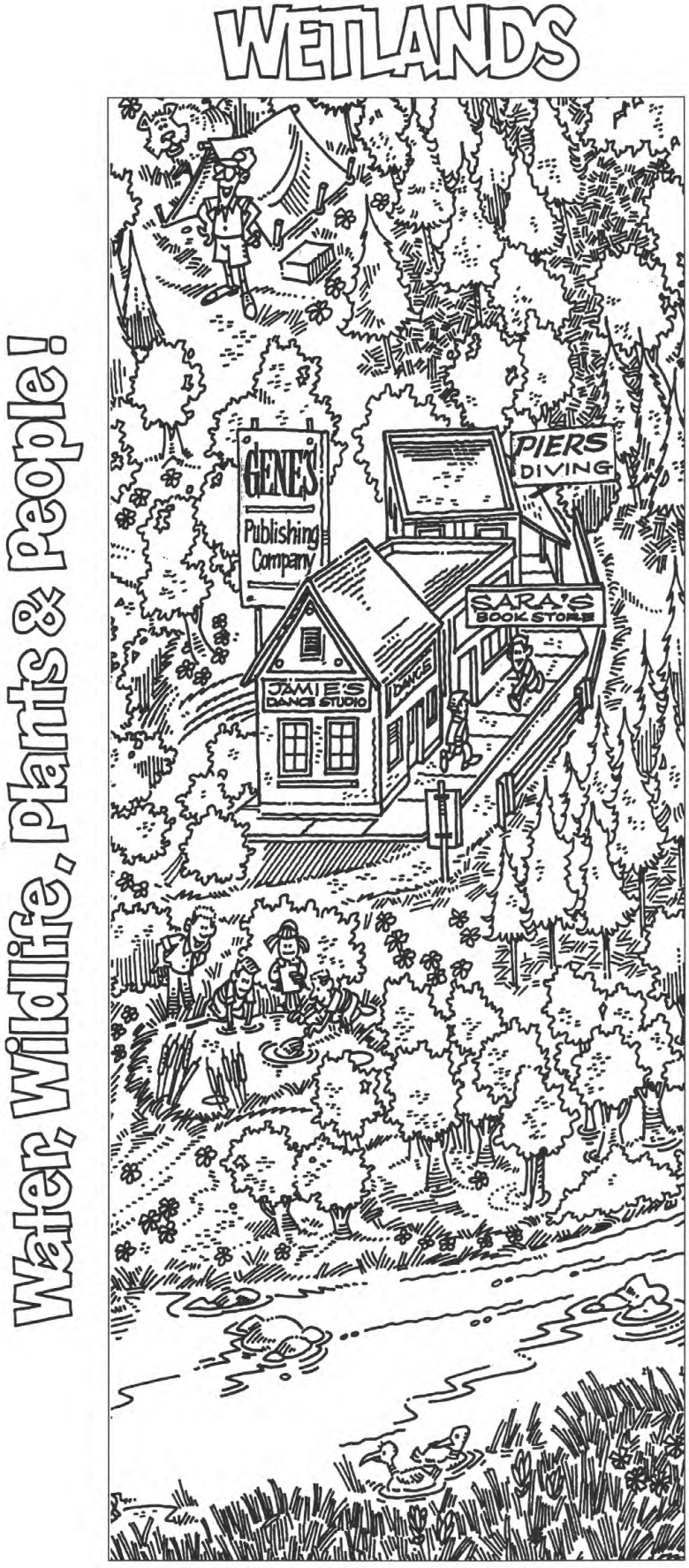
Sixth grade students from Dogwood Elementary School measure the level in a ground-water well at the USGS National Center as part of the Partnerships in Education project, "With Bucket and Broom."

Learning About Water

By Stephen J. Vandas

The Water Resources Education Initiative, a USGS cooperative effort on water education, has been an extremely successful venture. The U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service of the Department of the Interior, the U.S. Army Corps of Engineers, and the Nebraska Groundwater Foundation joined the initiative as new partners in 1992. These groups join the Interior Department's Bureau of Land Management, the American Water Resources Association, and the National Science Teachers Association as project participants.

Activities of the water education program are designed to stimulate interest in and provide a basic knowledge of water resources for students in grades K–12. A key element in the program is development of various teaching aids. The first of these aids is a series of water-resources educational posters designed to capture the student's attention visually and then support that attention with a variety of in-class activities. The second set of aids will consist of water-resources educational-training notebooks designed to be taught by water-resources professionals in the classroom or at afterschool programs. The third component, which is just beginning, is to coordinate children's water festivals around the Nation, based on a model founded by the Nebraska Groundwater Foundation.



Three posters in the series have been completed: water use, wastewater treatment, and wetlands. The water-resources topics for each of the posters are depicted in a cartoon format and are available in full color or in black and white. The reverse sides of the color posters contain educational activities and are separately designed for grades K–5 and grades 6–8. Posters have been distributed initially through Science and Children (grades K–5) and Science Scope (grades 6–8), publications of the National Science Teachers Association. As inserts to these magazines, copies of the posters were distributed to more than 43,000 teachers. To date, about 800,000 copies of the posters have been distributed. A Spanish-language version of the water-use poster is currently being developed.

The water-resources educational-training notebooks are being designed to enable a water-resources professional to assist an instructor—the teacher in the classroom, a scout leader, or a 4–H counselor—in presenting the science of water resources. Notebooks will be created around the five general topics of ground water, water quality, surface water, water use, and basic water properties. Three notebooks will be created within each topic—one each for grades 3–5, grades 6–8, and grades 9–12—making a total of 15 notebooks.

Ground water for grades 6–8 is the first notebook. The notebook was pilot tested in fiscal year 1992 by USGS employees working with teachers in 15 middle school classes in Texas.

The educational material in the notebooks represents a unique partnership of instructors working in concert with water-resources professionals. Five different lesson plans are provided for the educational partners to teach together. The instructor selects the lesson plan that best complements the students curriculum. Instructors complete previsit activities with the students before the water-resources employee visits. While in the classroom, the hydrologist conducts a hands-on activity concerning the selected water-resources topic. Postvisit activities provide instructors with ways to augment the visit with additional information on the water-resources topic. By working as partners, the instructors are able to do what they do best—stimulate learning—and the water-resources employees are able to do what they do best—present the science of hydrology.

In an exciting new project, the USGS is working with the Nebraska Groundwater Foundation to organize the 1993 Children's Water Festival in Nebraska. Held annually since 1989, the Nebraska Children's Water Festival has become a national model of hands-on ground-water education. The festival educates children in grades 4–6 about the

importance of ground water in their lives. Over 3,000 children attended the event in 1992, and there are over 8,000 children on the list to participate in 1993. The USGS and the Nebraska Groundwater Foundation have a cooperative agreement to prepare a manual to describe how to organize and coordinate a children's water festival. When completed, the manual, "Making Waves," can be used by USGS offices in every State to work with local agencies in developing similar water festivals for children throughout the country.

Outreach in Geology Education

By Laure Wallace

Comprehensive programs to enhance geology and earth science education have developed out of the impressive talents and interests of a workforce dedicated to the concept that education outreach is a fundamental part of their responsibility as citizens and as employees of the USGS.

Fiscal year 1992 was a banner year for support of technology and information transfer to the educational community. Nationwide workshops were given on the CD-ROM's developed under the Joint Education Initiative (JEdI). In cooperation with the National Aeronautics and Space Administration, a multidisc set of CD-ROM's on volcanoes was developed for the educational community. CD-ROM's, which contain Landsat Thematic Mapper imagery of the Navajo Reservation and the Grand Canyon and sets of digitized aerial photographs, were developed for the Navajo Reservation schools in cooperation with the Bureau of Indian Affairs' Nazalini School. A project with Mary Washington College in Fredericksburg, Va., began to develop a CD-ROM on data and imagery of Virginia for the Commonwealth's science teachers.

Working together in partnership is an important aspect of the outreach programs in the geological sciences. The USGS has been instrumental in developing the Coalition for Earth Science Education, an organization dedicated to communication, cooperation, and coordination within the earth science community—geology, astronomy, hydrology, atmospheric sciences, oceanography—on educational activities. The coalition will also provide a united voice on national and regional policy issues that affect earth science education reform. To date, more than 50 organizations, associations, Federal agencies, and academic institutions are committed to the vision of the coalition.

The USGS is also continuing its commitment to support local and regional teaching communities. The following are a few notable examples:

- Field guides on the Pacific Northwest region were developed for earth science teachers by the USGS field office in Spokane, Wash., in conjunction with local school systems, the Idaho Geological Survey, and Eastern Washington University. A summer field program put the field guides to good use.
- Geo-Teach, a comprehensive field program for local area earth science teachers, was presented for the second year by scientists in the USGS central region in Denver, Colo. They also developed a field guide on the Cretaceous-Tertiary boundary for Colorado teachers. These scientists also presented a comprehensive field and laboratory program, complete with a publication and classroom activities, for Bureau of Indian Affairs teachers on the Pine Ridge Reservation in South Dakota.
- Nearly 40,000 copies of "What's Under Your Feet," an earth science activity book for elementary-age children, were distributed.
- The library-based Teacher Resource Centers at the USGS centers in Menlo Park, Calif., and Denver, Colo., were expanded, and a new center was developed in Reston, Va., at the National Center.
- Educational outreach to Historically Black Colleges and Universities was expanded through a grant and through cooperative programs with Hampton University in Hampton, Va., for teacher programs and workshops; and through support of geology majors at Elizabeth City State University in North Carolina.

Enriching Partnerships in the Southwest

By Jim Crawforth and Fred Joines

Partnerships—one new and one long term—between the USGS and university communities in the Southwest are enriching the USGS with new ideas from bright and talented students and professors and are helping the communities by connecting the USGS to important local issues.

The USGS continued its cooperative efforts with New Mexico Highlands University that began in 1991. USGS representatives met with heads of the engineering, environmental science, mathematics, and business departments to discuss further the cooperative efforts, including guest lecturers, summer hires, and cooperative education appointments. A USGS scientist, for example, served as a guest instructor at the Eagle Peak Summer Camp sponsored by New Mexico Highlands. The goal of the Eagle Peak Summer Camp is to introduce minority high school

students to higher education and to career opportunities in the natural sciences.

In Flagstaff, the USGS, local high schools, and Northern Arizona University have enjoyed a mutually beneficial, informal relation for the past 25 years. Over the years, the USGS has hired several high school students as well as students and faculty from Northern Arizona University. USGS employees have served as mentors, speakers, and instructors and have participated on several advisory committees. The relation was the natural result of the close proximity of a small community and the high level of interest in education and science in the Flagstaff area.

From the days of the Apollo space program in the late 1960's to the present time, several faculty members and about 25 students have been employed each year at the USGS center in Flagstaff. Most of the students have come from the Northern Arizona departments of geology, geography, mathematics, engineering, and computer science. The students performed many tasks, including fieldwork, data manipulation, map compilation, and computer programming and operation. A major contribution to the hiring of students was the Minority Participation in the Earth Sciences program, a nationwide USGS program that was established at the center in 1972. This program provided funding to hire 10 to 15 minority and women students each year, and additional project funding enabled the USGS to hire an additional 10 to 15 students, for a total of 25.

Collectively, these employees contributed tremendously to the work done at the USGS center and helped to reduce costs. The faculty benefited from the participation in real projects with actual data. The students received many benefits including meaningful employment, encouragement to continue their education, and work experience that would help them in the job market after graduation. The USGS now has 25 employees, many of them women and minorities, who started with the USGS as students and who compose almost one-fourth of the permanent workforce at the Flagstaff Center.

Education Outreach at Hampton University

By Ellen Findley

The USGS continues to strengthen its relation with Hampton University in Hampton, Va., a historically black university, through increased interaction among the students, the faculty, and the USGS scientific community. Beginning in fiscal year 1993, a new cooperative education initiative with Hampton's graduate program in computer science will allow a student to remain on the university campus and work on earth science data base and telecommunications projects for the USGS. One of the goals for the project is to increase the knowledge of careers in the earth sciences and at the same time develop and implement highly flexible data-management and processing systems for earth science applications. Rapidly changing technological environments supply the means to achieve the underlying information-retrieval protocol necessary to automatically collect, collate, and integrate diverse scientific data.

Highlights of the Hampton education partnership include

- Developing an awareness of the increased productivity that is possible through the use of local area networks in earth science applications, such as sharing scientific data.
- Giving students hands-on experience with the UNIX operating system, which is emerging as a primary scientific computing environment.
- Providing students an opportunity to experiment with earth science data in a distributed data-base environment through a local area network.
- Fostering a mentor relation with the students.

Career Planning for the Year 2000

By Maxine C. Jefferson

The USGS unveiled a significant career development tool in 1992, the Career Planning Manual, designed to help career goals of women, minorities, and persons with disabilities. Distributed bureauwide to clerical, administrative, and secretarial employees in grades 1–7, and their supervisors, the manual provides a self-directed guide to developing career goals, gaining self-awareness, and achieving personal growth. The Civil Service 2000 report, recently issued by the Office of Personnel Management, indicated that the skill needs of the Federal Government will continue to increase, while the supply of skilled employees diminishes. The Career Planning Manual reflects the USGS commitment to meet the challenge of the year 2000 and beyond by providing its workforce with assistance and direction in the development of work skills, the identification of career interests, and the pursuit of career goals. Both the employees and the USGS can benefit from this career planning approach—the employees find guidance with which to enrich their knowledge, skills, abilities, and qualifications; and the USGS gains more versatile, well-trained employees and is better able to promote from within.

The career manual includes job analysis information, a self-assessment exercise that helps individuals pinpoint their own strengths and weaknesses, a guide for setting performance goals, and tips that can make it easier to achieve personal career goals. The manual also encourages the mentoring concept by providing an opportunity for employees to interact with their supervisors and coworkers to obtain useful career information and perspectives on career development.

The Career Planning Manual is specifically tailored to allow individuals to match their personal preferences, skills, and abilities with the following USGS jobs: administrative operations assistant, computer clerk and assistant, accounting technician, editorial clerk and assistant, purchasing agent, hydrologic technician, cartographic technician, and library technician. These career targets were selected because these are job classifications in which there are large numbers of incumbents, there is a reasonable turnover, the jobs are found in sufficient numbers in all USGS geographic locations, and the jobs offer a diverse pool of career opportunity.

The Career Planning Manual was distributed bureauwide early in 1992, and briefing sessions were held at USGS headquarters and regional offices. The initial response from employees and supervisors has been positive. Supplements to the manual are planned that will focus on USGS employees in technical occupational series.

Women's Advisory Committee

By Margo Kingston

The Women's Advisory Committee (WAC) was established in 1990 within the Geologic Division to promote communication with managers on issues related to the professional development of all women employees. Committee members represent administrative, clerical, scientific, and technical women employees. WAC objectives are to examine opportunities for career enhancement that can be made available to all women in the Geologic Division and to identify problems that prevent or restrict women from realizing these opportunities. Since the committee began, numerous employees' concerns have been identified, recommendations have been made to managers, and actions have been taken to address these concerns. Both the WAC recommendations and management responses are made available to employees.

As a result of WAC recommendations, a classification task force was established to provide occupational and position classification information on support occupations. The task force report is being used by the bureau's personnel office to revitalize the classification of secretarial, administrative assistant, and editorial support positions.

The WAC also tackled sexual harassment issues that were seen as barriers to career advancement for women. A USGS policy statement on sexual harassment was issued in October 1992, based on the draft statement prepared by WAC members. The WAC developed a questionnaire on sexual harassment issues, and a special task force prepared a report on the results. In addition, employees will receive training in preventing and dealing with behaviors and actions that are sexually harassing.

Improving communication is an important issue of the WAC. Program forums in each region have enabled employees to meet with program managers and coordinators to learn about opportunities and important developments. Career and Management Resource Centers have been established in the three regional USGS libraries to centrally locate books, videos, and other materials on topics such as leadership training, team building, mentoring, and USGS programs and organization.

A human resources specialist is now on staff in the Geologic Division to better implement new training programs for improving the quality of management and to provide career-development growth opportunities. A series of leadership-development and team-building programs was sponsored by the division chief. A task force has begun work on a statistical study of career patterns of scientific personnel.

Family and quality of work life are important concerns to the WAC, which sponsored employees in short-term detail assignments to investigate and report on alternative work schedules and family leave and childcare issues.

Women's Executive Leadership Program

By Susan Roach

The Women's Executive Leadership program, an initiative of the Office of Personnel Management, is designed to train capable women who are interested in managerial and executive careers. The program provides for increased visibility and expanded experiences in preparing women for management positions.

A pilot program was introduced in 1984 with 63 participants from Federal agencies in the Washington, D.C., area. The program

was expanded nationwide in 1986, growing to 161 participants. In 1992, there were 305 graduates from 30 agencies across the country. Four USGS women from the National Mapping Division have participated in the program; three have graduated, and one is enrolled in the 1992–93 program.

The primary benefit of the Women's Executive Leadership program is the exposure to a wide variety of experiences and management styles through developmental assignments and managerial contacts. Developmental assignments from which the USGS and its participants have benefited include the Departments of the Interior, Agriculture, and Veterans Affairs and, through a cooperative agreement, IBM. In addition to an increased knowledge of other government agency practices, programs, and policies, the participants gained a better understanding of USGS operations and its interactions with other organizations. USGS graduates of the program in the National Mapping Division have enhanced their career potential through the program.

Ethnic Minority Advisory Committee

By Jackie M. Williams

To ensure that the professional well-being and career development of ethnic minority employees are being met, the USGS Geologic Division established an Ethnic Minority Advisory Committee. The committee met for the first time in June 1992 and included ethnic minority representatives from each of the regions and from scientific, technical, administrative, and clerical job categories.

Specific goals of the Ethnic Minority Advisory Committee are to achieve equitable representation, to increase cultural awareness, and to promote open communications. At the first meeting, the committee developed recommendations for issues of concern to the minority community. The main concerns cited were promotion and advancement, career development and training, increasing minority staffing, communications, and conflict resolution. These concerns will be addressed by the Ethnic Minority Advisory Committee in the coming year.

Enjoy Outdoors America!

By John H. Wittmann

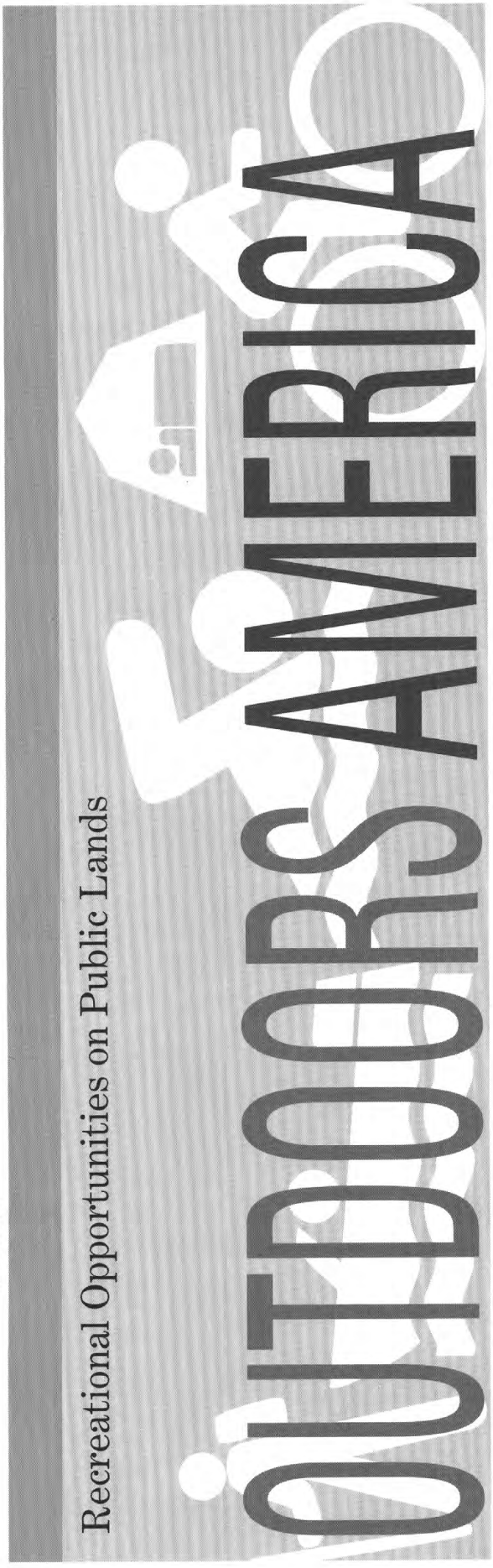
The "Federal Recreation Lands Map—An Invitation to Enjoyment" was published in 1992 as a cooperative venture among the seven primary Federal land-managing agencies, the USGS, and the Secretary of the Interior's Outdoor Recreation Initiative. On one side the map depicts more than 1,400 sites managed by the U.S. Fish and Wildlife Service, National Park Service, Bureau of Reclamation, and Bureau of Land Management of the U.S. Department of the Interior, the U.S. Army Corps of Engineers, the Tennessee Valley Authority, and the Forest Service of the U.S. Department of Agriculture. The map also shows the interstate highway system and 70 major cities to give travelers a frame of reference for locating areas they wish to visit.

The other side of the map has information about each of the participating agencies, with lists of regional offices that travelers can contact for more information on specific sites. Also included is a list of all the State tourism offices and a description of the types of outdoor recreation opportunities available on public lands. The map sites and the agency information panels are color coded for easy use.

Although the USGS does not manage Federal lands, it prepared and printed the outdoor recreation map. The USGS has detailed topographic maps for the entire country and special maps for national parks and monuments. The maps are available from the USGS and from private map dealers. The outdoor recreation map lists primary contacts for USGS map products.

LEWIS THOMPSON

DOI and USGS officials examine first printed copy of the new Federal lands recreation map.



WATER RESOURCES INVESTIGATIONS

PHOTOGRAPH USE COURTESY OF PAUL STONE

MISSION

The U.S. Geological Survey has the principal responsibility within the Federal Government to provide the hydrologic information and understanding needed by others to achieve the best use and management of the Nation's water resources. To accomplish this mission, the Water Resources Division, in cooperation with State, local, and other Federal agencies,

- Systematically collects and analyzes data to evaluate the quantity, quality, and use of the Nation's water resources and provides results of these investigations to the public.
- Conducts water resources appraisals describing the occurrence, availability, and physical, chemical, and biological characteristics of surface and ground water.
- Conducts basic and problem-oriented hydrologic and related research that aids in alleviating water resources problems and provides an understanding of hydrologic systems sufficient to predict their response to natural or human-caused stress.
- Coordinates the activities of Federal agencies in the acquisition of water resources data for streams, lakes, reservoirs, estuaries, and ground water.
- Provides scientific and technical assistance in hydrologic fields to other Federal, State, and local agencies, to licensees of the Federal Energy Regulatory Commission, and to international agencies on behalf of the Department of State.
- Administers the State Water Resources Research Institutes Program and the National Water Resources Research Grants Program.

Message from the Chief Hydrologist, Water Resources Division

Through studies of the distribution, availability, quality, and use of the Nation's water resources, USGS water-related programs have evolved over the past 100 years to today's unique combination of hydrologic data collection, research, and investigations. Today's programs are relevant to such present and emerging concerns as ground-water and surface-water quality, water supply and demand, wetlands, nonpoint-source pollution, and hydrologic hazards.

One strength of these water-related programs is the widely dispersed field organization that promotes the development of programs based on a synthesis of local and regional needs. These needs are identified on a continuing basis in collaboration with the more than 1,000 Federal, State, regional, and local agencies that provide funds to the USGS for cooperative water-resources investigations, as well as with many others who use the results of the work.

Recent highlights of ongoing programs include the National Water-Quality Assessment (NAWQA) program, which identified sources of pesticides in the ground water of the Delmarva Peninsula in Maryland, Delaware, and Virginia and enabled the U.S. Department of Agriculture to structure surveys of farming practices. Also, through the NAWQA program, the surprisingly large amount of DDT still present in the Yakima River was found to be closely related to sediment movement, which permitted Washington State and U.S. Environmental Protection Agency officials to determine areas where erosion control would be most beneficial.

The Federal-State Cooperative program provides for most of the continuous streamflow stations operated by the USGS, including about 3,000 that constitute the National Weather Service's flood-forecasting network. More than 500 hydrologic investigations and research activities were conducted in fiscal year 1992 as part of the program. These studies emphasize issues such as ground-water contamination from wastes and saltwater intrusion, the effects of agricultural activities and stormwater runoff on water quality, and the identification of the effects of continued urban and industrial development on water supplies.

USGS activities supported by other Federal agencies during fiscal year 1992 included investigations of ground-water contamination at military bases for the U.S. Department of Defense, characterization of the geology and hydrology of the proposed radioactive waste repository site at Yucca Mountain, Nev., for the U.S. Department of Energy, and operation of 2,300 stream-gaging stations needed to manage the Nation's flood retention reservoirs and navigable waterways for the U.S. Army Corps of Engineers.

In fiscal year 1993 and the future, we will continue to stress cooperative working relations so as to make the most of the talents of the people and other resources available to us. We are committed to ensuring that our programs consistently produce high quality, credible information that is directly on target with emerging issues.

Philip Cohen

The 1992 Chicago Underground Flood

By Stephen F. Blanchard and Arthur R. Schmidt

On April 14, 1992, the underground portion of the downtown Chicago area known as the Loop was flooded. The Loop is underlain by about 50 miles of old tunnels that were constructed around the turn of the century. The tunnels, dug beneath the Chicago River, were used to deliver supplies, such as coal, to office buildings and to remove solid waste. The flooding was caused when a piling cluster was driven through the bottom of the Chicago River and possibly into the tunnel during summer 1991. This weakened or perforated the tunnel wall and eventually allowed water from the Chicago River to flow into the underground tunnel system and basements of the tunnel-connected buildings. The result was an "underground flood." The flood devastated the Loop. Property was damaged, businesses lost revenue, and cleanup costs totaled millions of dollars.

USGS water-resources personnel pour rhodamine WT, a harmless vegetable-based water-soluble red dye, into a well bored into a tunnel beneath Kinzie Street in downtown Chicago, Ill.

STEPHEN F. BLANCHARD

Sampling for the presence of rhodamine WT in water from a well bored into the tunnel.

The dye allows detection of leaks as small as 1 gallon per minute. . .

The U.S. Army Corps of Engineers (Corps) initially contacted the USGS on April 15 to request assistance in locating the hole from the Chicago River into the tunnel system. USGS hydrologists provided assistance to the Corps by measuring velocity in the tunnels, detecting leaks in plugs installed in the tunnels, and monitoring water levels in the tunnels. The Corps installed several plugs in the tunnels to block the flow of water from the river to the tunnels. At the request of the Corps, the USGS set up a velocity meter (initially an acoustic velocity meter and later a mechanical meter) in the tunnel on the landward (undamaged) side of a selected plug to evaluate the effectiveness of the plugs. Velocity measurements were made every 15 minutes, 24 hours a day. Drawbacks to the use of velocity meters to monitor leakage through a plug include the detection of low-velocity movement by the meters and the possibility that velocities measured by the meters could be caused by pumping rather than a leak in the plug. Because velocity measurements alone were insufficient to guarantee that leakage had been stopped, the USGS used a fluorescent dye, rhodamine WT, to determine if there was leakage past the plugs. The dye allows detection of leaks as small as 1 gallon per minute, whereas the minimum leak that could be detected by the velocity meter is about 550 gallons per minute.

Plans for the dye injection were based on results from computer models of dispersion and horizontal movement of water in the tunnels. One model simulated the mixing of the dye with the water in the damaged part of the tunnel, which was open to the river but separated from the rest of the tunnel system by the plugs. This model also estimated the time until the dye reached the plug and the change in dye concentration over time at the plugs. A second model simulated the horizontal movement and dispersion of dye-water that leaked into the undamaged (landward) side of the tunnel through the plugs. Use of the two models permitted scientists to estimate the leakage rate. These models were also used to plan the amount of dye to use at each injection site.

The USGS has used rhodamine WT extensively as a water tracer since the mid-1960's because it is vegetable based, water soluble, inexpensive, and harmless to humans, fish, and water quality in the low concentrations used. Dye tests are commonly done to measure traveltime, dispersion, and discharge in surface- and ground-water systems. Nearly all applications include introducing a known amount of dye into a water body, collecting water samples at different times and locations, and using an instrument called a fluorometer to measure the amount of dye in the samples.

The presence of dye in water samples collected on April 23 from holes bored into the tunnel indicated that some river water was still leaking through the plugs separating the damaged section from the undamaged sections of the tunnel. On the basis of this result,

STEPHEN F. BLANCHARD

A hydrologist processes water samples by using a fluorometer to detect dye in the water. The laboratory was set up in a government-owned van onsite in downtown Chicago, Ill.

the Corps ordered additional grouting to seal the plugs and stop the leaks. Water samples collected on April 24, after grouting was completed, indicated that the leaks had been stopped. The USGS continued to monitor dye concentrations until the undamaged tunnel sections near the plugs were dewatered on April 25. None of the samples indicated any further leakage. Because of this dye work, the Corps was successful in plugging the leak and stopping the flow of water from the river to the tunnels.

The USGS also installed seven stage gages to monitor the level of water in the tunnels. These gages were based on a float-and-pulley system with an electronic data logger to record water-level readings. In addition, the stage gages were equipped with phone telemetry so that the Corps could have realtime access to the data. The information provided by the stage gages was crucial to the Corps for regulating the rate of tunnel dewatering. These gages would also have served as an early warning system if another breach had occurred during tunnel dewatering. The gages were installed in basements of buildings, in manholes in streets, and in excavated access shafts.

The Chicago flood was a devastating incident. It did, however, provide the USGS an opportunity to demonstrate how routine methods and instrumentation could assist in a very unusual situation. Techniques that would normally be used to measure traveltimes, discharge, and water levels of streams in the field were used instead to measure leakage through plugs and the water levels of an underground flood in an urban area, providing invaluable assistance to the Corps and a unique form of community service.

Hydrologic Research at the Five Management Systems Evaluation Areas

By David W. Morganwalp

The Management Systems Evaluation Area (MSEA) program is part of an interagency initiative to evaluate the effects of farming on water quality. The cooperating agencies of the MSEA program include the U.S. Department of Agriculture's Agricultural Research Service (ARS) and Cooperative State Research Service, the U.S. Environmental Protection Agency (EPA), the USGS, and several State agencies. The MSEA's are located in a 12-State region in the Midwest, which includes the highly productive agricultural area known as the Corn Belt.

Recent census data shows that in 1989, this 12-State region accounted for 86 percent of the Nation's corn production and over 78 percent of the Nation's soybean production. The high level of agricultural productivity of the region is sustained by agricultural chemicals, such as atrazine, the most heavily used herbicide in the Nation. About 64 million pounds were applied to croplands in 1989, with about 62 percent applied to the corn acreage in the 12-State region. This intensive use of agricultural chemicals can affect water quality in the region. For example, USGS researchers have measured atrazine concentrations as high as tens of micrograms per liter in the rivers and streams of the 12-State region, after herbicides were applied in spring, which correlate with high stream discharge caused by storms.

The general goal of the MSEA program is to reduce adverse effects of agricultural chemicals on the environment through use of improved farm management practices. The cooperating agencies of the MSEA program are collaborating on research at scales that range from laboratory experiments to small watersheds of about 20 square miles (52 square kilometers).

Five MSEA sites were selected to represent the principal hydrogeologic settings and geographic diversity of prevailing farming systems in the 12-State region. MSEA sites in sand and gravel settings are located in Minnesota, Nebraska, and Ohio; those in loess and till are in Iowa and Missouri. Research focuses on ground-water processes at all sites, but stream processes are also a major consideration at sites in Iowa and Missouri.

The controlled application of agricultural chemicals to different types of experimental farming systems is typical of the research at MSEA sites, where researchers are trying to

The general goal of the MSEA program is to reduce adverse effects of agricultural chemicals on the environment through use of improved farm management practices.

Objectives of the MSEA Program

The objectives of the interagency effort are to

(1) measure the effects of prevailing and modified farming systems on surface- and ground-water quality,

(2) understand the processes and factors that affect the fate of selected agricultural chemicals in aquatic ecosystems,

(3) assess the effect of selected agricultural chemicals on ecosystems,

(4) assess the projected benefits to water quality of implementing modified farming systems,

(5) evaluate the effects on the economy of using modified farming systems, and

(6) encourage farmers to adopt new farming systems that have less of an adverse effect on surface- and ground-water quality.

determine which farming systems are the least detrimental to the environment. To this end, the movement of agricultural chemicals from each experimental plot into ground and surface water is being tracked and the data compared between the different plots.

The transport of agricultural chemicals in the environment is extremely complex and is influenced by physical processes and by agricultural management systems. The multidisciplinary research of the MSEA program seeks to provide greater scientific understanding of the fate of agricultural chemicals so that farmers and government officials can make informed decisions about agricultural management systems and their effects on the environment.

Even though all of the MSEA sites have the same goal, there are differences in emphasis at each site. These differences are a result of the hydrogeologic settings and the farming techniques used in the general area of the site. USGS research at each MSEA site is described below.

Iowa MSEA.—The Iowa MSEA site is the Walnut Creek watershed, underlain by loess, near Ames, Iowa. USGS researchers are defining the ground-water flow paths in the watershed and relating the distribution of agricultural chemicals to the major transport processes in the watershed. In addition, the USGS is evaluating the ability of its Precipitation-Runoff Modeling System to simulate the major flow paths of water and sediment in the watershed. The Iowa MSEA is also the site for EPA's Midwest Agrichemical Subsurface-Surface Transport and Effects research program that focuses on ecological effects of agricultural chemicals in surface water.

Location of Management Systems Evaluation Area (MSEA) sites in the Midwest.

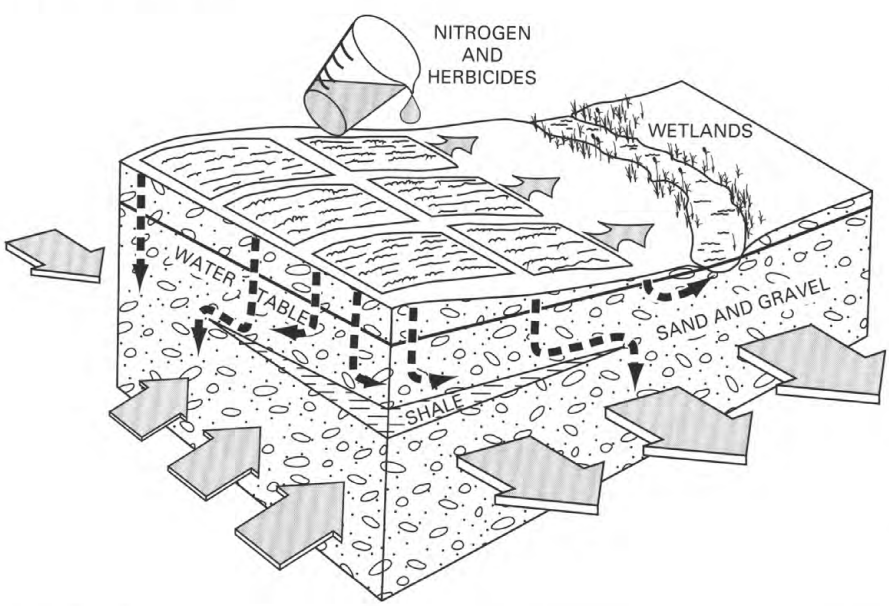
Minnesota MSEA.—The Minnesota MSEA site, located near Princeton, Minn., and its satellite sites in North and South Dakota and Wisconsin are the focus of the effects of climatic differences in farming systems. The USGS is studying the effects of transient recharge, topography, evapotranspiration, and diverse soil composition on the transport of agricultural chemicals from croplands.

Missouri MSEA.—The Missouri MSEA site is the Goodwater Creek watershed, which has been monitored by ARS personnel for 18 years. The USGS is investigating the nitrogen cycle in claypan soils and glacial drift aquifers. Interagency research includes computer models of fluid flow and solute transport.

Nebraska MSEA.—The Nebraska MSEA site, which focuses on alternative irrigation systems, is located 2 miles (3 kilometers) north of the Platte River near Shelton, Nebr. The characteristics of the ground-water flow system in the shallow Quaternary sand and gravel deposits and the characteristics of possible hydraulic connections between the underlying Ogallala formation and the shallower Quaternary sand and gravels are being studied.

Ohio MSEA.—The Ohio MSEA site overlies a buried valley aquifer near Piketon, Ohio. Similar buried valley aquifers in Ohio and elsewhere in the Midwest frequently have high concentrations of nitrates. In addition to describing the hydrology and evaluating the buried valley aquifer, USGS researchers are investigating how changes in water chemistry and microbial populations affect the fate of agricultural chemicals in the ground water of such aquifers.

An illustration of the controlled application of agricultural chemicals to experimental farming systems.



Using Hydrologic Data to Forecast Floods

By Charles W. Boning[1] and Eugene A. Stallings[2]

Floods are dangerous, life-threatening, and destructive. Accounts of floods and flood disasters as well as droughts and famine appear in numerous biblical writings. The Romans used dams and diversions in attempting to reduce potential floods and to manage water resources. Concerns about floods have existed in the United States since the first settlers came to the New World. Early efforts to reduce flood-related deaths and damages, however, were primarily devoted to flood-control measures such as levees, dams, and storage reservoirs. Flood-warning systems would not be feasible until suitable communication systems were developed.

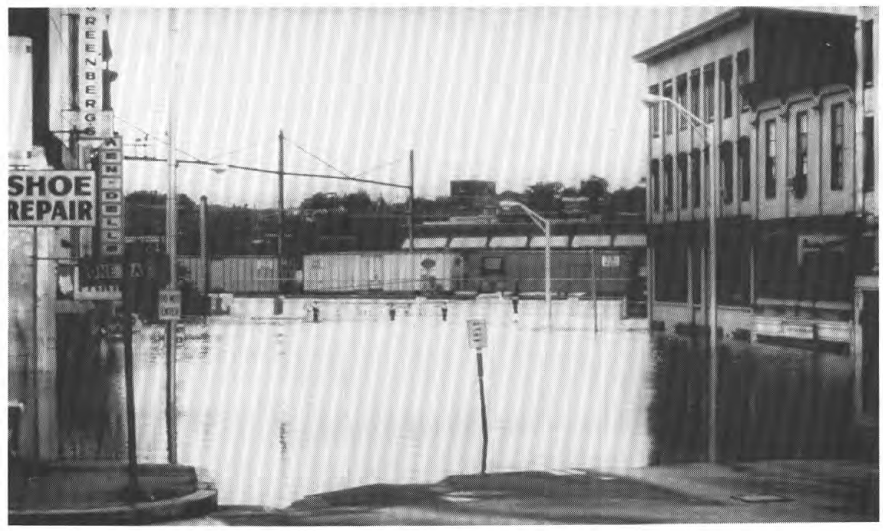
Early flood-warning systems for people living along streams undoubtedly involved personal travel and verbal exchange of information. Communication systems such as the telephone greatly improved timeliness of flood warnings. Federal, State, and (or) local water-management agencies began to remotely access data from USGS gaging stations in the 1930's by using an instrument called "Telemark." When accessed by telephone, the Telemark transmitted river stage by a series of beeps or rings. Very high frequency radio also began to be used in the 1930's to obtain river-stage data. By the 1950's, river stage at hundreds of USGS gages throughout the United States could be accessed to forecast floods, provide flood warnings, or for water-management purposes including drought.

The continued evolution of communication and stage-sensing equipment has further improved data access for flood-warning and flood-forecasting purposes. The principal devices currently in use in USGS gages for obtaining near realtime data for flood-warning or other water-management purposes are those that transmit data via satellite to a receiving station where the data are then relayed to the end users. In addition to satellite telemetry, many gages are equipped with conventional radio and telephone systems, which contribute to the timeliness of data critical to warning or water-management purposes.

The initial use of remotely accessed data to forecast floods was often limited to the interpretation of correlative relations that existed between different streams or stream locations, which required a great deal of intuitive expertise and knowledge on the part of the river or weather forecaster. The rapid development of more sophisticated computer systems since the 1970's, however, has permitted large amounts of data to be incorporated into computer-simulation models for more accurate and timely forecasting. Although data from USGS gages are used for a wide variety of water-management purposes, a most critical use of such data is to provide warnings or forecasts of floods.

The National Weather Service (NWS) of the National Oceanic and Atmospheric Administration, is the Federal agency in charge of weather forecasts and warnings for the Nation. Many people, however, are not aware that the NWS is also charged by law with the responsibility to issue forecasts and warnings of floods. The mission of the NWS's Hydrologic Services program is to save lives and decrease property damage by issuing timely flood warnings and river-stage forecasts. Although many cities, counties, or other local flood-management agencies are involved in the operation of local flood-warning networks, the NWS, through its nationwide hydrologic-forecasting mandate, is the principal agency that uses nonstructural methods to decrease flood damage. In addition, NWS reviews hydrologic and meteorological data during periods of deficient rainfall and snowfall to make predictions of water-supply and to issue drought advisories.

Flooding along major rivers that is caused by rainfall takes many hours and even weeks to develop. Floods caused by snowmelt runoff may take months to develop. Flash floods occur when intense precipitation falls during a brief time span on smaller rivers; the time between the onset of intense precipitation and the cresting of the river is hours instead of days. More than 10,000



USGS

Flooding of Susquehanna River at Market Street, Harrisburg, Pa., a result of Hurricane Agnes in June 1972.

More than 10,000 precipitation and streamflow stations, including more than 3,000 streamflow gages operated by the USGS, provide hydrologic data to NWS offices across the country for use in the flood-forecasting program.

[1] U.S. Geological Survey.
[2] National Weather Service.

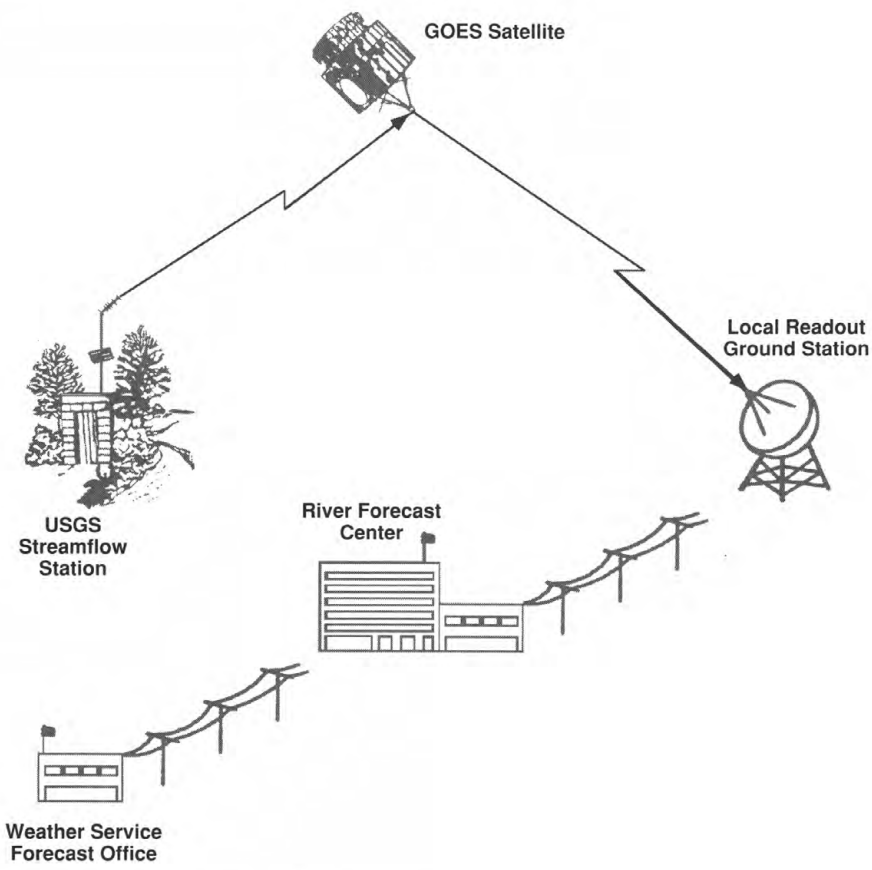
precipitation and streamflow stations, including more than 3,000 streamflow gages operated by the USGS, provide hydrologic data to NWS offices across the country for use in the flood-forecasting program. Hydrologic data collection at stream-gaging stations is telemetered through the Geostationary Operational Environmental Satellite (GOES) to regional NWS River Forecast Centers (RFC). The data are incorporated into hydrologic models that are used in making hydrologic forecasts and advisories. The data provided by the USGS streamflow gages are essential in creating timely and more accurate hydrologic forecasts and advisories. Most of these data are archived over a long period of time. As a result, a large base of hydrometeorological data is available for research and development activities and for statistical analysis.

The NWS has 13 regional RFC's that serve as the principal mechanism for developing warnings against floods. Each RFC is responsible for warnings within at least one major river system. The staff of each RFC prepares river and flood forecasts and warnings, and provides guidance to a network of 52 National Weather Service Forecast Offices (WSFO). Each WSFO redistributes this information to users in cities, counties, and States (including Puerto Rico) within its area of responsibility.

A new era of river and flood forecasting is beginning. Expanded use of telemetry at the USGS streamflow stations and refinement of telemetry equipment continue to improve the timeliness and reliability of data that are transmitted for forecasting purposes. The NWS is beginning a major modernization of its forecasting system—the Next Generation Weather Radar—a doppler-based system that is replacing conventional radar. Automated surface observing systems are replacing manual weather observations, and advanced telecommunications systems are improving the integration and distribution of data. Modernization of the NWS forecasting systems will result in earlier and better warnings of severe thunderstorms, tornadoes, winter storms and hurricanes, general flooding, flash floods, and water supply.

Scientific understanding of the Earth's atmosphere and technology for data communication continue to improve, but the need for hydrometeorological information and data for weather and river forecasting will not diminish. A principal basis for constructing, verifying, and executing streamflow-simulation models for river and flood-forecasting purposes is the raw hydrologic data from USGS streamflow stations. Without such data, the NWS mandate to provide river-flood forecasts for the protection of life and property would be greatly limited.

Schematic showing flow of data from a USGS streamflow station via the Geostationary Operational Environmental Satellite (GOES) to a Weather Service Forecast Office.



National Water-Quality Assessment: Public Outreach and Involvement

By Pixie A. Hamilton

The USGS began the National Water-Quality Assessment (NAWQA) program in 1986 to promote a better understanding of the quality of surface- and ground-water resources across the country. The NAWQA program is providing a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources, defining long-term trends (or lack of trends) in water quality, and identifying and explaining the major factors that affect observed water-quality conditions and trends. NAWQA combines investigations in 60 study units that represent a variety of geologic, hydrologic, climatic, and cultural conditions throughout the Nation. These study units are the building blocks for understanding regional differences in the physical, chemical, and biological quality of the Nation's surface water and ground water. Information from

Shaded areas show locations of NAWQA studies begun in 1991, the first phase of the national program. (None were begun in Alaska or Hawaii in 1991.)

the NAWQA program is needed to enhance the effectiveness of programs and policies that are designed to alleviate the Nation's water-quality problems.

An important goal is to ensure that key findings are available to meet public-information needs. A comprehensive public-outreach program promotes communication, information exchange, and cooperation between the USGS and the public sector, other interested scientists, water-management personnel, and interest groups.

Public outreach includes publications and audiovisual presentations, advisory and interagency groups, symposia, workshops, public meetings, and technology transfer and coordination. Some activities target local audiences that include citizens who are interested in how NAWQA findings might affect their lives and communities. Other activities reach policy makers and water managers at the U.S. Department of the Interior, Office of Management and Budget, Congress, and local, State, and Federal agencies who relate NAWQA findings to existing policy and other publicly funded programs. Each public-outreach method plays an important role in communicating information to public and private audiences. Some workshops, for example, are designed to communicate information on a broad, regional or national scale, whereas some are targeted to specific local areas and selected audiences. Some publications are written for technical research groups whereas others are written for general-interest audiences.

Publications.—NAWQA publications communicate information and important findings to as wide an audience as possible. Some NAWQA publications are produced by the USGS and others are produced in cooperation with other government agencies or the private sector. For example, NAWQA findings on the distribution of radon in the Carson River basin in Nevada are presented in a document produced in cooperation with the Nevada Cooperative Extension Service. The USGS is copublishing with EPA, Region 7, a listing of more than 700 references on water resources in the Platte, Loup, and Elkhorn River basins.

In addition, the USGS and the National Geographic Society have launched a collaborative effort to increase public understanding of the Nation's freshwater resources. As part of this joint agreement, NAWQA findings will be presented in selected publications and educational products produced by the National Geographic Society.

Audiovisual Presentations.—Videos are used primarily for educational purposes within school systems and in educational programs of local, State, and Federal agencies. For example, a video produced on the NAWQA study unit in Kansas, in cooperation with the Kansas State Board of Agriculture, has been distributed to more than 100 Kansas conservation districts and is part of an 8-hour Kansas certification course for chemical applicators.

Liaison Committees.—Each NAWQA study unit has a liaison committee whose members meet every 6 to 9 months to help ensure that the scientific information produced by the program is relevant to local and regional interests. The committees are composed of about 25 to 30 non-USGS members who represent a balance of technical and management interests. Represented organizations include Federal, State, interstate, and

Communication and coordination among the USGS and other interested scientists and water-management personnel are important components of the NAWQA program. To make best use of the resources available, we are committed to foster information exchange and cooperation among all relevant agencies through the duration of this long-term program. Every level of government and the private sector has a role to play.

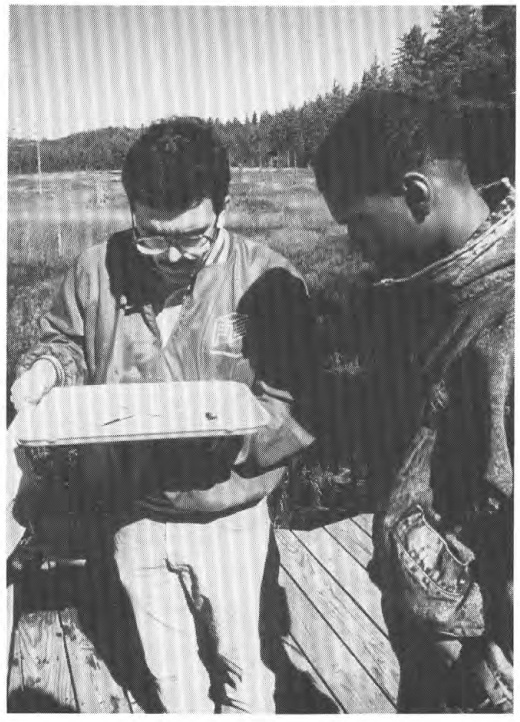
Philip Cohen,
USGS, Chief Hydrologist

local agencies, Native American tribes, public-interest groups, and universities. Liaison committee activities include exchange of information about water-quality issues of local and regional interest, relevant data and information, and project design and products. Notable NAWQA liaison committee efforts include surface-water monitoring and sampling in the Upper Illinois River Basin (Illinois Environmental Protection Agency); reservoir monitoring and sampling in the Trinity River Basin, Tex. (Tarrant County Water Control and Improvement District); and fish collection and identification in the Central Nebraska study unit (U.S. Fish and Wildlife Service (FWS)).

Federal Advisory Council.—This group was established to advise the USGS on making national aspects of the NAWQA program timely and appropriate for planning needs. Under the general auspices of the Interagency Advisory Committee on Water Data and the Advisory Committee on Water Data for Public Use, the work group advises the USGS on water-quality information needs of Federal and non-Federal agencies. Beginning in 1994, the Federal Advisory Council will play a key role in identifying national issues relative to pesticides, nutrients, and suspended sediment.

ROBERT J. SHEDLOCK

The Delmarva Peninsula study-unit liaison committee participates in a demonstration of NAWQA field-sampling techniques.



An Adirondack Park Interpretive Center scientist and high school student assess aquatic insects in monitoring water quality of streams. (Photograph by Keith Wheeler, Adirondack Park Interpretive Center.)

Interagency Agreements.—The USGS has established national interagency agreements with EPA, U.S. Department of Agriculture, and FWS that outline terms and conditions relative to the roles and responsibilities of the USGS and respective agencies in support of a fully implemented NAWQA program. For example, an individual from the EPA Office of Pesticide Programs has been detailed to the NAWQA national staff to help ensure that pesticide findings from the NAWQA program help to support the information needs of the regulatory community and the public. Similarly, several FWS scientists are working for the USGS on temporary duty status to provide support to NAWQA regional and national staffs to coordinate and provide technical support for biological field studies.

The USGS also has interagency agreements with local agencies. For example, the NAWQA study unit in the Hudson River basin in New York is working cooperatively with the Adirondack Park Agency to coordinate hands-on stream-quality monitoring by high school students. This educational outreach program provides an interdisciplinary learning experience for science teachers and students at several schools in the Hudson River basin and complements data collection for the NAWQA program. USGS personnel working on the NAWQA study unit in the Upper Snake River basin in Idaho and Wyoming are working cooperatively with personnel of the Soil Conservation Service who have initiated a national program to implement and evaluate agricultural crop-management practices.

Local Advisory Groups.—NAWQA findings that address water-resources issues are provided, often informally, to technical advisory groups within and adjacent to study units. These findings often become important components of local and State policy decisions. For example, NAWQA findings on the distribution of herbicides in surface water in the lower Kansas River basin in Kansas and Nebraska were used to establish the Delaware River Pesticide Management Area in Kansas. The NAWQA study of ground-water resources on the Delmarva Peninsula in Maryland, Delaware, and Virginia was used to help develop a comprehensive water-supply strategy for the Eastern Shore of Virginia. Findings on concentrations of DDT in streams and fish of the Yakima River basin, Wash., sparked a human-health-impact analysis by the Washington State Department of Health

to assess health threats to people who consume fish and drinking water in the basin.

Special Symposia and Workshops.—Symposia and workshops are organized by personnel of the NAWQA program to present NAWQA findings of national or regional emphasis. The NAWQA program personnel have coordinated special sessions within international organizations dedicated to water resources, such as the American Water Resources Association, American Geophysical Union, and the American Society of Civil Engineers, as well as hosting workshops at the New York Botanical Garden Institute of Ecosystem Studies on state-of-the-art methods for sampling biota in large rivers.

Special symposia and workshops are also coordinated in the individual NAWQA study units to address specific topics that are often narrow in scope or specific to a local area. Information is provided in the symposia and workshops to a technical audience, such as university researchers, to enhance basic research and development of methods and to an administrative audience, such as water-resource managers, to aid in local and regional decisions. For example, a 1-day symposium on the Central Oklahoma Aquifer NAWQA study unit was held in Oklahoma at the completion of the study in 1991, at which NAWQA study unit personnel, researchers at state universities, and water managers and health officials at local and State agencies presented papers.

Public Meetings.—Large meetings that are open to the public provide valuable information to local citizens interested in how NAWQA findings might affect their lives and communities. These meetings provide an opportunity for wide participation and education. Public meetings were used effectively in the Virginia part of the Delmarva Peninsula study unit, where more than 200 citizens gathered to learn about the quality and quantity of their ground water, which is the only source of water for drinking and irrigation on the peninsula.

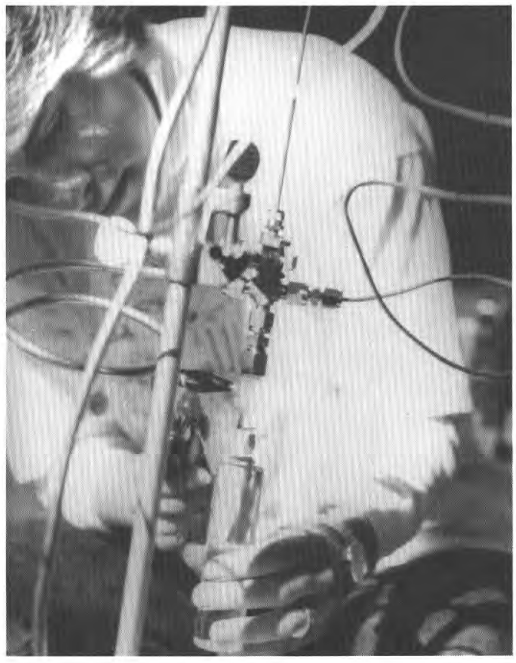
Technology Transfer and Coordination.—To ensure that NAWQA findings represent state-of-the-art science, the results, basic research, and development of methods by USGS researchers and by researchers from other organizations are coordinated within the NAWQA program. This coordination occurs at the local, State, national, and even international level. For example, exchange researchers from the People's Republic of China worked closely with NAWQA staff in sampling fish and biota in the Yakima River basin in Washington.

Facilitating the exchange of data among water-resource managers in Federal, State, and local agencies as well as with university researchers and extension personnel, and sharing results of these data through public-outreach programs, is a major mission of the NAWQA program and will remain so for the duration of the program.

CFC's—Tools for Age-Dating and Tracing Shallow Ground Water

By L. Niel Plummer and Eurybiades Busenberg

Shallow ground-water supplies are valuable and renewable resources that are often more susceptible to contamination than older, deeper waters. In developing management strategies for shallow ground-water systems, age-dating can be an extremely useful tool to define recharge rates, develop hydrologic models of ground-water systems, classify hydrogeologic environments on the basis of contamination potential, and estimate remediation times for contaminated ground-water systems. There are relatively few methods for age-dating ground waters that have recharged over the past 50 years and, until recently, none of those methods were successful for use in establishing regional or even local-scale patterns. USGS personnel have now developed a method to age-date ground water based on the chlorofluorocarbon (CFC) content of the water. This age-dating method is practical and suitable for most shallow ground-water systems.



L. NIEL PLUMMER

A hydrologist welds a water sample into a 50-cubic centimeter borosilicate glass ampule of the specially designed sampling apparatus that prevents contact between air and the water sample.

CFC's as Tracers and Age-Dating Tools

USGS scientists currently are extensively using CFC's as tracers and age-dating tools for shallow ground water in a number of locations throughout the United States. Some of these studies include using CFC's to

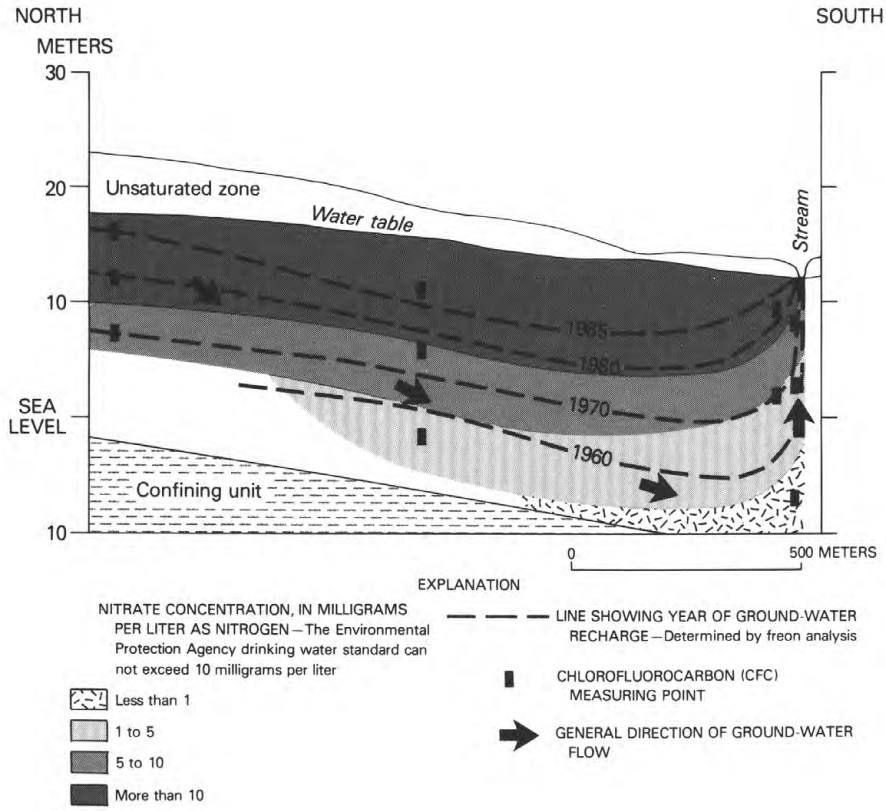
(1) trace recent recharge to the Floridan aquifer from the Withlacoochee River at Valdosta, Ga.,

(2) test models of flow in unconsolidated sands and gravels in the Atlantic Coastal Plain of southern New Jersey and in the Portland Basin in Washington and Oregon,

(3) study leakage to the Floridan aquifer relative to the extent of confinement in north-central Florida,

(4) trace the flow of contaminant plumes at the Idaho National Engineering Laboratory in Idaho and at Globe, Ariz., and

(5) investigate the hydraulics of ground-water flow in fractured rocks in New Hampshire.



Cross section showing relation of dissolved nitrate concentrations and CFC recharge ages of ground water that discharges at Chesterville Branch near Locust Grove, Md., in the north-central Delmarva Peninsula.

CFC-dating indicates that up to 30 years may be required to flush the present high-nitrate water from several small agricultural watersheds in the Delmarva Peninsula.

CFC's are stable compounds that are used as refrigerants, aerosol propellants, solvents, cleaning agents, and similar products. Concentrations of CFC's in the atmosphere have steadily increased since they were first introduced in the 1930's. Although CFC's are detrimental to the atmosphere, they are a valuable tracer of recently recharged ground water because they are soluble in water and enter ground water during the recharge process. By using CFC solubility data and data on the fluctuation of CFC's in the atmosphere, recharge ages can be determined from the amount of CFC's in ground-water samples.

Field studies conducted on the Delmarva (Delaware-Maryland-Virginia) Peninsula and in central Oklahoma, in conjunction with pilot NAWQA projects, have defined advantages and limitations of CFC dating. CFC dating is best suited for relatively rural environments because localized contamination, such as from septic systems, sewage effluent, or urban runoff, can contain CFC concentrations well in excess of that of atmospheric sources. Although CFC's are very stable compounds, evidence suggests that microbes can degrade CFC's in some anaerobic (oxygen-free) environments. Nevertheless, the CFC dating method appears to work well in shallow, aerobic, sand aquifers that are low in particulate organic matter. Preliminary indications are that CFC dating can be accurate within several years for this type of environment.

More than 100 wells in the Delmarva Peninsula NAWQA study site were sampled for CFC's between May 1989 and November 1991. Results indicate that ground-water recharge on the Delmarva Peninsula occurs predominantly from December through March. The CFC ages of ground water on the Delmarva Peninsula are consistent with tritium data, as well as with the known hydrology and the known dates of the introduction of nitrates and pesticides to the Delmarva Peninsula. For example, water from depths of approximately 15 feet (4.6 meters) at the Fairmont watershed in the east-central Delmarva Peninsula was recharged in the mid- to late-1980's and is approximately 10 to 20 years younger than water from depths of from 50 to 80 feet (15–24 meters). Throughout the Delmarva Peninsula, CFC dating indicates that the vertical component of ground-water movement ranges from 1 to 2 feet (0.30–0.61 meter) per year.

A cross section of CFC recharge ages and nitrate concentrations from an agricultural area near Locust Grove, Md., in the north-central Delmarva Peninsula, shows that water recharged since the early 1970's exceeds the EPA drinking water standard for dissolved nitrate and indicates the increased rate of application of nitrogen fertilizers, which began in the early 1970's. Water recharged prior to the early 1970's has lower nitrate concentrations. CFC dating indicates that ground water now discharging to streams that drain agricultural areas of Delmarva, as well as to coastal areas of Chesapeake Bay and the Atlantic Ocean, was recharged in nearby fields in the 1960's and 1970's. This ground water has lower levels of dissolved nitrate than does more recently recharged ground water from the same areas. Even if the application of nitrate to the fields stopped today, streams, rivers, and estuaries will continue to receive increasing amounts of nitrate from ground-water discharge until the contaminated water is flushed through the system. CFC dating indicates that up to 30 years may be required to flush the present high-nitrate water from several small agricultural watersheds in the Delmarva Peninsula.

In central Oklahoma, water discharged from deep (400–800 feet (122–244 meters)) municipal supply wells in the central Oklahoma aquifer indicates that some mixing of shallow ground water with deep and presumably old water is induced by pumping. In this case, CFC's can be a valuable tracer for testing hydraulic seals of municipal water wells. Some of the shallow water from the alluvium and

terrace aquifer system in central Oklahoma has recharge ages ranging from the early 1950's to the mid-1970's. The distribution of CFC recharge ages in the alluvium and terrace system corresponded to the wetter periods of 1945 to 1960 and 1967 to 1975, whereas fewer mid-1960's recharge ages suggest that less recharge occurred in central Oklahoma during this drought period.

Detectable concentrations of CFC's were also found in the Snake River Plain aquifer beneath the Idaho National Engineering Laboratory (INEL) in southeastern Idaho. CFC recharge ages ranged from 4 to more than 50 years, with most waters having recharge ages between 20 and 30 years. The ground water CFC concentrations were not in equilibrium with the unsaturated zone air, which indicates that recharge does not occur at the INEL by slow percolation through the unsaturated zone. Temperatures derived from permanent gas solubilities in ground water suggest that the Snake River Plain aquifer at the INEL is recharged locally rather than at higher elevations that would have cooler soil temperatures and correspondingly cooler water temperatures. These observations yield important information concerning the recharge mechanism: apparently, most recharge at the INEL occurs during floods in the Big Lost River, Little Lost River, and Birch Creek. CFC concentrations in ground water are in equilibrium with the shallow soil air; this indicates that water passes rapidly through the fractured basalts to the water table, which minimizes reequilibration with the air in the deep unsaturated zone.

There are limitations to CFC dating of ground water, but when CFCs are present, they indicate that the water sample contains at least some post-1940's water. This fact alone points to CFC's as valuable tracers of recent recharge.

Glen Canyon Environmental Study

By J. Dungan Smith and Robert H. Webb

The Glen Canyon Dam impounds the Colorado River near the Utah-Arizona border to create Lake Powell, with the dam controlling the river's flow and suspended-sand transport as it flows through the Glen Canyon National Recreational Area and Grand Canyon National Park. The release of water from Glen Canyon Dam exerts a strong influence on the ecological characteristics of the river corridor in a unique and fragile environment.

USGS scientists have been studying the flow, sediment transport, and geomorphic processes in this river. Their work is a component of a large interagency study of the reach of the Colorado River between Lake Powell and Lake Mead. The study is designed to provide scientific information for an Environmental Impact Statement on the effects of Glen Canyon Dam. The interagency study, Glen Canyon Environmental Study II (GCES-II), is being conducted in cooperation with the Bureau of Reclamation (BOR), and is a follow-on to a pilot study that was conducted in the mid-1980's.

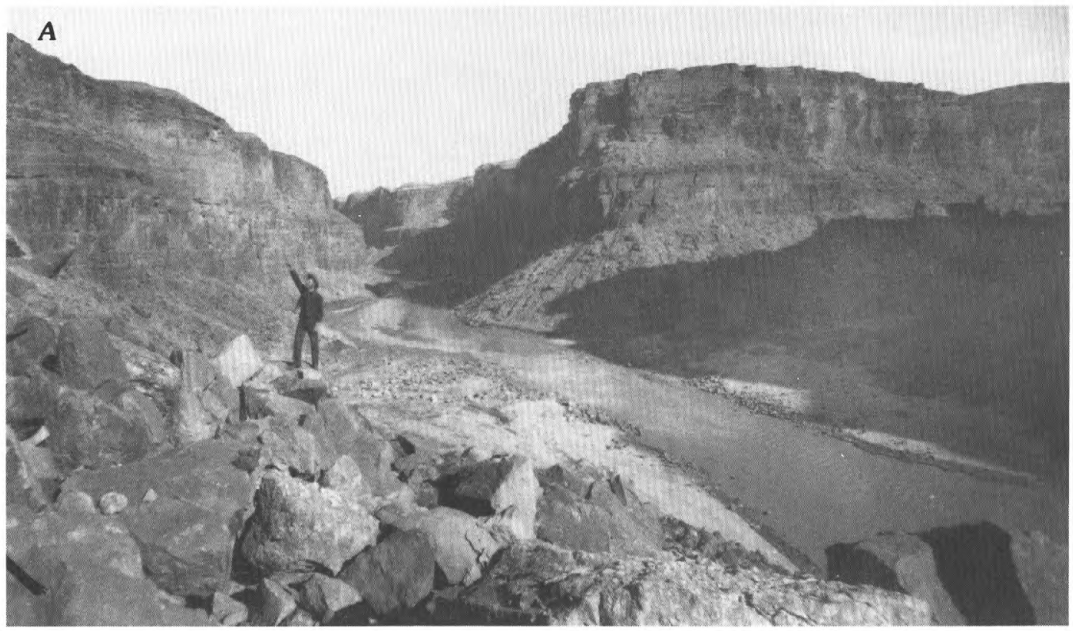
Information about the flow, sediment transport, and geomorphological processes in the Colorado River between Lake Powell and Lake Mead relative to the regulated discharge from Glen Canyon Dam forms the foundation for assessing the environmental impact of typical and proposed water-release scenarios. For example, daily increases and decreases in discharge from the dam control the characteristics of the discharge "wave" as it moves downstream. The effect that this wave has on the transport of suspended sand and on erosion and deposition on specific

Repeat Photography of the Grand Canyon and the Colorado River

The Grand Canyon and the Colorado River have been photographed during many expeditions. The Robert Brewster Stanton expedition, in winter 1889–90, had as its purpose systematic documentation of the river corridor in order to determine the feasibility of a railroad within the Grand Canyon. Professional photographer Franklin Nims was seriously injured in a fall on January 1, 1890, only 15 miles (24 kilometers) into Grand Canyon, so Stanton, who had never before used a camera, finished photographing the remaining 265 miles (426 kilometers) of river.

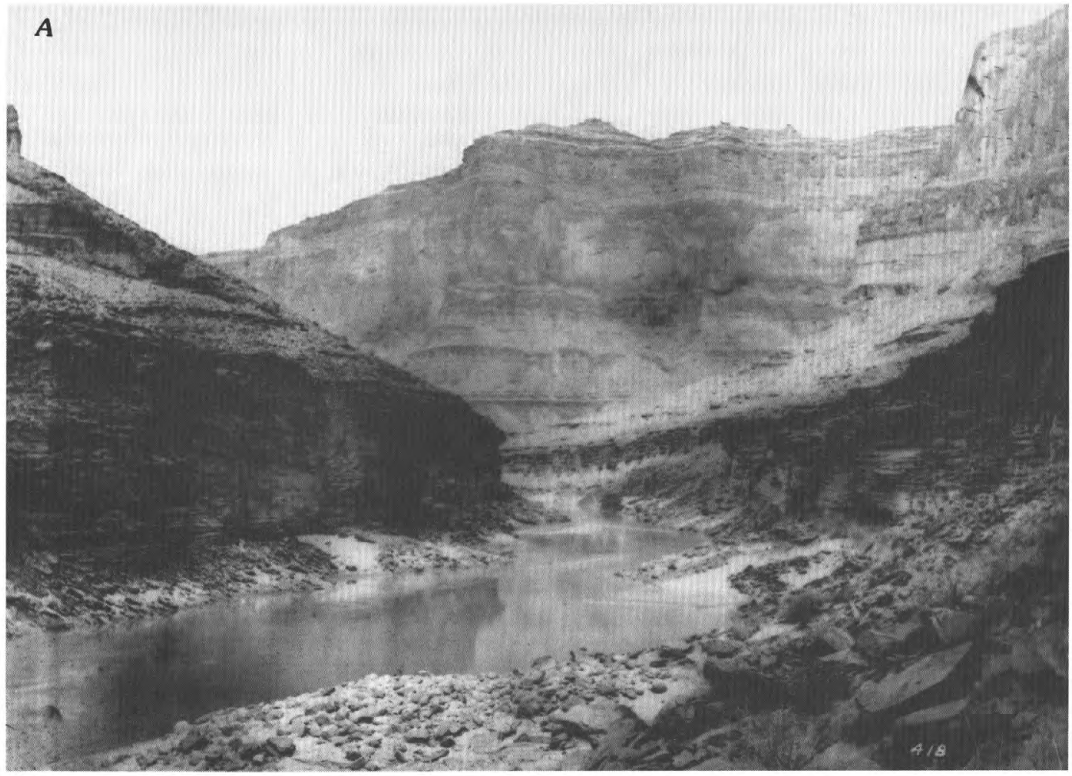
During winters 1990, 1991, and 1992, most of the 446 Stanton photographs were replicated. Comparison of 400 views shows numerous environmental changes over the intervening century, including a cessation of extreme frost after 1890. Also, 40 species of shrubs, grasses, and cacti that can persist as individuals for more than a century are documented. Closure of Glen Canyon Dam in 1963 caused substantial changes in the river corridor through the Grand Canyon because postdam clear-water releases eroded many of the sand bars that had been deposited previously by the sediment-laden river. Comparison of views taken a century apart reveal that in a sample of 557 sand bars, the amount of erosion decreases with distance downstream from Glen Canyon Dam. Although more than 90 percent of the sand bars near the dam show erosion, about equal numbers of sand bars have eroded and aggraded at distances greater than 160 miles (256 kilometers) downstream.

Badger Rapid, at mile 8.0 on the Colorado River.



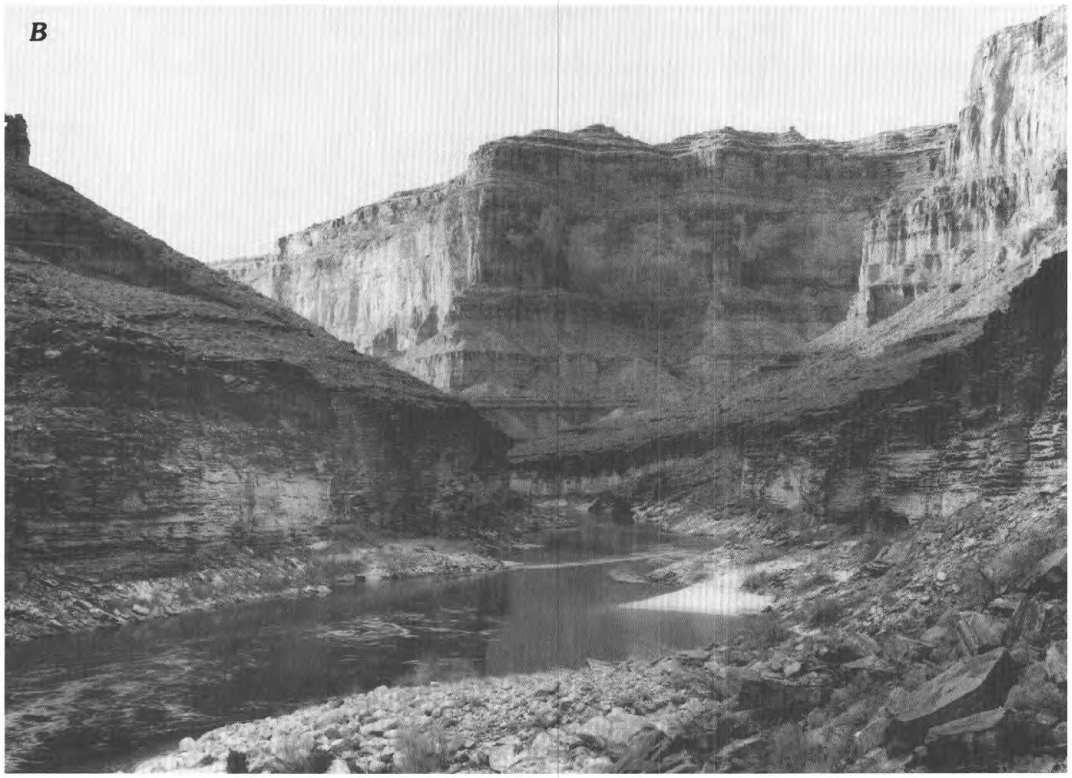
A, Badger Rapid is the first major rapid in the Grand Canyon downstream from Glen Canyon Dam. Professional photographer Franklin Nims took this photograph on December 28, 1889, during the Robert Brewster Stanton expedition to document the feasibility of a railroad route through the Grand Canyon. The railroad would have traversed the base of the cliffs on the right. Nims' view shows the entire rapid. Jackass Canyon, sand bar, and debris fan are middle right in the photograph, and Badger Canyon fan and sand bar are in the middle of the photograph. (See B, facing page, for comparison.)

At mile 119.0 on the Colorado River.



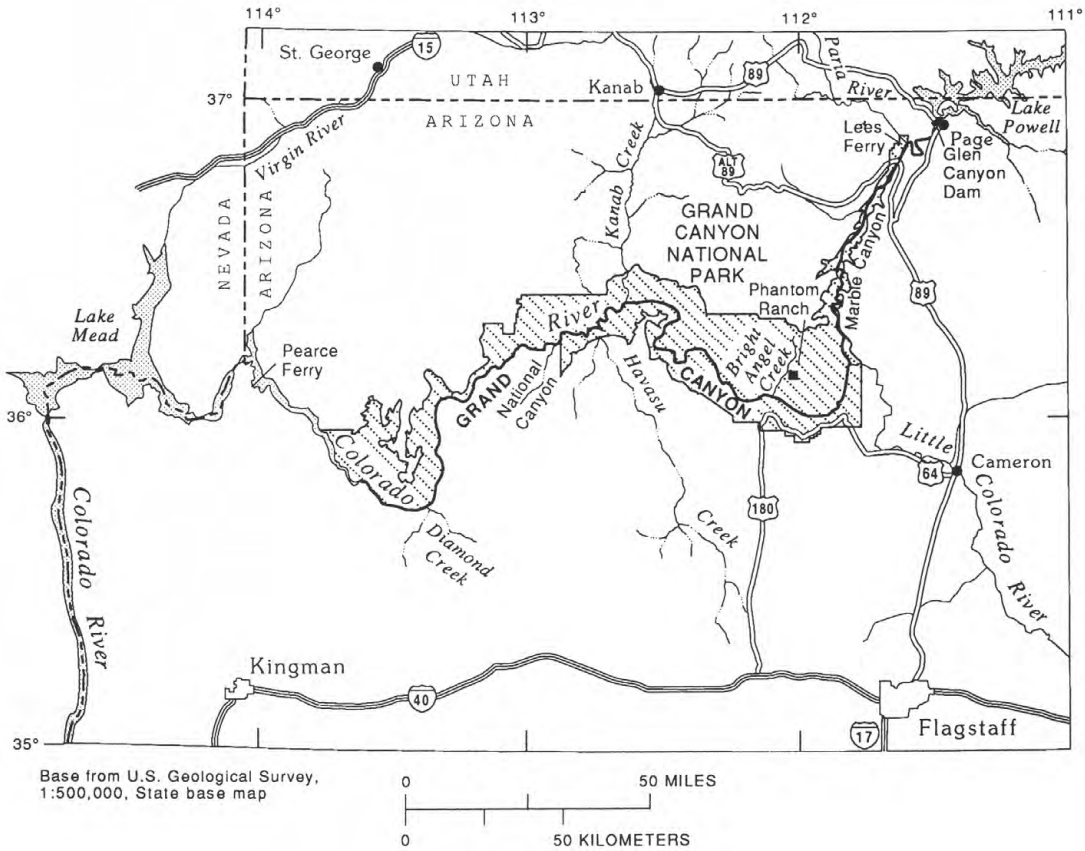
A, Reaches of the Colorado River in the Grand Canyon where Tapeats Sandstone is at river level typically have calm waters and only small rapids. In this downstream view at mile 119.0, several small riffles and quiescent eddies reflect these typical conditions. On February 20, 1890, after Nims was injured, Robert Brewster Stanton took this photograph to document his proposed railroad route, which would have traversed the right side of the river (and view) at the base of the first cliff above the river. (See B, facing page, for comparison.)

B, David Edwards replicated Nims' view on January 30, 1991. The Colorado River is several feet higher in 1991 than it was in the 1889 view. The camping beaches at Badger Rapid, which are heavily used by hikers and tourists rafting down the Colorado River, are significantly affected by dam operations because they are only 23 miles (37 kilometers) downstream from Glen Canyon Dam. The sand bar on the Jackass Canyon side has been studied for many years to determine processes of deposition and erosion of sediment. Several rocks that have monumented benchmarks in them show that the sand bar downstream from Jackass Canyon has lost 5 feet (1.5 meters) of sand since 1890. Tamarisk trees, which appear only in the 1991 view, are non-native invaders. The largest clumps at lower center germinated about 1938. From this distance, the rapid does not appear to have changed significantly, but other historic views show that a debris flow occurred between 1897 and 1909 in Badger Canyon and deposited the rocks that form a navigation obstacle at the upper right center of the rapid.



B, Ralph Hopkins replicated Stanton's view on February 3, 1990. The sand bar at right center appears to be about the same size as it was a century ago. Some sand bars in the view have eroded, whereas others have aggraded or are covered with riparian vegetation. About here, 135 miles (217 kilometers) downstream from Glen Canyon Dam, the widespread erosion characteristic of the upper half of the river corridor shifts to a more complex mixture of eroded, aggraded, or similar-looking sand bars.

Location map of Glen Canyon Dam in relation to Lake Powell and the Grand Canyon.



Information from these scenarios will be used by the BOR to develop operational procedures that are both environmentally sensitive and economically reasonable.

sand beaches is of considerable environmental concern. Another concern is coarse sediment carried from small steep tributaries to the main channel, because deposits from these catastrophic flows can bury camping beaches and riparian habitats and can block the river and produce new rapids. Information from these scenarios will be used by the BOR to develop operational procedures that are both environmentally sensitive and economically reasonable.

The Colorado River, like many rivers downstream of large dams, is cut deeply into bedrock, which controls many features of the river system. Rock falls from the steep valley walls result in irregular banks of coarse, poorly sorted talus along most of the channel, as well as many relatively short steep tributaries that intermittently contribute coarse, poorly sorted material to the main channel near the tributary mouths. Deposits from occasional large debris flows and floods partially block the main channel. These deposits produce pools on the upstream side, rapids over the top of the deposits, large deposits of sand (eddy bars) on the downstream edges, and downstream pools, which during normal flows are filled with materials transported through the rapids but are washed out during floods.

The fluctuations in water discharged from a dam and the quality (temperature, type of sediments, organic materials, and water chemistry) of that released water are the predominant influences on the riverine and riparian environments below the dam. Usually water quality is established by the way water is released from the reservoir. For example, water released from the bottom of a reservoir may be colder, oxygen deficient, and sediment laden relative to water released from the surface of the same reservoir. Because the downstream environment will evolve toward a condition of equilibrium as established by the discharge history of the dam over a prolonged period of time, it is possible to determine the effects that different operational scenarios will have on the downstream environment.

Glen Canyon Dam is operated to meet the hydroelectric power needs of the southwestern United States. It is critical that the computer model of daily fluctuations in river stage accurately reflects the changes in discharge that relate to fluctuating amounts of hydroelectric power usage. Changes in river stage control the water table near the stream, affect the stability of sand bars, control the rates of encroachment of plants onto the new eddy bars, and affect the rates of wind erosion and movement of sand on the beaches.

The Colorado River between Lake Powell and Lake Mead is characteristic of a gravel-bedded river system, but it has transported a significant amount of suspended sediment before and after the Glen Canyon Dam was

built. When the dam was completed in 1963, the major supply of sand to the system was cut off, and the annual sediment load at the Grand Canyon stage gage was reduced from 90 to 14 million tons (82 to 13 million metric tons) per year. The annual peak flow was reduced commensurately, however, and the distribution of sand in the system appears to have reached equilibrium with the reduced flow by 1980. About 30 percent of the channel bed was covered by sand before the dam was built, and only a slightly smaller fraction of the channel bed appears to be covered by sand at the end of 1991.

Coarse, rapidly drained talus predominates along the channel margin, and sand deposited at high stage near the edges of the river is important to plants and for people rafting down the Colorado River through Grand Canyon National Park. Thin bands of sand along the channel margin provide a substrate for the most dense riparian vegetation, large unvegetated sand deposits downstream of rapids provide some of the best camping beaches, and the vegetated beaches provide marsh habitat for birds and warm backwaters for native fish.

At moderate to high stage discharges, sand in the mainstream is transported in suspension and is continually exchanged with the sediment in the river bed and the eddy bars. As the stage rises, sand accumulates more rapidly than it is lost when the stage falls, which means that short periods of high discharge can be used to build up sand deposits. These beach-building flows, however, must be repeated every several years. Maintenance of high-elevation sand bars, which dominated the river system before the dam was closed, is extremely important because these beaches are necessary for recreation and riparian habitat. High stage discharge also removes a substantial amount of sand from the system, so the discharge must be timed carefully so as not to remove more sand from the Colorado River than is added to the river reach downstream from Glen Canyon Dam from floods in the Paria and Little Colorado Rivers between beach-building events.

The USGS component of GCES II is to model the response of a downstream environment to the water-release history of a dam and to obtain the flow data necessary to test and prove the model. Data on the rate of addition—by debris flows and floods—of coarse sediment to the main channel and recirculation zones of the Colorado River and the effect on the eddy beaches of the discharge wave—generated daily in response to electricity demands in the regional network—are providing the foundation for the environmentally sensitive operation of large dams with a minimum loss of revenue.

USGS Continues Coordination of Water-Resources Information

By Nancy C. Lopez and Paul V. Dresler

Within the United States, water-resources data and information are collected by thousands of Federal, State, and local agencies, public interest groups, Native Americans, and private groups and individuals at a cost of several billion dollars annually. Federal agencies collect water-resources information to meet their individual mission requirements, such as pollution control, weather forecasting, emergency response, natural-resource management, regulatory enforcement, and basic research. The Federal-State Cooperative program, for example, which constitutes more than 40 percent of all USGS water-resources activities, promotes working partnerships between the USGS and more than 1,000 Federal and non-Federal organizations, resulting in the operation of more than 50,000 water-measurement sites throughout the Nation. In addition, non-Federal agencies, local and private organizations, and public interest groups use water-resources information to manage and protect the resource and ensure that established standards and regulations are achieved.

Existing water-information acquisition and dissemination methods meet some, but not all, needs for decisionmaking at the Federal, regional, State, and local levels and in the private sector. Identifying opportunities to improve the effectiveness of water-information activities requires extensive communication and collaboration among collectors and users of water-resources information. Previously, coordination efforts were primarily focused on coordination at the national level. The recognition that future water-information needs are more likely to occur at the State and local levels rather than at the national level, however, has resulted in interagency and intergovernmental coordination efforts that are ensuring that water-resources information needs can be met at all levels.

On December 10, 1991, the Office of Management and Budget (OMB) issued Memorandum No. M–92–01 that directs the Federal Government to coordinate water-information activities. The OMB memorandum sets the requirements and objectives for the establishment of a Water Information Coordination Program (WICP) to ensure effective decisionmaking for the management of natural resources and protection of the environment at all levels of government and

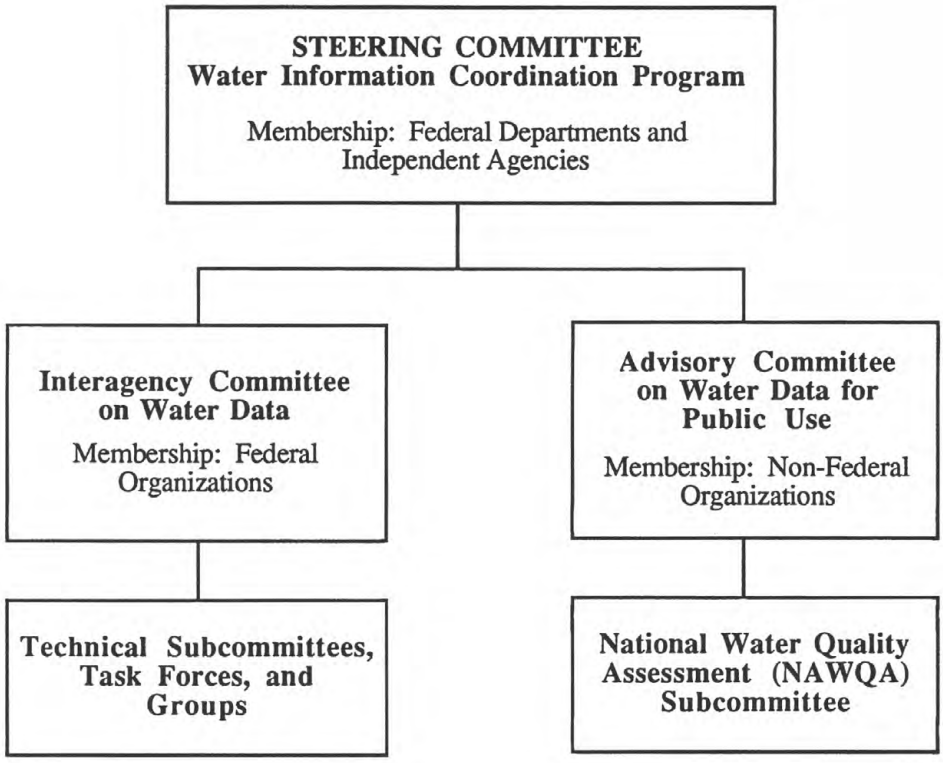
in the private sector. Lead responsibility for implementing the OMB memorandum was assigned to the USGS, which has historically been the Nation's principal agent for water-data acquisition. The new OMB memorandum supersedes OMB Circular A–67 on water-data coordination that was signed in 1964.

Implementation of the OMB memorandum, through the establishment of the WICP, will encourage and promote partnerships among water-resources information collectors and users at all government and nongovernmental levels, avoid duplication of efforts, result in more effective and economical natural-resource management, support environmental protection, and make better use of available resources to meet the Nation's water-information requirements. An important objective of the WICP is to coordinate the development of data-collection guidance to field operations on the best methods for collecting, analyzing, and reporting water-resources information.

The WICP also will promote interagency collaboration to establish data and information archives that are interlinked and accessible. These archives need to contain information sufficient to qualify and interpret the data holdings and identify the status, quality, and location of water-resources information. Achievement of these goals will be accomplished by focusing on four interrelated activities:

- Water Information Program Review.—Reviews water-information collection and dissemination programs for effectiveness and needed changes.
- National Water Information Network.—Develops plans and priorities to adjust existing national water-resources information collection to meet current and future needs more effectively and efficiently.
- Water Information Standards Development.—Develops, accepts, and disseminates water-information standards and establishes mechanisms to evaluate and test sampling and analytical methods that will produce comparable results.
- National Water Information Clearinghouse.—Develops archiving procedures for government and the private sector and for public access to available data and interpretive products.

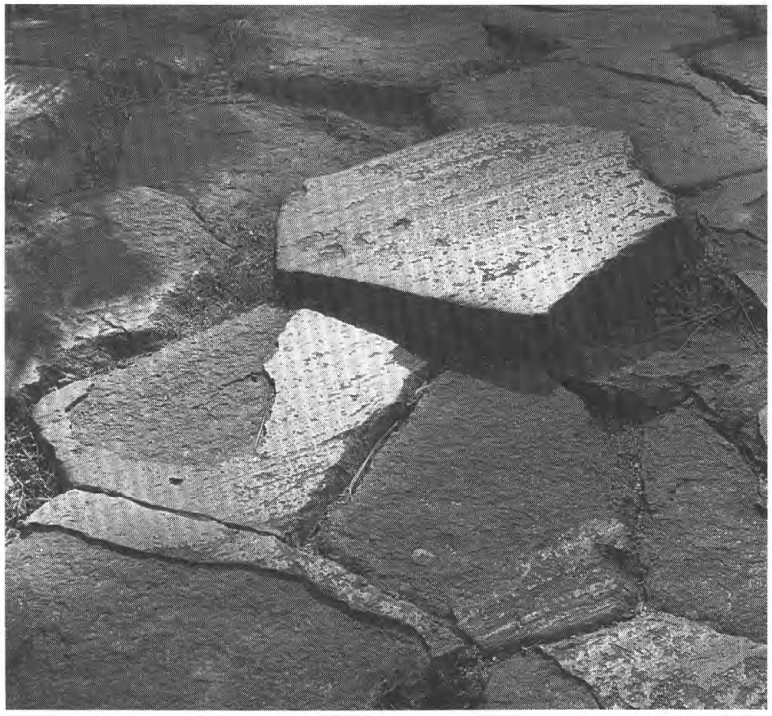
It is through the establishment and maintenance of a strong partnership among all members, Federal and non-Federal, of the water-resources information community that effective water-resources decisionmaking, based on reliable and accurate information, may be achieved for the Nation, States, and local communities. The USGS leads the effort to coordinate these partnerships and to provide water-resources information that is responsive to the public need.



Organization of the Water Information Coordination Program (WICP)

WICP is structured to improve collaboration and coordination among all members of the water-resources information community. The WICP Steering Committee, which is composed of subcabinet-level Federal agency officials, will oversee the implementation of the OMB memorandum. A Federal Interagency Committee on Water Data reports to the Steering Committee. Through its task forces and groups, the Interagency Committee on Water Data focuses on specific technical aspects of water-resources information collection and dissemination. An Advisory Committee on Water Data for Public Use parallels the Interagency Committee. The Advisory Committee is composed of representatives from the non-Federal sector who will advise the Steering Committee on non-Federal water-resources information holdings and requirements and will review existing Federal programs and advise the Steering Committee as to how the Federal programs meet the needs of the non-Federal community.

GEOLOGIC INVESTIGATIONS



PHOTOGRAPH USE COURTESY OF PAUL STONE

MISSION

The Geologic Division evaluates the Nation's geologic structure and the geologic processes that have shaped it, assesses the Nation's mineral and energy resources, and identifies and investigates geologic hazards.

- Investigations of geologic hazards provide information for predicting and delineating hazards from earthquakes and volcanoes and for identifying engineering problems related to ground failure hazards.
- Regional geologic studies provide geologic maps and regional syntheses of detailed geologic data essential to mineral, energy, and hazard assessments and to land use decisions such as landfill siting and selection of transportation routes.
- Offshore geologic studies identify and describe the mineral and petroleum resources of the offshore areas of the United States, including the Exclusive Economic Zone, an area one-third larger than the land area of the United States.
- Mineral-resource investigations assess the distribution, quantity, and quality of the Nation's mineral resources required for making land use decisions by Federal, State, and local land-management agencies.
- Surveys of energy resources provide assessments of the Nation's coal, petroleum, uranium, and geothermal resources and enhance capabilities to explore for and develop new sources of energy.

Message from the Chief Geologist, Geologic Division

The mission of the Geologic Division provides us with many challenges as we seek to provide the public with valuable information about the application of earth science data to our Nation and our planet.

Two of these challenges are to monitor natural hazards and to conduct extensive research that will help us to understand their causes and to mitigate their hazardous effects. In fiscal year 1992, the USGS responded to several large natural disasters including the Landers-Big Bear earthquakes in southern California, the ongoing volcanic activity of Mt. Spurr volcano in Alaska, and Hurricanes Andrew and Iniki, which devastated parts of Florida, Louisiana, and Hawaii.

The growing need for geologic map data in land use decisions, in identification and investigation of geologic hazards, in resolution of environmental issues, and in energy and mineral-resource assessments is reflected in passage of the National Geologic Mapping Act of 1992. Through this Act, the USGS is designated the Federal agency responsible for planning, coordinating, and managing the National Geologic Mapping Program. To implement the provisions of the Act and to develop closer partnerships with State Geological Surveys and other members of the geologic mapping community is our focus for fiscal year 1993.

Ocean-floor sediment pollution is an area of great environmental concern. In fiscal year 1992, the USGS carried out investigations of low-level radioactive-waste dumping in the Farallon Islands in San Francisco Bay and sludge dumping in the offshore areas of metropolitan New Jersey and New York.

The Nation needs energy and mineral resources to sustain its economic growth and to promote national security. Division resource-assessment programs provide credible, unbiased estimates of undiscovered domestic energy and mineral resources. In fiscal year 1992, we began planning for the next national energy resource assessment, which is being conducted in cooperation with the Minerals Management Service and State Geological Surveys. Mineral-resource activities included USGS sponsorship—in cooperation with the U.S. Bureau of Mines and State Geological Surveys of Minnesota, Illinois, Indiana, Michigan, North Dakota, Ohio, South Dakota, and Wisconsin—of a workshop to develop a balance between preservation of the environment and the increased need for industrial minerals to rebuild aging roads, bridges, buildings, and other structures in the Midwest.

The Geologic Division is striving to increase its outreach and technology transfer to the public and private sectors. Much emphasis is being placed on identifying our customers and their needs, improving productivity and publication timeliness and quality, and inspiring leadership and team spirit throughout the division.

Benjamin A. Morgan III

Southern Lake Michigan Coastal Erosion Study

By David W. Folger

About 15 percent of the U.S. population and 50 percent of Canada's population live along or near the 9,000-kilometer-long (5,500-mile-long) coastline of the Great Lakes. Eighty-three percent of the shoreline is privately owned. Erosion and flooding of this coastline, often associated with periodic high lake levels, have resulted in extensive damage to domestic, recreational, and industrial facilities.

Because of fluctuating water levels in the Great Lakes, hundreds of millions of dollars have been lost by the 40 million people who live in the Great Lakes Basin and the many vital industries that are located there. During each episode of high lake levels, bluff erosion increases, beachfront property is lost, and structures and beaches are submerged. During each intervening episode of lower lake levels, navigation channels and harbors require extensive dredging of sediments that are commonly polluted, hydroelectric output decreases, the load on freshwater-pumping facilities increases, and sewage-disposal problems become more complex.

Since the turn of the century, levels of Lake Michigan have been increasing in a series of peaks—each higher than the last—culminating in 1985–87, when high waters flooded the streets of Chicago and caused extensive coastline erosion. As a result of the

damage, a 5-year study was initiated to document the timing and magnitude of prehistoric lake-level fluctuations and to assess the geologic processes causing the severe erosion of the Illinois-Indiana shoreline.

The Southern Lake Michigan Coastal Erosion Study has been a cooperative effort, involving research and technical personnel from USGS offices in Woods Hole, Mass., St. Petersburg, Fla., Denver, Colo., Menlo Park, Calif., and Reston, Va., and from the Illinois State Geological Survey, Indiana Geological Survey, Indiana University, Purdue University, Northeastern Illinois University, University of Wisconsin, Oregon State University, University of Washington, University of Rhode Island, and the Woods Hole Oceanographic Institution.

. . .wide fluctuations in lake levels related to climate in the future are not only possible but probable.

The work, started in 1987, was divided into three parts—geologic framework studies, lake-level studies, and process studies:

Geologic Framework Studies involved the collection of geophysical data, including single-channel seismic surveys to determine the thickness and distribution of the surface layers and sidescan sonar to determine, with bathymetric data, the physiography of the lake bottom and, with sample data and SCUBA observations, the areal distribution of various bottom sediment types. Sidescan sonar was also used to assess the condition and extent of damage to shore protection revetments along the Chicago waterfront. In addition, profiles of sand thickness on beaches and lake bottom were measured at 700 locations along 50 transects off the Illinois-Indiana shore. A hydraulic probe was used to penetrate as much as 12 meters (39 feet) into the sandy sediment from the beach to as far as 550 meters (1,800 feet) offshore on each transect. This study resulted in the most complete characterization of the thickness and distribution of the nearshore sand wedge available.

Location of the southern Lake Michigan Coastal Erosion study area.

Lake-Level Studies involved extensive single-channel seismic surveys of much of the deep southern basin of the lake to map the lake deposits and to guide the placement of piston cores. The sediment in this extensive collection of cores contains a record of prehistoric age, climate, and environment. The study in the lake basin was complemented by several detailed studies of exposed beach ridges and modern high-water deposits around the lake margin to document the age, frequency, and magnitude of high water levels.

Process Studies involved measurements and studies of bluff recession, evolution of beaches, effects of manmade structures on erosion and sand transport, the role of wind in removing sand from the nearshore system to form massive dunes such as those in the Indiana Dunes National Lakeshore, and the role of ice in eroding and protecting the coast. A model—derived from this information showing the sources, pathways, and sinks for the nearshore sediment—is essential to predicting the future of this coastline.

Important highlights of the results of the study include

- Sidescan sonar shows conclusively where, how, and why the revetments protecting the Chicago lakeshore are failing. Remedial designs based on this information are now being implemented.
- The lake-level studies show that prehistoric fluctuations have been as much as 3 meters (10 feet), almost twice as great as the 1.6-meter (5-foot) difference between the 1964 low level and the 1986 high level. One such high level occurred in the 1600's before the Great Lakes region was extensively settled by Europeans. Thus, wide fluctuations in lake levels related to climate in the future are not only possible but probable. The impact of global warming, due to increased CO_2 and the greenhouse effect, on the magnitude and frequency of these water-level cycles in the Great Lakes is still uncertain.
- Bluff retreat between Wilmette and Waukegan varies from 10 to 75 centimeters per year (4–30 inches per year) and averages 20–25 centimeters per year (8–10 inches per

Chicago, like many coastal cities in the United States, is particularly vulnerable to high lake levels and severe storms.

year). Erosion rates north of Waukegan, however, have been as high as 3 meters per year (10 feet per year).

- Sediment eroding from bluffs provides most of the sand to the nearshore zone. As people build more structures to protect the bluffs, less sand will be available to the system. As a result of this situation, at least in part, the nearshore sand wedge has dramatically decreased in volume during the last two decades. As the sand supply dwindles, more of the underlying finer textured lakebed will be exposed to wave attack, and coastal retreat will accelerate.
- Ice ridges as high as 7 meters (23 feet) that form along the lakeshore do not effectively protect the shoreline from winter erosion, as previously thought. Commonly, many ice ridges form and break up each winter along much of the shoreline; significant amounts of sand are trapped in floating fragments of ice and carried not only alongshore but offshore into the deep water. This continuing natural process is one of the principal mechanisms by which sand is lost from the nearshore system.
- The Indiana Dunes National Lakeshore, at the southernmost tip of Lake Michigan, appears to have been a major sink in the past for sand moving southward along the nearshore on both sides of the lake. Sand accumulating on broad beaches is blown inshore by strong winds from the north to form the dunes. Because scientists observed so little sand nearshore from Waukegan, Ill., to Gary, Ind., the main contribution to the dunes now is probably the eastern shore rather than both eastern and western shores of the lake.

A summary volume containing 16 papers covering most aspects of the study will be published by the International Association of Great Lakes Research and will serve as an easily accessible source for researchers, engineers, coastal managers, and municipal planners in the southern Lake Michigan area.

DAVID FOLGER

Ice ridges cause significant erosion of the Lake Michigan shoreline in winter, rather than protecting it as previously thought.

Volcanic Ash and Aircraft

By Thomas P. Miller

More than 40 active volcanoes are located along Alaska's southern coast, in a 1,500-mile-long (2,400-kilometer-long) belt extending from Cook Inlet and the Alaska Peninsula through most of the Aleutian Islands. Although this chain of volcanoes averages one to two eruptions per year, most of them are remote and their hazard has hitherto been thought to be minimal.

Recent eruptions of three volcanoes on the west side of Cook Inlet, however, have significantly affected the safety and commerce of 60 percent of Alaska's population, as well as domestic and international air travel. The 1989–90 eruption of Redoubt volcano, for example, caused an estimated $160 million in economic losses, principally to aircraft and to oil production revenues. The near-tragic encounter between a Boeing 747 jet and volcanic ash 180 miles (290 kilometers) downwind from a major eruption of Redoubt on December 15, 1989, emphasized how vulnerable modern jet aircraft engines are to shutdown caused by intake of volcanic ash. Even remote volcanoes can pose a hazard to life and property hundreds of miles away. Ash from the 1992 eruption of Mount Spurr volcano was reported as far away as Sitka, 760 miles (1,200 kilometers) southeast of the volcano.

The USGS recognized the potential for hazardous eruptions in Alaska following the 1986 eruption of Augustine volcano, 180

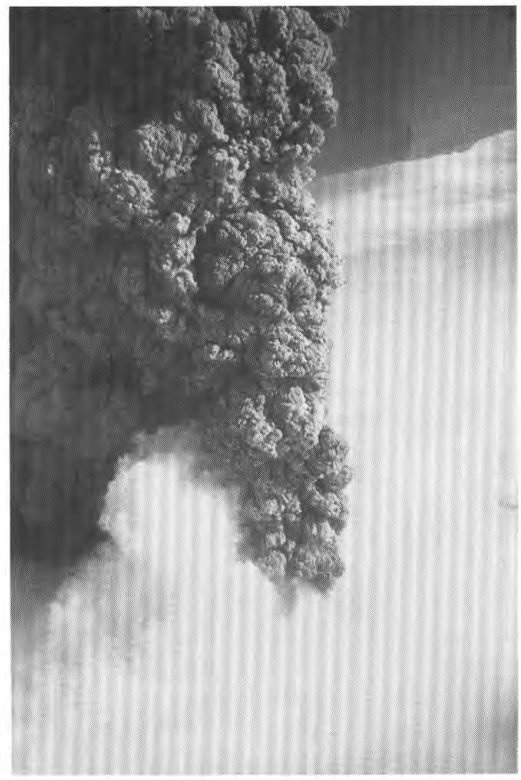
miles (290 kilometers) southwest of Anchorage, and formally established the Alaska Volcano Observatory (AVO) to study these little-known volcanoes in 1988. To make effective use of existing facilities and expertise, AVO was established as a cooperative venture consisting of scientists and facilities of the USGS, the Geophysical Institute of the University of Alaska, Fairbanks, and the Alaska Division of Geological and Geophysical Surveys.

Although AVO depends on a number of techniques for monitoring active volcanoes, the primary surveillance technique in the area around Anchorage and Cook Inlet (where four historically active volcanoes are found) is seismic monitoring. When molten rock moves through the Earth's crust before an eruption, swarms of small earthquakes mark its advance. As a result, short-term predictions can be made of many impending eruptions. The network of seismographs around Cook Inlet volcanoes and new seismic-recording and analysis systems that run on small personal computers permit accurate, timely interpretation of the seismicity, which is critical to determining the volcano's state of activity or potential activity. Electronic alarm systems allow for continuous monitoring of volcanic activity even during nonbusiness hours.

Cook Inlet volcanoes are also studied through frequent overflights to monitor gas emissions and other parameters, field observations, ground-deformation studies using state-of-the-art satellite signals, and slow-scan TV monitoring. An innovative system that detects ash-induced lightning in an eruption cloud enables the USGS to warn pilots about areas hazardous for aircraft. A mudflow-detection system was installed in 1990 to detect and track volcanic mudflows that threatened an oil storage facility 25 miles (40 kilometers) from Redoubt volcano.

Away from Cook Inlet, AVO depends primarily on information from pilot reports, satellite images, and observations from local inhabitants to prepare warnings and issue announcements on future volcanic activity.

The eruptions of Redoubt volcano in 1989–90 and Mount Spurr volcano in 1992 led to the development of procedures for a rapid flow of information including briefings, news media releases, a color-code system designating the status of the volcano, and forecasts of plume trajectories. When measurable changes in the state of a volcano are noticed, AVO offices in Anchorage and at the Geophysical Institute in Fairbanks go on 24-hour duty. A formal call-down list has been established for the immediate notification of eruptive activity. The Federal Aviation Administration, the National Weather Service, Elmendorf Air Force Base, the Alaska Division of Emergency Services, and any facility near the volcano are notified immediately by telephone.



ALASKA VOLCANO OBSERVATORY

The August 18, 1992, eruption of Crater Peak on Mount Spurr volcano.

During an eruption, AVO issues a printed Volcano Update one or more times daily, which describes eruptions, associated earthquake activity, and other noteworthy events. The updates also include a general summary of potential volcanic hazards over a period of days to weeks and, when possible, specific predictions about future events. These updates are faxed to a wide variety of government agencies, industry, and news media users. This information is also provided on recorded telephone messages that are continually updated.

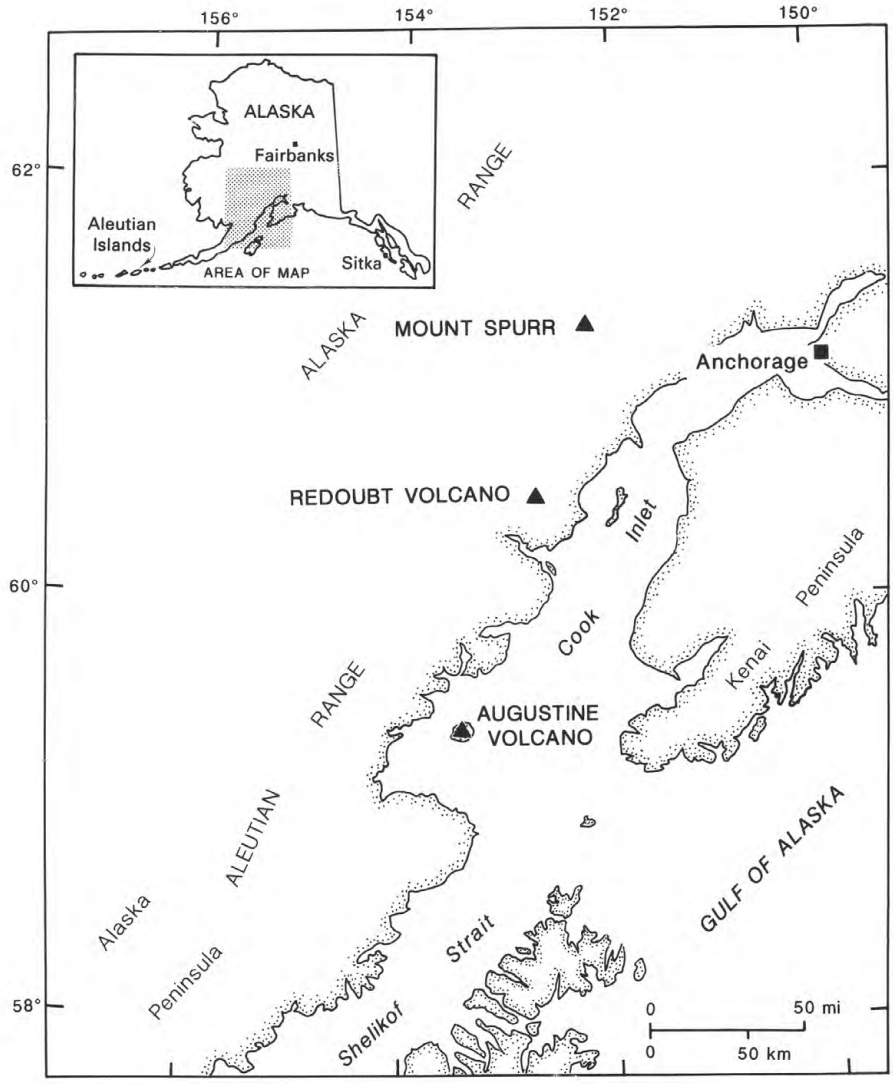
A scheme of color codes was developed to represent the level of concern based on the seismic activity beneath a particular volcano or confirmed by visual observations by AVO field crews or the airline industry. This system was implemented in order to more consistently describe the status of the volcano when a potentially hazardous event was in progress or was expected. Four colors were chosen to represent different levels of activity that were either presently occurring or expected to occur at the volcano. Green, for example, means the volcano is in a "dormant" state, and yellow indicates the volcano is "restless." Orange indicates either the occurrence or the imminence of a large explosion likely to send ash as high as 25,000 feet (7,620 meters)

above sea level, and red indicates potential for ash plumes higher than 25,000 feet (7,620 meters). This simple but effective color-code system is being widely adopted by the airline industry.

AVO also receives forecast data on winds above south-central Alaska from the National Weather Service in order to plot the potential ashfall area downwind from an erupting volcano. The maps produced are used to anticipate probable ashfall-hazard zones following an eruption.

The value of these monitoring techniques and information procedures was apparent during the eruptions of Redoubt (1989–90) and Mount Spurr (1992) when AVO was able to issue warnings of impending eruptions and, in some instances, issue predictions of explosive eruptive events. Such predictions (ranging from 4 to 34 hours in advance and averaging 14 hours) were made for four different Redoubt eruptions. One forecast was made for Mount Spurr on the basis of seismic activity and was released 14 hours before the June 27, 1992, eruption. For 19 explosive eruptions of Redoubt, notifications began 2 to 17 minutes after the onset; the average response time was 7 minutes. Notifications were made 11 minutes after Mount Spurr's June 27 eruption and 3 minutes after the August 18 eruption.

These warnings, forecasts, predictions, and notifications resulted in the efficient rerouting of air traffic and allowed the people likely to be affected to prepare for the hazards associated with ashfall, mudflows, and tsunamis. More than 40 Alaskan volcanoes have been active in the past 200 years, however, and only 4 of them are adequately instrumented at present. The remainder of Alaska's active volcanoes, although more isolated, lie along major international air routes across the Pacific Ocean and constitute a significant hazard to air traffic. The instrumentation and hazard analysis of these volcanoes remain a challenge for the future.



Recent eruptions of Mount Spurr, Redoubt, and Augustine volcanoes have significantly affected more than half of Alaska's population.

Nearly A Century of Earth Science Cooperation in Puerto Rico

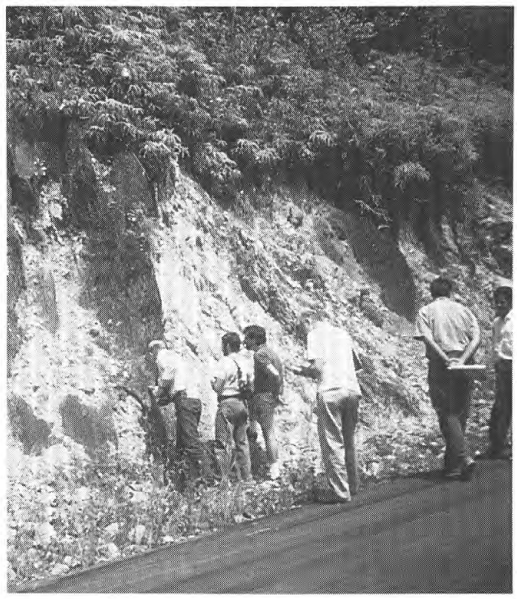
By Walter J. Bawiec, Robert E. Learned, and Jean N. Weaver

For almost a century, geoscientists of the USGS, often in cooperation with agencies of the insular government of Puerto Rico, have studied many aspects of Puerto Rican geology. Projects have focused on irrigation and ground-water studies, systematic topographic mapping, the search for mineral resources, and assessment of natural hazards. These efforts have resulted in major contributions to an understanding of the island's geology and to the welfare of its people. The chronology of events in the study of earth sciences in Puerto Rico by the USGS and insular agencies demonstrates the spirit in which long-term beneficial goals can be pursued by cooperating agencies.

In 1969, the USGS, in cooperation with the Puerto Rico Department of Public Works, began an investigation of the mineral resources of the island and established a geochemical laboratory in San Juan. Much of the project's attention was focused on the geology

and geochemistry of the porphyry-copper deposits in west-central Puerto Rico, an area that also provided training for Puerto Rican geologists. The geochemical laboratory, which analyzed all the samples collected by project geologists, was staffed entirely by Puerto Rican personnel. The project produced many scientific publications, including a metallogenic map of Puerto Rico. In 1980, the USGS and the Puerto Rico Department of Natural Resources initiated a systematic geochemical survey of the drainage basins of Puerto Rico. The geochemical survey was terminated before its completion, but the results for one major drainage basin were published in 1981. The remaining results are incorporated in the mineral-resource assessment of Puerto Rico, a 2-year project that began in 1990 and represents a culmination of the years of cooperative efforts in mapping and collection of geological, geochemical, and geophysical data.

The most recent example of cooperative activity culminated in a June 1992 public meeting in San Juan, sponsored by the USGS, Puerto Rico Department of Natural Resources, and the University of Puerto Rico (Mayaguez Campus). The public meeting was designed to communicate to government officials, mining company personnel, and interested organizations the results of a cooperative mineral-resource assessment of Puerto Rico. More than 100 people from the U.S. Bureau of Mines, U.S. Forest Service, mining companies, and universities attended the 2-day meeting and 1-day field trip.



WALTER BAWIEC

The final day of the public meeting featured a field trip to some of the mineralized areas of Puerto Rico. Here participants examine the alteration zone of a copper deposit in south-central Puerto Rico.

Although the conclusions of the study and an assessment of Puerto Rico's undiscovered mineral resources—probabilistic estimates of numbers of undiscovered mineral deposits—are important and will be published as a USGS map portfolio, a more far-reaching aspect of the meeting was a clearer sense of how this information can be used and how these cooperative projects provide benefits to the governments and the people. To ensure that both scientists and public officials could fully benefit from the discussions at the meeting, explanations were provided for each of the related disciplines. For example:

- Comprehensive geologic maps of the entire island resulted in a better understanding of the map units and the geology.
- Geochemical data showing the areas that contained anomalous metallic values were displayed, and interpretations of this information were presented.
- Geophysical maps depicting magnetic and gravity characteristics of the island provided insight into the subsurface geology and an indication of subsurface faults.
- Known mineral occurrences in Puerto Rico were displayed, with computer listings available so attendees could examine production statistics, mineral deposit characteristics, and other types of information.
- Mineral-resource tracts, which outline areas most likely to contain specific mineral deposit types, were displayed and explained. Estimates of the numbers of undiscovered deposits at different probability levels were also provided.
- A demonstration of digital geologic information in combination with geographic information systems (GIS) and compact disc, read-only memory (CD-ROM) provided an example of how this information is used. With this technology, attendees were able to combine geology, aeromagnetic data, gravity values, roads, rivers, and mineral occurrences, and to manipulate the information as desired. They were, for example, able to display all known landslide areas, hydrothermally altered rocks, or the extent of limestone deposits, important to the island's cement industry.

The use of earth science information to address issues in a world with greater demands upon diminishing available space, decreasing resources, and a more sensitive environment is becoming critical. Long-term cooperation among research organizations, both in the collection of data and in the application of these data to social and economic problems, is vital to solving these problems in an informed and efficient manner.

National Oil and Gas Assessment

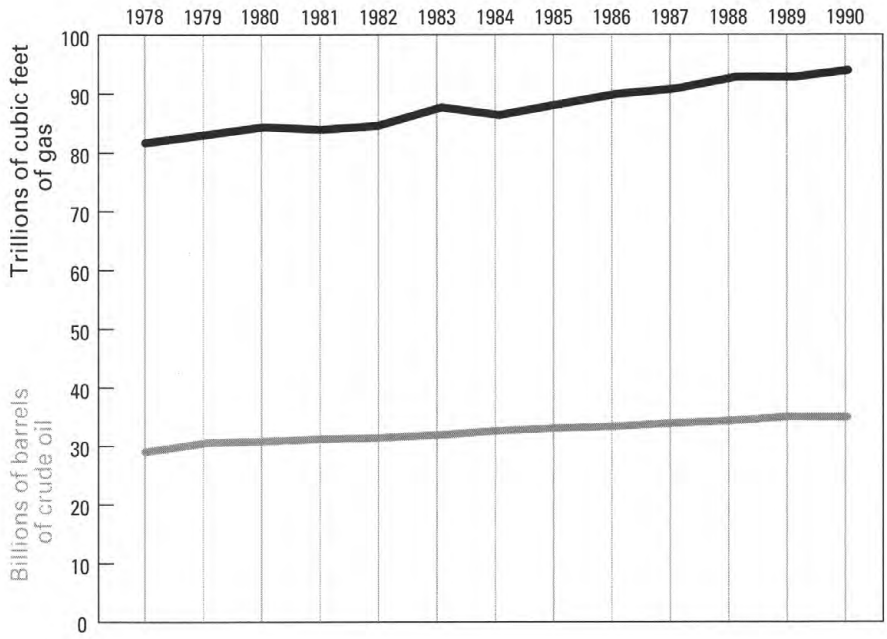
By Donald L. Gautier

The USGS, in cooperation with the Minerals Management Service (MMS), formally began a new national assessment of oil and gas resources on January 1, 1992. The national assessment is scheduled for completion and submittal to the Department of the Interior by January 1, 1995. The USGS has responsibility for all onshore areas, including private lands, Federal lands, State lands, and other land categories, as well as the State offshore waters. The MMS maintains responsibility for assessments of oil and gas resources in all Federal offshore areas. The principal purpose of the national assessment is to provide the government and the citizens of the United States with a consistent set of scientifically based judgments of the amounts of oil and gas resources remaining to be added to reserves in the United States.

The 1995 national assessment will be based upon the "play" concept. A play encompasses a set of oil and (or) gas accumulations that are geographically and temporally related and that exist by virtue of identical or similar geological conditions. The oil or gas accumulations may be real (discovered) or imaginary (undiscovered). The play-based assessment is a sound and practical approach because it provides a method for assessors to relate data from known oil and gas accumulations, such as dates of discoveries, production histories, reserves, recovery factors, and the like, to their own geologic knowledge and insights on undiscovered oil and gas accumulations. The ability to relate the geologic understanding of oil and gas data from discovered fields gives a basis for estimating the sizes and number of undiscovered fields in the play.

Many plays to be used in the national assessment were defined and characterized in the previous national assessment in 1987. The next step is to analyze the plays and develop hypotheses concerning resources contained within the play. The assessment will utilize a combination of play analysis, discovery-process modeling, and other techniques.

Beginning at least as early as 1909, the USGS has conducted assessments of the oil and gas resources of the United States. This work has historically focused upon estimates of the undiscovered, conventionally recoverable (that is, recoverable with existing technology) resources of oil and gas of the United States. However, the scope of the 1995 national assessment will be expanded somewhat over previous assessments to include, in addition to the conventional undiscovered resources, evaluations of those unconventional resources that can be expected to be produced through a wellbore; these resources include heavy oil, gas in low-permeability (tight) reservoirs, coal-bed gas, and gas entrapped in clathrates (lattices of water molecules). Measurements of total in-place unconventional resources yield quantities of resource estimates that are orders of magnitude larger than all conventional resource categories. Many of these unconventional resources are either technically or economically unavailable. Only the portion of the resource that can be reasonably expected to be available for additions to U.S. reserves over the next few decades will be included in the assessment. This evaluation will require determining the fraction of the unconventional resources that is technically recoverable and developing cost-supply curves to estimate potential availability of such resources. The issue of development of new technology and its effect upon the availability of the unconventional resources will be discussed.



Perceptions of the total amount of recoverable oil and gas (including past production) from fields discovered before 1920 are still changing upward, as this graph shows. Increases between January 1, 1978, and January 1, 1991, were 5.5 billion barrels of oil and 14 trillion cubic feet of gas.

Review of new data demonstrates that reserve growth is much greater than previously believed. . .

Another topic receiving special attention in the new national assessment is the phenomenon of reserve growth. When fields are discovered and reserves are calculated, the total amount of reserves and production are often recorded as of a particular date. If these historical views of the total reserves and production of fields are determined for a number of years, the total of reserves and production commonly increases through time. Review of new data demonstrates that reserve growth is much greater than previously believed, particularly in California and in the Permian Basin

of West Texas and New Mexico. Many old fields, especially in California and West Texas, discovered in the 1920's or before, have shown significant growth in ultimate production (production plus reserves) that continues to this day. Although the exact amounts of reserve growth in the United States are still subject to research and interpretation, it is clear that the amount of oil and gas to be added to U.S. reserves from reserve growth is about as large as the amount of oil and gas estimated remaining to be found in the last national assessment. The new assessment will include a detailed and comprehensive evaluation of the anticipated impact of reserve growth on both discovered and undiscovered resources of oil and gas.

In addition to a national total, the new national assessment will give subtotals for provinces, regions, individual States, and Federal and native lands. The results will be summarized and published jointly by the USGS and MMS, in CD-ROM format as well as in more conventional publication media. A significant effort is being made to involve other Federal agencies and State geological surveys and to use the latest industry information in the assessment.

The Southern California Earthquake Center

By Lisa Wald

The Southern California Earthquake Center (SCEC) is one of 14 new National Science Foundation Science and Technology Centers. SCEC is a consortium of more than 100 researchers working at 7 core academic institutions—University of Southern California (coordinating institution), California Institute of Technology, Columbia University's Lamont-Doherty Earth Observatory, University of California at Los Angeles, University of California at Santa Barbara, University of California at Santa Cruz, and University of California at San Diego's Scripps Institution of Oceanography—in partnership with the USGS. A major goal of SCEC is development of a "master model" for earthquakes in Southern California, which will integrate all available geoscience information to develop methods for estimating and analyzing the seismic hazards of the region and for mitigating the damage caused by earthquakes. The master model is being developed through working groups and seminars with participation from other scientists who will use the model.

Another goal of SCEC is to produce maps showing the probability of ground shaking throughout Southern California at any given time. Eventual results of the project include research products such as maps of shear-wave and compressional-wave velocities for the three principal layers of the lithosphere—the brittle upper crust, the ductile lower crust, and the upper mantle—and maps of the probability of damaging earthquakes occurring on major faults for time periods ranging from weeks to decades.

The master model and the pertinent geophysical and geologic data are being archived at a readily accessible data center in Pasadena, Calif. The data center has purchased a mass storage system to archive all the information that will be integrated into the master model from the various sources. Currently, earthquake data from the past 10 years have been loaded into the system and are available to the user community via electronic access. A data base is being developed that will enable users to search for different types of data that meet specific parameters.

Education and outreach are also vital parts of SCEC's program. Education for the general public and primary and secondary schools in Southern California is currently being done through the Southern California Earthquake Preparedness Project (SCEPP), which is part of the California Office of Emergency Services (OES). Additionally, a visitor's program allows researchers and postdoctoral fellows not affiliated with the center to interact with center scientists at one or more of the participating institutions.

Southern California is an excellent natural laboratory in which to develop this new method of hazard mitigation. The State of

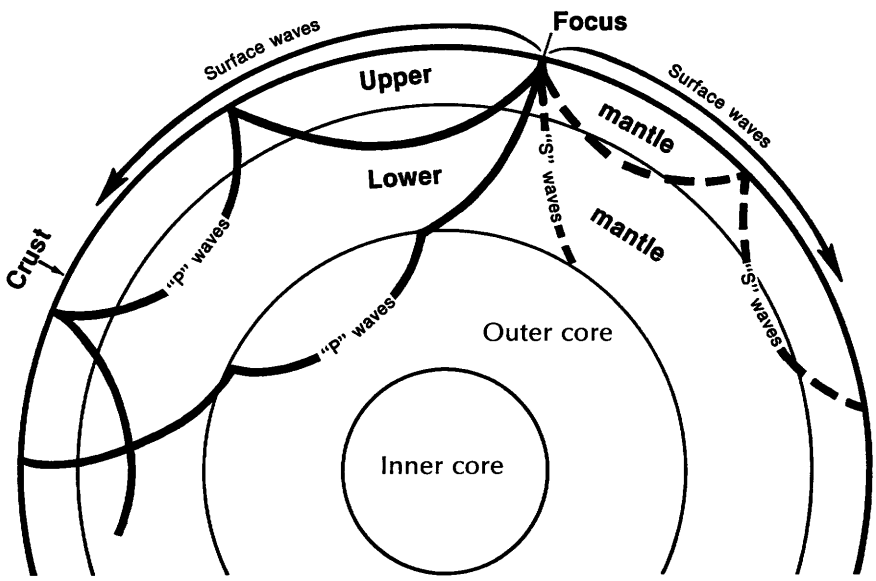
Southern California is an excellent natural laboratory in which to develop this new method of hazard mitigation.

California is the most seismically active area in the conterminous United States and is threatened by major earthquakes, which will have serious effects on densely populated areas such as the Los Angeles, San Diego, and San Francisco Bay areas. In addition, California's academic institutions have an established technical infrastructure and a history of earthquake research in which to conduct this work and to test the model as it develops.

Many of the probability estimates for large earthquakes are based solely on the length of the fault segment and the current slip rate. The problems of fault segmentation, fault behavior, and earthquake recurrence are being addressed by detailed mapping and trenching across known faults. Knowledge of the recurrence interval for earthquakes on different fault segments will make those probability estimates more accurate and reliable.

Southern California has specific earthquake problems that will be addressed by the master model. For example, the southern section of the San Andreas fault is expected to produce a large earthquake sometime in the coming decades. Depending on the magnitude, epicentral location, and, perhaps most crucially, the time of day that it occurs, the loss of life and property could be catastrophic. Furthermore, recent earthquake activity in the Los Angeles basin suggests that a complex system of buried faults, capable of producing a moderate or large earthquake, lies directly beneath metropolitan Los Angeles. Reducing the risk from future earthquakes requires a good understanding of potential earthquake sources and the types of ground shaking that they can produce.

To measure the tectonic, or earthquake-related, movement of the Earth's crust, highly accurate, interconnected survey networks have been established throughout Southern California. These networks provide sparse geographic coverage in most areas but good coverage over time. By learning more about the nature of these crustal movements, scientists



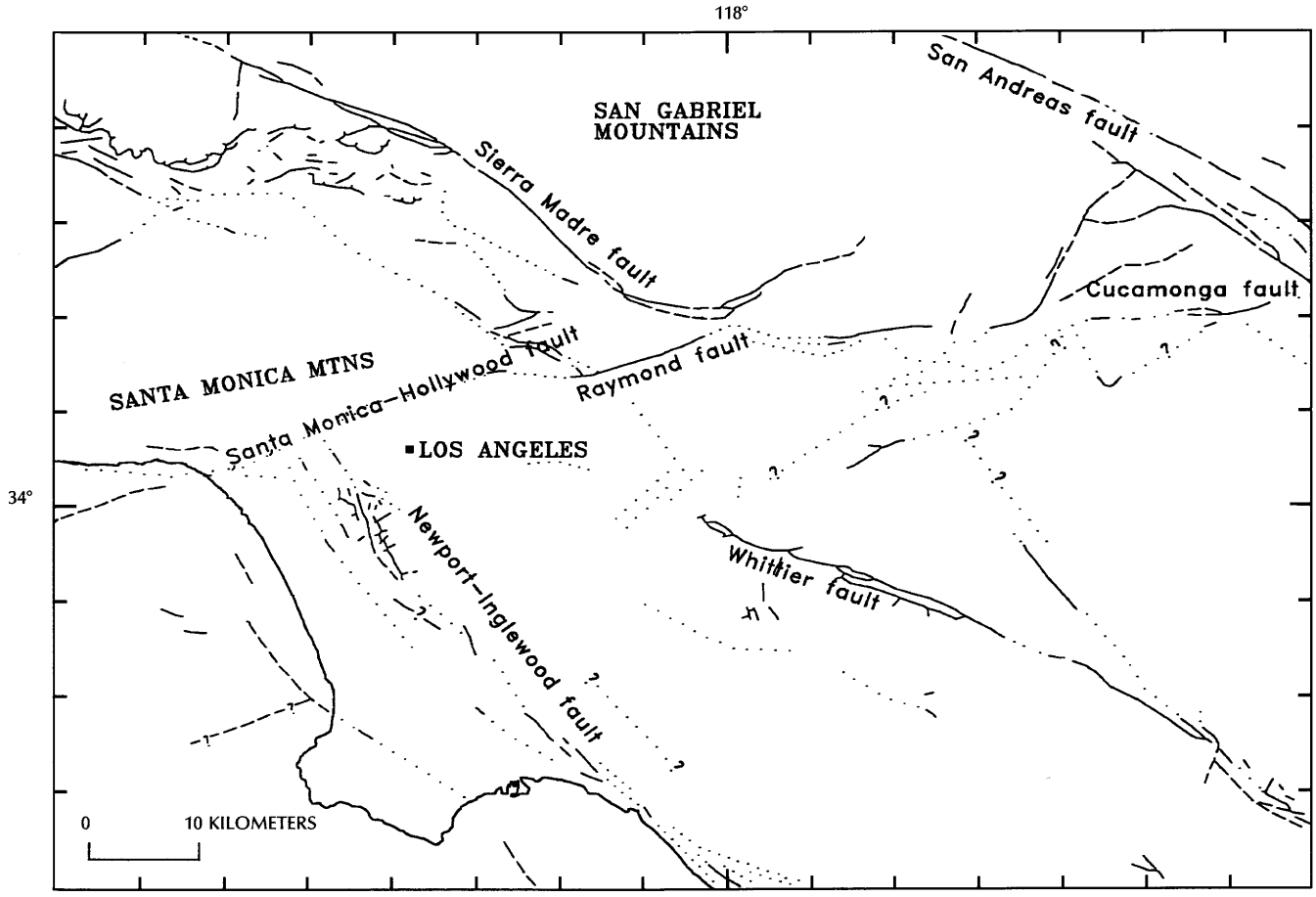
The two general types of vibrations produced by earthquakes are *surface waves*, which travel along the Earth's surface, and *body waves*, which travel through the Earth. Surface waves usually have the strongest vibrations and probably cause most of the damage done by earthquakes.

Body waves are of two types, *compressional* and *shear*. Both types of body waves pass through the Earth's interior from the focus of an earthquake to distant points on the surface, but only compressional waves travel through the Earth's molten core. Because compressional waves travel at great speeds and ordinarily reach the surface first, they are often called "primary waves" or simply "P" waves. P waves push tiny particles of Earth material directly ahead of them or displace the particles directly behind their line of travel.

Shear waves do not travel as rapidly through the Earth's crust and mantle as do compressional waves, and because they ordinarily reach the surface later they are called "secondary" or "S" waves. Instead of affecting material directly behind or ahead of their line of travel, shear waves displace material at right angles to their path and are therefore sometimes called "transverse" waves.

The times of arrival of compressional and shear waves at selected seismograph stations throughout the world indicate where and when the earthquake occurred and, sometimes, its focal depth. The recorded amplitudes of seismic waves indicate the amount of energy released by the earthquake.

From the USGS general-interest publication, Earthquakes.



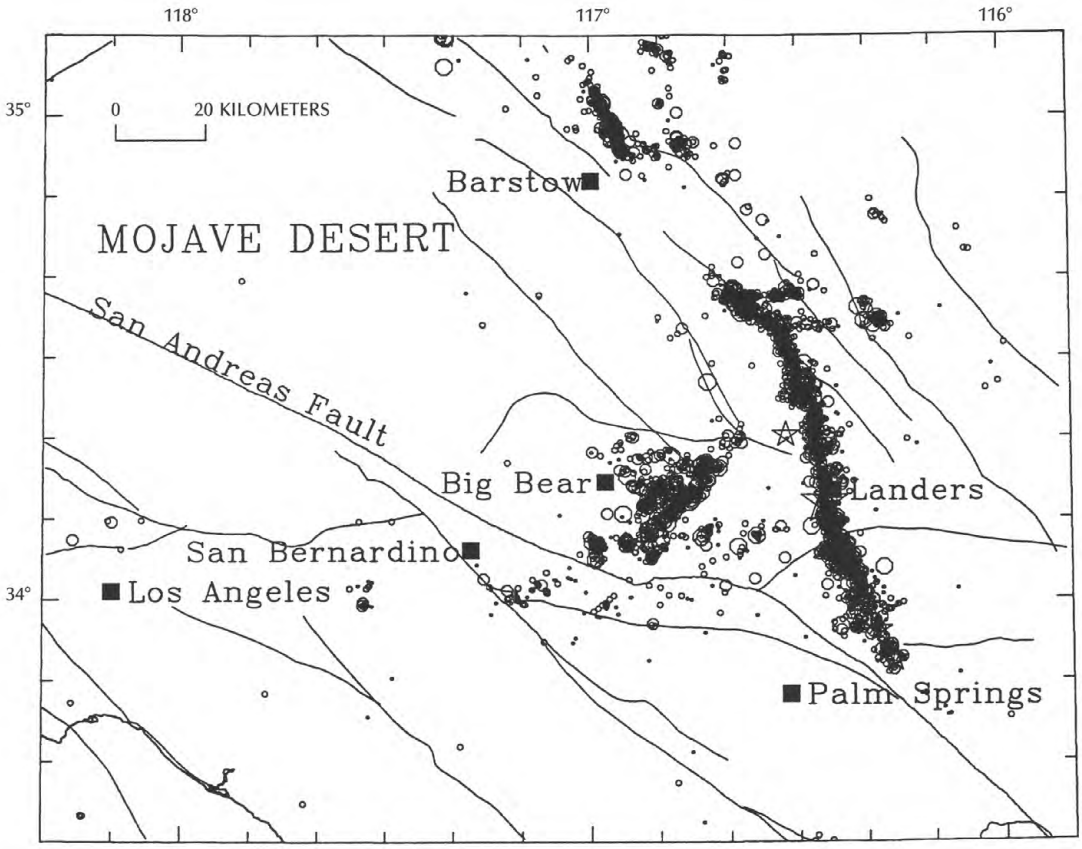
Mapped faults in the Los Angeles basin and surrounding area. The solid lines are known faults; the dashed lines are faults inferred on the basis of surface displacements during the last 10,000 years; the dotted lines are faults concealed by younger rocks.

will be better equipped to forecast when and where the next large earthquake might occur. The Los Angeles basin is a primary focus for this study, since it is poorly understood and has a large population at risk. Many counties in Southern California and the California Transit Authority are helping to fund this effort and also are providing independent survey data.

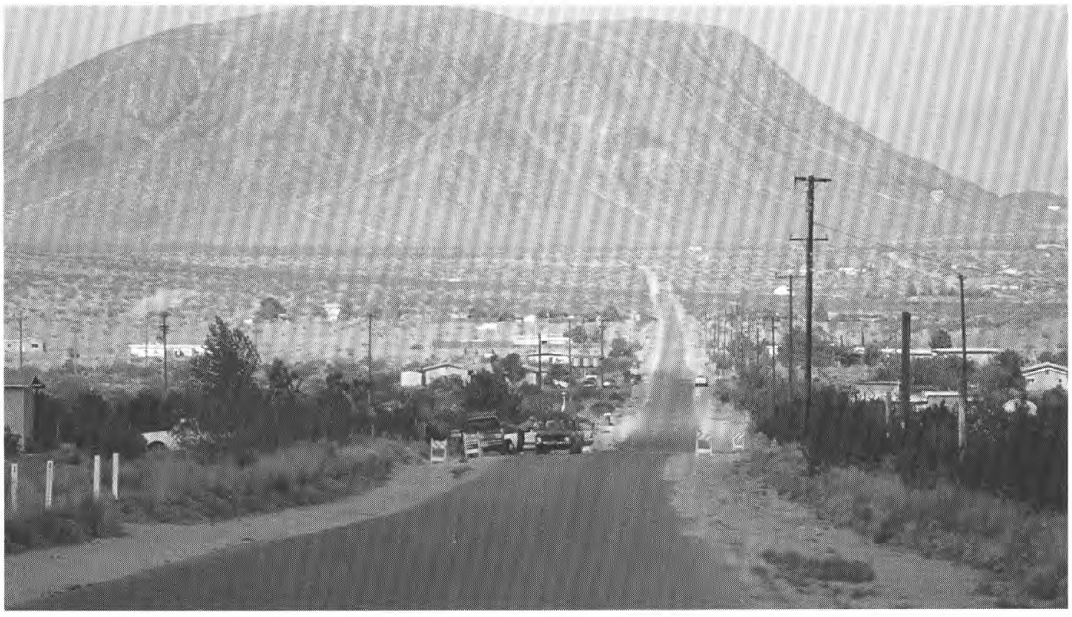
Many activities are currently focused on the Los Angeles area, specifically the Sierra Madre fault system, near the San Gabriel Mountains north of Los Angeles, and the Santa Monica-Hollywood fault system, which runs east-west from the Pacific Coast north of downtown Los Angeles to the Pasadena area, where it becomes the Raymond fault. There has not been a large earthquake on this fault system in historic times, so the recurrence interval is unknown. The Hollywood fault is currently being trenched so that the record of past movement in the geologic record and the recurrence interval of large earthquakes can be determined. A large earthquake on this fault could be devastating to the Los Angeles area since it is situated in the middle of the most developed and most highly populated area.

The SCEC operation was tested during the Landers-Big Bear earthquake sequence, which began just after 5 a.m., P.d.t., on June 28, 1992. The magnitude-7.5 Landers mainshock ruptured a 70-kilometer-long (43-mile-long) fault about 95 kilometers (60 miles) east of San Bernardino; the magnitude-6.5 Big Bear mainshock occurred 3 hours later. Four hours after the Landers mainshock, USGS scientists met with OES officials and issued a public warning advising residents of San Bernardino and Riverside Counties to "avoid nonessential activity, including use of the freeway system." The warning was accompanied by a B level alert for a large earthquake in Southern California for the next 24 hours, meaning that there was a greater than 50 percent chance of a magnitude-6.0 or larger earthquake in the area of the main shock. These probability estimates, based on statistics from seismicity in the past, enable fire departments, hospitals, police departments, utility companies, and other emergency units to make preparations for responding quickly and efficiently during emergency situations. They also allow the public who may be affected to ready themselves.

The participating groups in SCEC cooperated successfully in response to the Landers earthquake sequence. Portable instruments were deployed within hours of the mainshock, and many details of the surface



The Landers and Big Bear earthquake sequence, recorded on the Southern California Seismic Network from June 28 through August 31, 1992. Size of circle denotes magnitude of earthquake; stars denote epicenters of earthquakes magnitude 6 and greater. The dense clusterings of dark circles represent the thousands of aftershocks that occurred in the weeks after the mainshocks.



KEN HUDNUT

This road near Landers was offset 2.5 meters (8 feet) by the June 28, 1992, Landers earthquake.

rupture as well as the earthquake source itself were determined very quickly. That information was then used to inform the public and to direct the emergency response.

The Landers and Big Bear earthquakes and the associated seismic activity revealed some unexpected problems associated with earthquake hazards in California. The most alarming is that the Landers earthquake ruptured four separate adjacent faults simultaneously. In the past, separate fault segments were generally thought to behave independently, rupturing in earthquakes at different times. Consequently, past research has focused on faults that are long enough to produce a sizable and damaging earthquake. Scientists now know that several fault segments can rupture simultaneously to produce a large earthquake, although the mechanism that controls this type of behavior is not known. The earthquake potential of many of the adjacent small fault segments that exist throughout Southern California, especially the intricate system of faults in the Los Angeles basin, must be reconsidered in light of this discovery.

The National Geologic Mapping Act of 1992—Background and Challenges

By Mitchell W. Reynolds

The most significant national legislation affecting the geological sciences in more than a decade was passed by the U.S. Congress and became law on May 18, 1992. The bill, *The National Geologic Mapping Act of 1992* [Public Law 102–285], authorizes a national program of geologic mapping that will be accomplished through the partnership of State geological surveys, academia, the private sector, and the USGS. Such a partnership is essential to develop the extensive amount of geologic map information needed across the Nation for informed decisionmaking regarding land use and resource identification and management.

Why Are Geologic Maps Important?—Geologic maps provide users with a wealth of information. They define the areal distribution of rocks, sediments, and geologic structures exposed at the surface of the Earth. By means of symbols, patterns, color, and words of explanation, geologic maps also define the compositions and relative ages of the earth materials, structures, and events that resulted in the distribution of the materials. Numerical ages are provided, for example, in cases where selected isotopic compositions of key minerals, such as zircon, in the earth materials can be studied. By studying the arrangement of the rock layers or units and structures on the map, a user can determine whether units lie above or below adjacent units, interfinger with adjacent units as a result of depositional or intrusive processes, or are faulted against adjacent units. Geologic maps display directly or provide information from which scientists can deduce the distribution beneath the Earth's surface of geologic units containing economically valuable accumulations of minerals, fossil fuels, or construction aggregate and stone. Geologic maps define faults that can move or have moved to produce earthquakes and provide information regarding the ages of such fault movements. The timing and extent of volcanic eruptions, of landslides, or of earth failure produced by liquefaction of sediment are portrayed on geologic maps. Every element of information displayed on a geologic map has potential application to needs or circumstances of daily living.

Who Uses and Produces Geologic Maps?—In view of such varied and widespread applications of geologic map information, it was not surprising that results of a 1988 nationwide canvass of map users were decisive: Users want geological map information, preferably in color, and at intermediate and large map scales. The survey, conducted by the Board on Earth Sciences of the National Research Council, found that users need the information in realtime, which means that they are willing to sacrifice color for black and white maps in order to expedite release of the geologic maps. Other forms of geoscience map information, such as geophysical, geochemical, and ground-water maps, are also helpful to users.

Most responses to the nationwide canvass, which was designed to "determine current and future geoscience needs in the United States," came from the private sector, but academia and all levels of government also responded. As extrapolated from responses, more than 5 million geologic maps are used annually in the Nation. At the time of the survey, the private sector was the principal user group; use by governmental agencies has since increased as geologic map information is increasingly applied to issues of land-use planning and environmental management.

Currently, most geologic maps available to the public are produced by the USGS; State geological surveys and colleges and universities also produce significant numbers of maps. Firms in the private sector also make geologic maps, but generally their maps are of

specific areas for highly specific purposes and are generally not available to outside users.

Geologic mapping that is done cooperatively, through joint ventures and agreements, makes good economic sense. The cost of making geologic maps is high because each step of the process, from fieldwork to publication, is labor and time intensive. As a result, the private sector depends heavily on governmental agencies for production of geologic maps. In economic terms, geologic map making by public agencies can be defined as a *public good*: Information contained on the maps is available to everyone, and the use by one consumer does not diminish the availability or usefulness to any other user. The public and private sectors alike can use the information, whereas similar data if produced by a private firm would have highly restricted use. In order to achieve the full public good of geologic map information produced under the National Geologic Mapping Act of 1992, State geological surveys and the USGS will work in partnership.

What Are the Goals of the Legislation?—The objective of the National Geologic Mapping Act of 1992 is "to determine the geologic framework of the Nation by the systematic development of geologic maps at scales appropriate to the geologic setting and perceived applications" of the maps [P.L. 102–285, sec. 4, (c) (1)]. A national geologic map data base will be the principal product. That data base will be available to the public through a three-level national archive: (1) At the State level, maps produced at large (1:24,000) and intermediate (1:100,000) scales by State geological surveys will be archived by them as open-file or published maps; (2) at the national level, maps produced at large and intermediate scales by the USGS will be archived initially in various map series; (3) separate parts of the large-scale archive from States will be consolidated by the USGS into an intermediate-scale national data base archive.

As rapidly as conversion can be accomplished, all geologic map information will be archived in digital format that will meet national digital geologic map standards and national data transfer standards. The geologic mapmaking will be performed in the context of ongoing Federal efforts to coordinate surveying, mapping, and related spatial data activities under Office of Management and Budget Circular A–16, revised.

Four other supplementary data bases will be products of the national program. A national geophysical-map data base, at a principal scale of 1:100,000; a national geochemical map data base at 1:500,000 scale; a national paleontologic data base; and a national geochronologic data base. All

106 STAT. 166 PUBLIC LAW 102–285—MAY 18, 1992

Public Law 102–285
102d Congress

An Act

May 18, 1992
[H.R. 2763]

To enhance geologic mapping of the United States, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

National Geologic Mapping Act of 1992. Conservation. Environmental protection. 43 USC 31a note. 43 USC 31a.

SECTION 1. SHORT TITLE.

This Act may be cited as the "National Geologic Mapping Act of 1992".

SEC. 2. FINDINGS AND PURPOSE.

(a) FINDINGS.—The Congress finds and declares that—

(1) during the past 2 decades, the production of geologic maps has been drastically curtailed;

(2) geologic maps are the primary data base for virtually all applied and basic earth-science investigations, including—

(A) exploration for and development of mineral, energy, and water resources;

(B) screening and characterizing sites for toxic and nuclear waste disposal;

(C) land use evaluation and planning for environmental protection;

(D) earthquake hazards reduction;

(E) predicting volcanic hazards;

(F) design and construction of infrastructure requirements such as utility lifelines, transportation corridors, and surface-water impoundments;

(G) reducing losses from landslides and other ground failures;

(H) mitigating effects of coastal and stream erosion;

(I) siting of critical facilities; and

(J) basic earth-science research;

(3) Federal agencies, State and local governments, private industry, and the general public depend on the information provided by geologic maps to determine the extent of potential environmental damage before embarking on projects that could lead to preventable, costly environmental problems or litigation;

(4) the combined capabilities of State, Federal, and academic groups to provide geologic mapping are not sufficient to meet the present and future needs of the United States for national security, environmental protection, and energy self-sufficiency of the Nation;

(5) States are willing to contribute 50 percent of the funding necessary to complete the mapping of the geology within the State;

(6) the lack of proper geologic maps has led to the poor design of such structures as dams and waste-disposal facilities;

(7) geologic maps have proven indispensable in the search for needed fossil-fuel and mineral resources; and

59–139 O - 92 (285)

106 STAT. 167

(8) a comprehensive nationwide program of geologic mapping is required in order to systematically build the Nation's geologic-map data base at a pace that responds to increasing demand.

(b) PURPOSE.—The purpose of this Act is to expedite the production of a geologic-map data base for the Nation, to be located within the United States Geological Survey, which can be applied to land-use management, assessment, and utilization, conservation of natural resources, groundwater management, and environmental protection.

Re-creation of an excerpt from Public Law 102–285, the National Geologic Mapping Act of 1992.

program participants will maintain local data bases, and the USGS is responsible for developing the formats and standards and for assembling the nationwide data bases.

The task of developing geologic map information for the Nation is immense. Basemap coverage for the Nation, exclusive of Alaska, at a scale of 1:24,000 (the standard format of the popular USGS topographic quadrangles), requires about 57,000 quadrangles. Nearly 1,800 base maps at a scale of 1:100,000 cover the country. Both large-scale and intermediate-scale maps are critical in deriving the most useful geologic information to solve the broadest spectrum of earth science concerns.

Priorities must be established at State and Federal levels in order to produce geologic maps in the most timely and cost-efficient sequence possible, first for areas of highest priority, then for areas of decreasing priority. Again through State and Federal partnership, priorities will be established. State geological surveys will canvass State, county, and local governmental agencies, local users from the private sector, and colleges and universities within each State to establish Statewide priorities. Working through the Federal Geographic Data Committee's Subcommittee on Geological Data, the USGS will canvass Federal agencies and national organizations to determine priorities for Federal geologic mapping. Finally, analysis of State and Federal requirements will be merged to guide development of work plans and funding proposals by all partners to accomplish geologic mapping of the highest priority at the beginning of the program.

Implementation of the National Geologic Mapping Program will be achieved through four components. Each component will work to accomplish its specific goals, but all will work together toward the goal of developing national geologic map data bases. The State geologic mapping component, for example, will determine the geologic framework of areas that States "determine to be vital to the economic, social, and scientific welfare of the individual States" [P.L. 102–285, sec. 4, (f) (3)]. This component is fundamental to the program, because Federal funds will be available to be matched by the State on a one-to-one basis with non-Federal funds, thereby multiplying the extent and effectiveness of geologic mapping.

The USGS conducts two components of the program. In one Federal component, the USGS performs geologic mapping to establish the geologic framework of areas that are vital to the economic, social or scientific welfare of the Nation. The second Federal component provides interdisciplinary support for the geologic mapping by performing paleontologic and isotopic geologic studies to determine the ages of earth materials, and support for the development of techniques for and assembly of a national digital geologic map data base.

The final program component, geologic mapping education, is critical for the long-term vitality of the overall national program. During the past 15 years, the teaching of geologic field methods and analysis has declined or been abandoned in many colleges and universities. A combination of factors, such as a past decrease in the availability of funds for geologic mapping, the time- and labor-intensive character of geologic mapping compared to other kinds of earth science investigations, and a general decline in mineral and energy exploration in the Nation, has led to a decrease in well-trained geologic mappers. The fourth component of the National Geologic Mapping Program would develop programs that teach students the principles of geologic mapping and field analysis and would support field teaching institutes.

What Are the Challenges of the Legislation?—The National Geologic Mapping Act of 1992 provides intriguing challenges to institutions across the country that have responsibility for mapping the geology of our Nation. One challenge is to reinforce partnerships in geologic mapping and to reinvigorate geologic mapping among all geological surveys. A second challenge is to develop methods of accelerating geologic mapping and publication of geologic maps. Another major challenge is to develop new methods of representing geologic map information clearly to an expanding, sophisticated clientele, which is able rapidly to assimilate and use such information in geographic information systems to solve a variety of problems that require geologic data. A final challenge is to interpret and apply geologic map information for effective policymaking at all levels of government. An effective partnership among all participants in the geologic mapping program is the key to meeting these challenges successfully.

Robotics in the Geochemical Laboratory

By Steve Wilson and Richard O'Leary

The geochemical laboratory has undergone a dramatic change in recent years, due to the development of techniques that can quantify most elements at concentration levels lower than previously thought possible. Along with this explosion in information is a basic need to improve data quality while keeping costs at a reasonable level. Because salary is one of the greatest laboratory costs, efforts are continually directed toward optimum use of personnel through increased automation. One of the most rapidly growing areas of laboratory automation is the use of robotics for sample preparation.

USGS involvement with robotics spans more than 10 years, and in the course of that decade the bureau has developed methods ranging from sample disaggregation to sample decomposition. The geochemistry lab maintains a fairly unusual position in the field of robotics by developing systems that tolerate the corrosive, high-temperature conditions required for geochemical analysis. The latest use of laboratory robotics deals with the automated digestion of geologic samples for mercury analysis. The procedure combines an existing method with a robotic system designed to operate independently for as long as 10 hours. Analysis of standards and real samples indicates that the robotic and manual methods are equal in terms of accuracy and reproducibility (plus or minus 10 percent). The robotic system can process up to 3 times as many samples as the manual method.

RICHARD O'LEARY

Laboratory robot prepares samples for geochemical analyses.

In addition to the obvious increase in productivity, laboratory robotics has several other advantages. By shifting trained personnel to more complex or technical applications, their interpretive and manipulative skills are put to better use. The presence of robotics provides a minimum level of analytical capacity, which is less affected by budgetary limitations than are skilled laboratory personnel. In addition, the use of robotics for the more mundane applications allows greater professional growth potential for technicians by using their skills in more challenging jobs.

NATIONAL MAPPING PROGRAM

MISSION

The National Mapping Division provides accurate and up-to-date basic cartographic information for the United States in forms that can be readily applied to present-day problems. Maps, digital data, aerial photographs, satellite images, and geodetic control information represent some of the cartographic products available. Topographic maps at various scales, which illustrate detailed and precisely referenced information about natural and manmade features on the Earth's surface, continue to be important products.

These maps provide basic cartographic information that is needed by Federal, State, and local government agencies in dealing with key issues ranging from satisfying energy demands to conserving natural resources, from identifying environmental problems to developing acceptable solutions, and from locating commercial facilities to designing public works.

In addition to maps, cartographic data in computer-readable form are becoming increasingly important. These data are used in computer-based resource and geographic information systems to evaluate alternative management plans and to study the effects of different management policies.

Message from the Chief, National Mapping Division

Since 1885, when an agreement was signed with the State of Massachusetts to produce topographic maps, the USGS has worked with Federal agencies, State and local governments, the private sector, and academia to provide accurate and timely maps and map-related descriptions of the Nation's terrain, water features, transportation networks, political and administrative boundaries, land cover and use, and other geographic features. Today, this geographic information produced through the National Mapping Program is a key ingredient in decisions that impact the many economic, environmental, and natural resource issues facing the Nation. At a time when the demand for this information has never been greater, no one organization has the resources to meet this need. The use of computerized technologies creates new opportunities for sharing data and challenges us to be innovative in allocating, budgeting, and concentrating resources to create and maintain these vital data.

Working through the Federal Geographic Data Committee and building on current agreements, we are developing a new network of partnerships to produce detailed, current digital geographic and orthophotoquadrangle coverage for the Nation by 2000. This initiative builds on the strengths of the partners so that each meets the needs of its programs and also benefits others. Much of the federally funded data will be developed through the private sector. In addition, we anticipate that at least a quarter of the data will be from State and local governments, utilities, and others in the private sector. With these rich sources of data in mind, we are strengthening our cooperative programs and beginning an innovative incentive program. Our work to implement the Spatial Data Transfer Standard will reduce the technical problems often encountered in these partnerships.

Partnerships are a key ingredient to understanding complex environmental issues. Working with the Department of Agriculture, we recently established the Terrestrial Ecosystem Regional Research and Analysis (TERRA) Laboratory to link disciplines and gain a better understanding of changing regional land conditions. Our activities in polar regions also depend on working with other agencies and nations.

The key to anticipating and responding to issues facing the Nation lies in the availability of current and accurate information about the rapidly changing landscape. The task of obtaining this information is huge, and success depends on all of us working together to share and benefit from the Nation's investment in geographic data.

Allen H. Watkins

Partnerships in the National Mapping Program

By Richard L. Kleckner

Geographic information systems (GIS) and related computer technologies have become crucially important land resource management tools. The best use of these systems, however, requires massive amounts of geographic data in digital form—data that can be compiled efficiently only through effective partnerships of major data producers and archivers.

To ensure that the necessary data are available, the USGS has established a network to gather and maintain high-quality spatial data. This network creates unprecedented opportunities for cooperation among government agencies and between the public and private sectors. Through these partnerships, scientists and managers soon will be able to perform resource assessments, socioeconomic analyses, and disaster preparedness plans faster and less expensively than ever before.

Although the USGS has devoted considerable effort over the past 10 years to digitize data from the 1:24,000-scale topographic quadrangles for entry into the National Digital Cartographic Data Base (NDCDB), less than 20 percent of the approximately 54,000 quadrangle maps that cover the contiguous United States have been digitized. Completing this essential data base and expanding the NDCDB to include other scales and coverage are paramount goals of the USGS effort.

Recognizing the need to better coordinate the collection of digital spatial data and to reduce duplication of effort, the Office of Management and Budget (OMB) issued

GIS

Geographic Information System (GIS) technology is a powerful new means of handling spatially related information and is a major element in the new digital direction of USGS mapping efforts. GIS's capture, store, and process data according to their geographic or spatial relations. From these systems, scientists can produce maplike layers of digital data that can be merged, separated, manipulated, and analyzed by computers to support more informed decision-making for many scientific, engineering, and planning purposes.

revised Circular A–16, "Coordination of Surveying, Mapping, and Related Spatial Data Activities," in October 1990. The revised circular expanded the breadth of spatial data coordination, assigned leadership to Federal departments for coordinating activities related to certain categories of spatial data, and established a new interagency coordinating committee to guide and oversee these activities. The objective of the coordinating committee, the Federal Geographic Data Committee (FGDC), is to promote the development, use, sharing, and dissemination of surveying, mapping, and related spatial data. The FGDC has proposed developing a national spatial (geographic) data base, linking all levels of government and the private sector. This data base (a distributed information system incorporating common criteria and standards) is expected to promote the efficient transfer of spatial data between producers and users. In its efforts to implement revised Circular A–16 within the USGS, the bureau is developing various partnerships to accomplish common data collection goals.

The USGS has developed the **National Map and Digital Data Cooperative Program** to increase its capacity to offer up-to-date maps, digital cartographic data, and remotely sensed data. Under this program, the USGS uses cooperative program resources to fund up to 50 percent of the costs of a mapping partnership project to produce spatial data more efficiently.

In 1991, the USGS formed more than 35 partnerships with other agencies and provided $2.8 million toward the cooperative production of standard USGS cartographic products. Although the number of partnerships remained stable in 1992, funding increased to $3.3 million.

Different types of agreements serve different potential partnerships. Funded agreements involve sharing production costs for a project. For unfunded agreements, either the USGS and its partners complete portions of the production work for a project without transferring funds or produce completed USGS standard products that are exchanged with no transfer of funds. To add flexibility and convenience to the cooperative program, partnership agreements may contain combinations of funded and unfunded activities. Additionally, a consortium of partners with identical product needs may collectively contribute to a project, reducing the cost to each partner to less than 50 percent.

The following are several examples of products developed through the varying partnership arrangements.

- **Electric Utility.** The USGS participated in a joint funding agreement with the City of Austin, Texas, Electric Utility, which called for the USGS to produce digital line graph (DLG) data from seven USGS 1:24,000-scale maps. The digital layers included boundaries, hydrography, and transportation. The data were combined with the Electric Utility data to form a resource data base that identifies alternate transmission line routes and substation sites.
- **Graphic revision of 7.5-minute topographic maps of Louisiana.** The Louisiana Department of Transportation and Development (LADOTD) used a joint funding agreement with the USGS for graphic revision of 7.5-minute topographic maps. The maps are being used by LADOTD for planning, maintenance, and management of the State's transportation network, as well as flood control and other water-resource needs. Other State agencies use the maps for research and management applications.
- **Digital line graphs and digital elevation models (DEM's) for Lake County, in northeastern Illinois.** Lake County had a joint funding agreement with the USGS for the preparation of DLG's (transportation, hydrography, hypsography, Public Land Survey System [PLSS], and boundary overlays) and DEM's for the 7.5-minute quadrangles covering the county. These data are being used by county officials and other agencies for wetlands management, storm water planning, and landform analyses.
- **Digital line graphs for Idaho.** The USGS is working with the Idaho Transportation Department to produce and exchange some 630, 1:24,000-scale DLG's. The overlays include transportation, hydrography, boundaries, and PLSS. According to the agreement, the work is shared, with each party completing half of the work and providing the other party with the data.
- **Digital elevation models for the U.S. Forest Service.** The USGS is close to completing a work-share agreement with the U.S. Forest Service (USFS) for the production of DEM's. This agreement calls for the one-for-one exchange of the 700 DEM's produced by each agency. The USFS uses the DEM data to develop forest plans, conduct environmental impact studies, and perform endangered species habitat assessments and pest control management studies.

Until recently, no mechanisms existed to effectively cooperate with public utilities and the private sector. Under the fiscal year 1993 National Map and Digital Data Cooperative program, the USGS began to initiate cooperative agreements with public utilities and private industry to acquire DLG data for entry into the NDCDB and for public distribution through the USGS Earth Science Information Centers. The intent is to identify sources of DLG's or map data of similar accuracy being

prepared in the private sector and by other government agencies to save costs in preparing the data to meet USGS standards. Acceptable data will be acquired for the public domain through cooperative DLG production agreements, through negotiated purchase of existing data that can be converted to DLG standards by the USGS, or through donation or data exchange. Incorporating DLG or other accurate base category data from these organizations into the NDCDB reduces duplicative data collection efforts and leverages government funds.

In addition to the funded and unfunded partnerships between the USGS and other organizations, a group of Federal agencies within the FGDC has proposed to produce the national spatial (geographic) data base required by Federal agencies and other GIS users by 2000. The group has proposed a multiagency approach whereby the data would be produced by a consortium of data producers and cooperators using common standards.

Organizations willing to participate in the consortium of data producers include the Department of Agriculture's Soil Conservation Service, Agricultural Stabilization and Conservation Service, and Forest Service; the Department of Commerce's Census Bureau and Coast and Geodetic Survey; the Department of the Interior's Bureau of Land Management and USGS; and the Tennessee Valley Authority.

The USGS will manage the consortium, which could include private contractors. Federal agencies will concentrate on administration, quality control, coordination, data sharing, and other activities that cannot be provided through contracts. The proposal also recognizes the potential for partnerships and data donor programs with the non-Federal community. About 25 percent of the digital base cartographic data sets are expected to be acquired in this way.

Initially, the USGS will focus on meeting digital base cartographic needs of high-priority Department of the Interior (DOI) lands, such as those managed by the Bureau of Land Management, the U.S. Fish and Wildlife Service, the Bureau of Indian Affairs, and the National Park Service. DOI lands constitute about 20 percent of the total land area of the United States (not including Alaska).

Partnerships among all levels of government and the private sector are no longer a management luxury but have become a necessity. The demand for large amounts of high-quality, digital spatial data, produced quickly and easily exchanged, is necessitating a wholesale change in the way organizations will do business.

Spatial Data Transfer Standard: The Key to Data Sharing

By Kathryn Wortman

An essential step in data sharing is to have a mechanism by which data can be transferred from one computer system to another without distorting or losing data. The Spatial Data Transfer Standard (SDTS), being coordinated and promoted by the USGS at the direction of the National Institute of Standards and Technology (NIST), does just that. The standard consists of specifications for the organization and structure of digital data transfer, definitions of spatial features and attributes, and encoding instructions for data transfer.

The SDTS was approved in July 1992 as Federal Information Processing Standard (FIPS) Publication 173. FIPS are issued and administered by the NIST (formerly the National Bureau of Standards) of the Department of Commerce after approval by the Secretary of Commerce pursuant to public law. The purpose of a FIPS is to achieve efficiency and cost savings by standardizing automated data processing (ADP) within the Federal Government. The SDTS contributes standardization for spatial data transfer. FIPS are mandatory for all ADP applications implemented by a Federal agency or its contractors. Effective February 15, 1993, the SDTS becomes mandatory for Federal agencies 1 year from that date. The SDTS is also available for use by State and local governments and the private sector.

For additional information regarding the SDTS, contact:

SDTS Task Force
U.S. Geological Survey
526 National Center
Reston, VA 22092

Electronic mail messages may be sent to:

sdts@usgs.gov

The components of the proposal to develop a national spatial data base that will link all levels of government and the private sector are

- A fully funded national aerial photography program that would cover 20 percent of the contiguous United States each year;
- Tide-coordinated, geodetically controlled aerial photography to update the official shoreline of the contiguous United States on a 5-year cycle;
- Digital orthophotoquad coverage of the United States by 1998 and replacement of the coverage on a 10-year cycle thereafter;
- Completing digitization of USGS 1:24,000- and 1:25,000-scale maps by 2000;
- Completing the review and updating of USGS 1:24,000- and 1:25,000-scale digital cartographic data by 2000 and establishing a capability to continue updates on a 5- to 10-year cycle;
- Achieving accurate coordinate values for the PLSS corner monuments for all PLSS States by 2000;
- Establishing a comprehensive digital nautical information data base of U.S. coastal waters by 2000.

Spatial Data Models

There are two fundamental approaches to the representation of the spatial component of geographic information: The vector model and the raster model.

Vector.—In the vector model, spatial objects consisting of points, lines, and polygons are used to represent irregularly distributed geographic objects or conditions in the real world. There is a direct link between a vector model-spatial object and the real-world entity it represents. The position of each object is defined by its placement in a map space that is organized by a coordinate reference system. Each position in the map has a unique coordinate value.

Raster.—In the raster model, spatial objects consisting of cells are used to represent a regular subdivision (usually square) of the real world. A value stored for each cell indicates the type of real-world object or condition that is found over the area covered by the cell. Unlike the vector model, a raster model-spatial object does not correspond directly to a real-world entity. Instead, a group of adjacent raster spatial objects (cells) with the same value may together represent a real-world entity. The spatial units in the raster model are the cells which are organized into rows and columns so that the entire map surface is covered. The location of a real-world entity can only be recorded to the nearest cell in the raster model.

SOURCE: Aronoff, S. 1989. *Geographic Information Systems: A Management Perspective*, p. 164–165.

The USGS is actively promoting the use of the SDTS by conducting workshops and training, as well as developing practical user guides and software, a spatial feature and attribute dictionary, and a spatial data transfer processor.

As with all FIPS, the SDTS now enters a required 5-year maintenance cycle. During this cycle, the USGS will provide the capability for the spatial data community to review the contents of the SDTS in order to address requirements for changes to the standard. The SDTS has a modular design that allows for modifications and enhancements to be made with relative ease. In addition, approvals will be sought from the American National Standards Institute (ANSI) and the International Standards Organization (ISO) in an effort to broaden access to the SDTS among the commercial and international communities.

The SDTS is implemented through the use of profiles, or subsets, of the SDTS designed to handle a specific type of data. Defining a profile allows for the elimination of numerous options, thus simplifying the encoding and decoding process. The first of these profiles is the Topological Vector Profile (TVP). The TVP will standardize the distribution of one of the more common types of spatial data currently created by Federal agencies—topologically structured vector data. Two prominent data sets covered by this profile are U.S. Census Bureau TIGER data and USGS digital line graphs. The TVP was drafted in early 1992. A comprehensive test and demonstration period for the TVP was then initiated with final results expected by the end of 1992. The profile will then be forwarded to NIST for approval as an annex, or amendment, to FIPS 173.

Development of a draft raster profile of the SDTS will be completed by early 1993. The process to define and refine the profile will follow the process used to develop the TVP. The profile will focus on georeferenced, regularly spaced raster data, such as digital elevation models, digital orthophotoquads, and some types of remotely sensed data. A test and demonstration period will begin by mid-1993.

Additional profiles being considered for development include one for network data structures, one for Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) graphics, and one for data that replaces or modifies an existing data set. The USGS is actively working with State and local communities to identify requirements for SDTS profiles to support municipal and utility requirements. Information for profile development needs is being requested from State and local governments and the private sector through the major professional societies.

User guides and other training materials for the SDTS will be developed in the near future. Educational information, such as user guides, is critical to increasing knowledge and understanding of the SDTS within the user community. The USGS will use these materials in workshops and other presentations to educate the spatial data community and to promote the use of the SDTS.

Although the vendor community will have a large role in software development, the USGS plans to develop publicly available software tools to support encoding and decoding of SDTS data. The first of these tools, an ISO 8211/FIPS 123 Function Library, is currently available. In addition, the USGS is designing a processing system to support SDTS transfers of its own digital spatial data, such as digital line graphs and digital elevation models. Digital line-graph data will be made available in the SDTS TVP by May 1993.

The SDTS contains a standard model for a spatial features data dictionary as well as a list of terms and definitions for entities and attributes. The feature and attribute glossary provides a foundation for standardizing spatial features. This glossary currently contains a limited set of hydrographic and topographic terms. Because of the increased efforts to share and integrate spatial data, the glossary must be expanded to include additional terms and definitions for additional categories of data. As such, the NIST has established a FIPS Spatial Features Register at the USGS to allow the periodic addition, modification, or deletion of spatial features to the register. A plan to maintain the register, and to identify sponsoring groups for appropriate categories of spatial features, is being developed with input from the Federal Geographic Data Committee (FGDC).

Longer term goals for SDTS activities include maintenance of FIPS 173 to ensure that it continues to meet data exchange requirements for spatial data and continued cooperation with the spatial data community to address national and international implementation needs.

The USGS is working closely with the FGDC and relevant professional societies to ensure that everyone is actively involved in the development and promotion of the SDTS. Participation from all areas of the spatial data community is critical. To encourage widespread use of the SDTS, the USGS is developing additional agreements to increase participation and support.

Digital Orthophotoquads

By Gary L. Fairgrieve

One of the most significant advances in spatial data technology in the past 10 years is the automated processing of orthophotographs. What was once a fairly slowprocess requiring extensive human assistance can now be accomplished better and faster by computer. This new process brings spatially corrected photographic images into computers, where the data can be overlaid with other digital map data (such as roads, boundaries, and hydrography) and can be used in many ways.

A digital orthophotoquad (DOQ) is created by scanning an aerial photograph into a computer in a raster file format. Using a pixel size of about 25 microns (about one-third the diameter of a human hair), a computer then digitally compares the photographic image to the corresponding digital terrain model to mathematically adjust the image, pixel by pixel. This is a fast and effective way to

Portion of a 1:12,000-scale digital orthophotoquad experimental edition of Black Earth SW, Wisconsin, made from 1:40,000-scale National Aerial Photography Program photography.

eliminate displacement caused by tilt of the airplane and the somewhat distorted view of the photograph, since the camera cannot be directly over every object in the photograph.

A DOQ, then, is spatially corrected aerial photographic data that are available in a 3.75-minute quadrangle format—four DOQ's per standard large-scale USGS topographic map.

As part of its map modernization program, the USGS is planning to use DOQ's in revising its 1:24,000-scale topographic map series. DOQ's will serve as a source of new information that can be compared directly with topographic maps that are in need of revision. This process will expedite map revision. As a byproduct of this process, a new form of digital data will be available for these quadrangles (in addition to the digital line graphs and digital elevation models). These forms of digital data will be available through the USGS National Digital Cartographic Data Base. The availability of this product will provide geographic information system (GIS) users with high quality images to use in the collection of data related to their specialized applications. It will provide an image base for the collection and display of cartographic and geographically referenced data.

Partnerships are being established with other Federal and State agencies and private organizations that need DOQ data.

DOQ data are important to all agencies involved in mapping or using spatial data. Partnerships are being established with other Federal and State agencies and private organizations that need DOQ data. For example, the Department of Agriculture's Soil Conservation Service plans to use DOQ's as a basis for a GIS that will be used to allocate farmland for certain crops and for preventing soil erosion and water pollution. By using DOQ data, the Department of Agriculture will establish a more systematic method for organizing and analyzing geographic resource data in their field offices. This tool will provide a common method to locate and number permanent farm field boundaries and locate and identify the various classes of wetland. Through the use of accurate DOQ's and collection standards, data will be shared usefully with other Federal, State, and local agencies.

The use of DOQ's is being explored in the joint development of a data base between the USGS and the Census Bureau. Procedures are being developed that will link census information from local agencies and enumerators back to the original digital files and DOQ's to allow updating of the 1:100,000-scale transportation data.

The USGS is also cooperating with the U.S. Fish and Wildlife Service by providing DOQ data for GIS projects that involve land use and endangered species. The Bureau of Land Management is also arranging to use this type of data for programs in land management, wilderness preservation, and recreation. The National Park Service plans to obtain DOQ data to be used for GIS applications in park management.

The use of DOQ's in GIS is expected to facilitate partnerships and cooperation needed by Federal, State, and local agencies to carry out resource planning more effectively. They will provide a common image base for map revision and GIS development.

Arctic Region—Sensitive Indicator of Global Change

By Mark Shasby and Jeff Eidenshink

Arctic and sub-Arctic ecosystems, due to their short growing seasons and highly adapted species, are extremely sensitive to chemical, biological, and physical changes brought about by human activity. When these factors are coupled with the potential for global climate change, it is relatively clear why the International Geosphere-Biosphere Program has identified the Arctic as the "bellwether of global change and the zone of early warning for global greenhouse warming." An understanding of the implications of climate change in the Arctic and its ecosystems is essential.

Improved understanding of the effects of a changing climate on the Arctic is the mission of a cooperative effort of the USGS, the U.S. Environmental Protection Agency, U.S. Forest Service, U.S. Fish and Wildlife Service, Environment Canada, and other international environmental and land management agencies. Characterization of land-based ecosystems around the pole is necessary to establish a system for monitoring these changes. This international research is examining the composition, structure, function, distribution, and extent of the ecosystems and the vegetation and wildlife that compose them.

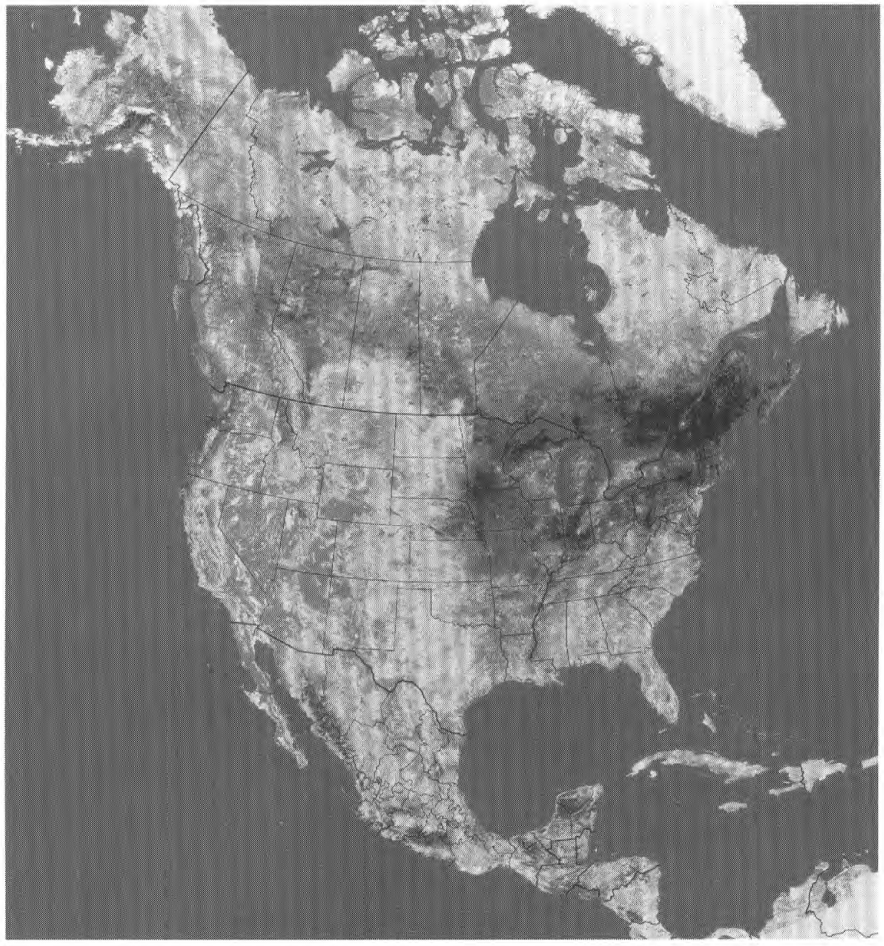
With geographic information system (GIS) and remote sensing technologies, scientists are able to study and classify these remote regions in ways never before possible. Because of the remoteness of the region, the short growing seasons, and the migrations of many important wildlife species, remote sensing and GIS technology are more important in developing data bases for global change studies here than anywhere else on the planet.

Satellites are the primary remote sensing tools for gathering data on land surface conditions in the Arctic. For example, detailed vegetation maps derived from computer analysis of Landsat multispectral scanner data have been integrated with topographic data, soils, hydrology, and other earth science data

bases into a GIS that characterizes the habitat conditions on the Arctic National Wildlife Refuge. Radio collar transmitters on caribou, polar bears, and other large mammals enable scientists to track the daily movements of these animals, and to integrate these migratory patterns into the GIS to study the relations between the animals and their habitat.

Another primary source of remote sensing data comes from the advanced very high resolution radiometer (AVHRR) data on one of the National Oceanic and Atmospheric Administration's polar orbiting weather satellites. The AVHRR provides daily observations at 1-kilometer resolution of the entire Arctic region. These daily observations are combined biweekly and analyzed to determine the general types of vegetation and to render a profile of the vegetation condition throughout the Arctic growing season. The condition of the vegetation is one of the key indicators of the effects of change caused by human activity as well as the climate.

By pulling information together from satellite observations, maps, and field observations, this project is establishing a system for monitoring conditions in the Arctic with precision and timeliness. The interagency and international nature of the project will result in comprehensive studies that can be integrated and related. The derivative data bases will show the effects of environmental changes from climatic sources, as well as the effects of human activity from such things as airborne pollutants. Improved understanding of the Arctic, a region up to now poorly understood, may lead to a better picture of the entire Earth's processes.



North American Vegetation Greenness Index, August 11–20, 1990. Produced by the USGS, in cooperation with Energy, Mines, and Resources Canada, this prototype data set of the North American continent allows scientists to assess the "greenness" of the vegetation. Low values (lighter shades) indicate poor or sparse vegetation, while high values (darker shades) indicate dense, healthy vegetation such as crops and forests.

Cooperating on TERRA Firma

The Terrestrial Ecosystem Regional Research and Analysis (TERRA) Laboratory was established in 1992 at Fort Collins, Colo., by the USGS and the U.S. Forest Service, the Agricultural Research Service, and the Soil Conservation Service of the Department of Agriculture. Scientists will work cooperatively at the lab to combine land models from different disciplines—hydrologic models, tree growth and soil erosion models, and other land resource study models. These disparate models now operate independently. TERRA lab scientists are also developing technology for coverting these models to geographic information systems (GIS) and their data bases. The main objective is to evaluate changing regional land conditions and resources by using geographic information, modeling, and remote sensing. For example, USGS scientists will research the vulnerability to environmental change of national parks and monuments, changes in wildlife habitat, and potential changes in Native American lands in the Western United States.

Involvement in the Earth Observing System

By R. J. Thompson and Lyndon R. Oleson

Many nations sponsor programs to study the effects of both natural and human-induced environmental change. The United States has initiated the U.S. Global Change Research Program (USGCRP) to develop a strong scientific understanding of the interactive physical, chemical, biological, geological, and social processes that regulate the Earth's environmental system. This knowledge may prove to be a scientific basis for national and international policy decisions related to changes in the global system.

The USGS is contributing to the USGCRP not only through its own global change data and information systems initiatives but also through involvement in other agency initiatives such as the National Aeronautics and Space Administration Earth Observing System (EOS). EOS is a 15-year program consisting of a series of Earth-orbiting spacecraft designed to study the atmosphere, oceans, cryosphere, biosphere, and solid Earth.

Those portions of EOS data relating to land processes will be archived, processed, and distributed by the USGS EROS Data Center (EDC) in Sioux Falls, S. Dak.

The first of a series of EOS spacecraft is scheduled to be launched in 1998. The EDC will be involved in the archiving and distributing scientific data from two of the five instruments aboard this initial spacecraft. The EDC will archive and distribute data from the moderate resolution imaging spectro-radiometer (MODIS) and the advanced spaceborne thermal emission and reflection radiometer (ASTER) instruments. MODIS will measure Earth vegetation and land surface cover to monitor change in land surface cover, conditions, and productivity. ASTER, a Japanese instrument, will be used to study surface vegetation and temperature, rock types, and volcanoes.

The EDC is participating in pre-EOS programs to make existing earth science data more useful. For example, the EDC is involved in an international program to obtain complete 1-year coverage of all the land surfaces of the globe with National Oceanic and Atmospheric Administration advanced very high resolution radiometer (AVHRR) sensor data. This global land AVHRR data set will be a precursor data set for EOS investigators developing algorithms and scientific models. Other similar activities include improved access to existing global topographic, aircraft scanner, and synthetic aperture radar data sets.

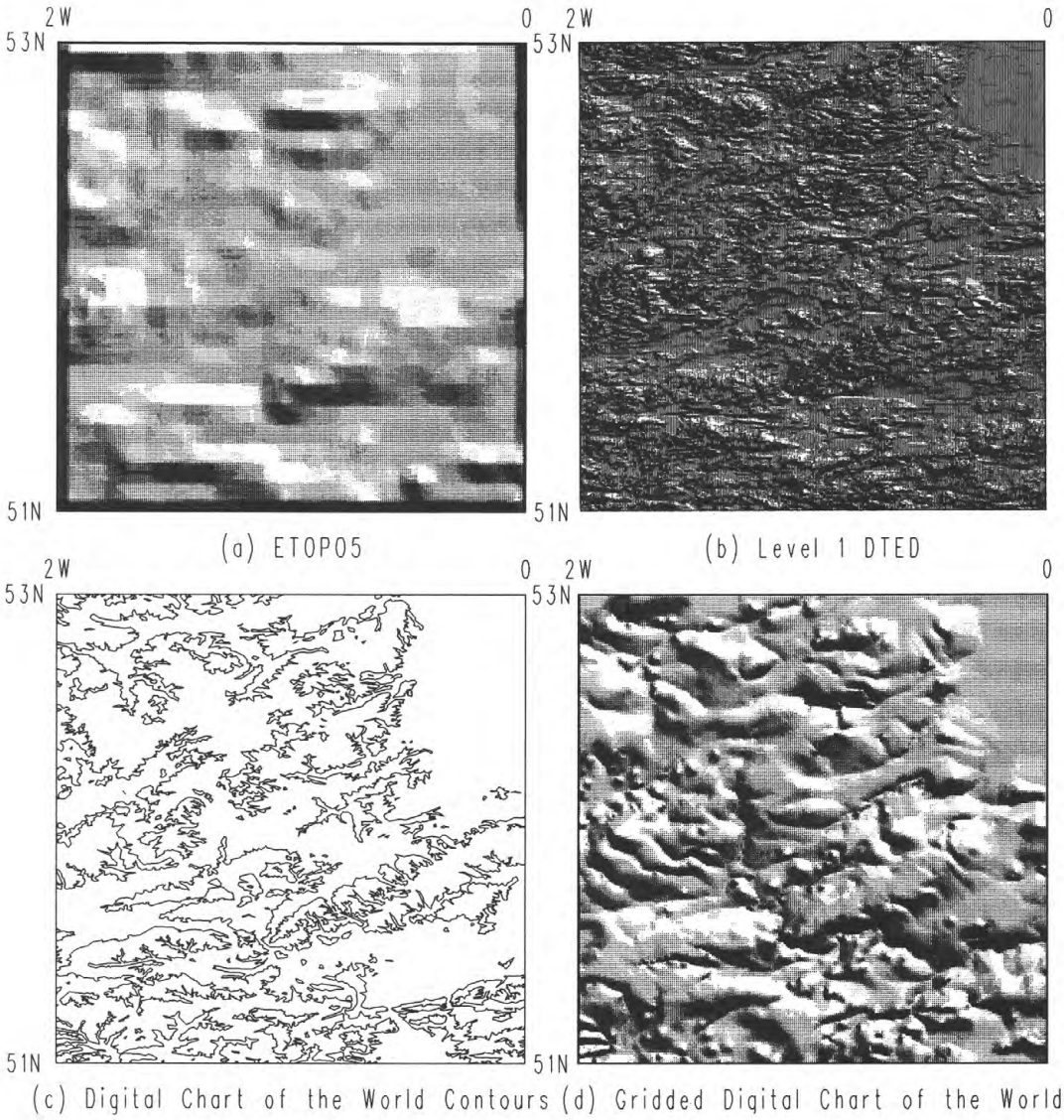
Availability of Global Digital Topographic Data

By Susan K. Jenson and Kevin S. Larson

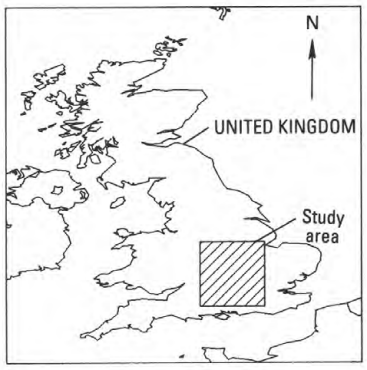
Increasingly, earth scientists need digital topographic data at many scales for applications ranging from geometric and radiometric correction of satellite data, to slope computations for surface-water modeling, to studies of plate tectonics. Data availability for areas outside the United States, however, has remained limited to the National Oceanic and Atmospheric Administration's ETOPO5 data set with a 5-minute (approximately 10-kilometer) resolution.

The Defense Mapping Agency's (DMA) newly available Digital Chart of the World (DCW) provides 1:1,000,000-scale global contour data. DMA's digital terrain elevation data (DTED) contain topographic information with a 3-arc-second resolution (approximately 90 meters). DTED exist for much of the Earth, primarily in the northern hemisphere. At this time, distribution of DTED is limited to agencies within the executive branch of the U.S. Government. The DCW is a source of global topographic information with the potential for generating elevation grids with a 0.5- to 1-kilometer cell size, thus providing greater detail than ETOPO5 but less than DTED. The figure (see p. 79) shows a data comparison for these three data sources for a 2°-square study area in the United Kingdom.

The USGS plans to continue to generate global digital elevation data from the DCW. The island of Madagascar was recently completed, along with parts of Africa, Haiti, and Puerto Rico.

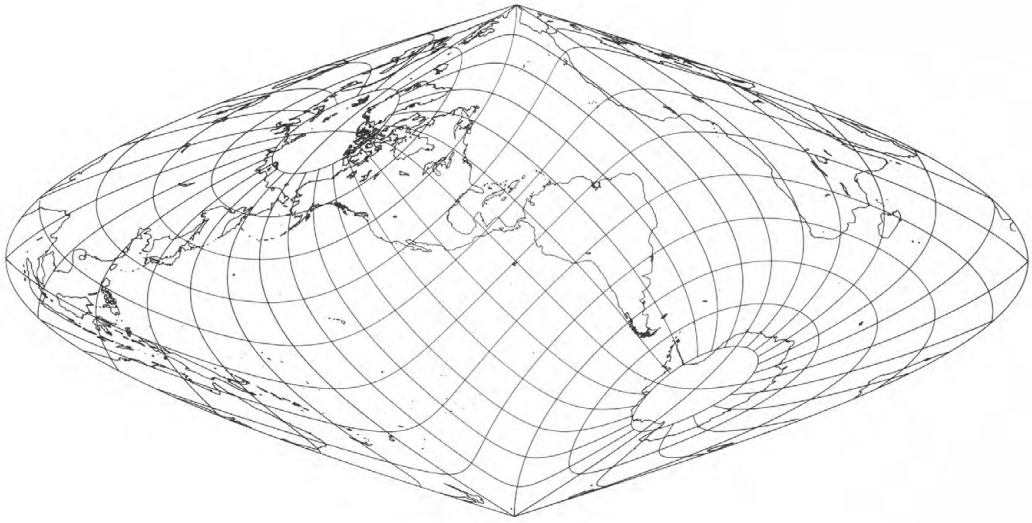


Elevation data comparison. (a) shows a shaded-relief representation of the ETOPO5 data for the area. The ETOPO5 grid of elevation values consists of 24 cells by 24 cells. (b) shows the DTED data for the area. With a resolution of 3 arc-seconds (approximately 90 meters), there are 2,401 by 2,401 cells in the DTED grid. (c) shows the contours of the same region from the Digital Chart of the World with a contour interval of 250 feet (76 meters). Finally, (d) shows a shaded-relief representation of the grid that was generated from the contours in (c). The 481 by 481 grid in (d) has a 15-arc-second cell size. The same major landform components are visible in each of the three data sets, but the grid produced using DCW provides improved detail over ETOPO5.



Location of 2°-square study area in the United Kingdom.

INTERNATIONAL ACTIVITIES



MISSION

U.S. Geological Survey cooperative science and technology studies with foreign nations are authorized under the Organic Act, as revised, and the Foreign Assistance Act and related legislation when the activities are determined by the Departments of State and the Interior to be in the best interest of the U.S. Government. Objectives of the investigations include:

- Liaison will be established and maintained with foreign counterpart organizations, scientists, and technicians. The technology transfer and data exchange will be facilitated through cooperation, goodwill, and harmony.
- Comparative international studies will expand the range and contribute to the attainment of domestic research objectives through testing and application of scientific concepts and techniques in favorable areas abroad.
- Worldwide data bases will be established into which information about known and potential foreign resources of interest to the United States will be incorporated. These data bases will be available worldwide to all interested parties.
- Worldwide cooperative studies in the earth sciences will broaden the expertise of both USGS and foreign-counterpart scientists and technicians.
- Earth science and natural resource programs of other Federal agencies, international organizations, academia, and the private sector that share mutual interest with USGS efforts will be supported; the Department of State, in particular, will be provided with information from which to formulate objectives and decisions on matters of foreign policy.

Introduction

USGS foreign studies in the earth sciences continued in fiscal year 1992 as essential and complementary aspects of the domestic scientific program. These international studies are done under U.S. Government-approved, bilateral or multilateral agreements with foreign organizations. USGS technical assistance programs provide for the transfer of technology by means of advice, training, and demonstrations and are commonly carried out under the auspices of other Federal agencies, international scientific organizations, international financial institutions, or foreign governments. USGS international cooperative programs in the earth sciences include activities ranging from informal contacts between individual scientists to cooperative activities that are formally organized, jointly staffed and funded, and sanctioned by international treaties between the United States and foreign governments. USGS scientists also serve as officers, committee members, and participants in international earth sciences organizations, commissions, and associations.

Programs in the geological, hydrological, and mapping sciences are underway in Europe and the Near East, and proposals for new programs in Africa, South America, and the Far East are under discussion.

International activities highlighted in this chapter include the International Geographical Congress and concurrent meetings of the International Society for Photogrammetry and Remote Sensing and the American Society for Photogrammetry and Remote Sensing held in Washington, D.C.; the International Geological Congress held in Kyoto, Japan; mineral resource assessment studies of Bolivia; advice to the Government of Hungary; the continental deep drilling program; assessment and redevelopment of the prehistoric Hamdah gold mine, Saudi Arabia; and mapping in the Antarctic in cooperation with New Zealand.

Global Resources Information Data Base

By Ronald E. Beck

The USGS Earth Resources Observation System (EROS) Data Center became the North American segment of the United Nations Environment Global Resources Information Database (GRID) with dedication of an office at the Center in March 1992. The GRID office at the EROS Data Center, near Sioux Falls, S. Dak., joins a network with other offices in Kenya, Thailand, Switzerland, Nepal, Japan, Norway, Brazil, and Poland.

The GRID offices were established to help scientists obtain information for environmental studies such as land forms, land use, and vegetation condition, as well as recent satellite images. The staff in the GRID offices help scientists find the appropriate data and work with them on how best to use the information.

The Sioux Falls facility was established as a cooperative program among the United Nations, the USGS, the National Aeronautics and Space Administration, the University of New Hampshire, and the University of California at Santa Barbara.

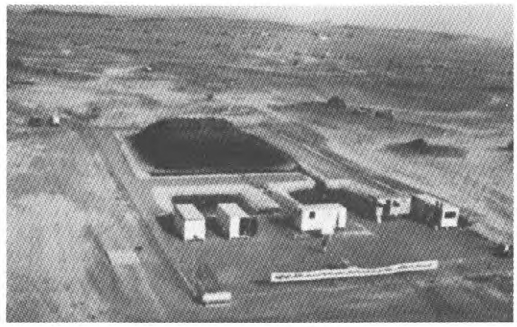
Gold Exploration in Saudi Arabia

By Kenneth Sargent

Following a successful cooperative exploration program with the Saudi Arabian Directorate General of Mineral Resources (DGMR), USGS studies at the Hamdah gold prospect in the southwestern part of Saudi Arabia phased out at the end of 1992 with the completion of a series of evaluation reports. Cooperative agreements with the Saudi Arabian government date to 1963 and include extensive regional geologic mapping and mineral exploration.

The Hamdah gold project included a heap-leach test, executed over 17 weeks, to dissolve the gold from the rock in which it is found. The test culminated in a ceremonial gold pour on July 21, 1991, at which the gold was poured into ingots. Officials of the Saudi Arabian government and of DGMR joined USGS scientists at the ceremony to mark the project's completion. The pour yielded 19.2 kilograms (more than 42 pounds) of gold of 91 percent average purity. The deposit contains 1.1 million short tons (1 million metric tons) of overburden at an average grade of 0.1 troy ounce of gold per short ton (2.8 grams per metric ton) and 89,000 short tons (81,000 metric tons) of bedrock containing significant amounts of gold.

The Hamdah deposit was originally worked more than 800 years ago and was reinvestigated starting in 1989. More than 10,000 collected samples, almost 4,000 meters (more than 13,000 feet) of recent core drilling, and 6,000 meters (almost 20,000 feet) of trenching confirmed the presence of an economically significant amount of gold ore. The deposit is central to other smaller deposits



Aerial oblique view of the Hamdah heap-leach plant, in remote southwestern Saudi Arabia.

(Left to right) His Excellency Hisham Nazer (Minister of Petroleum and Mineral Resources and Acting Minister of Planning), His Excellency Ibrahim Khaberi (Deputy Minister of Mineral Resources), and Dr. Mohammed Tawfiq (Assistant Deputy Minister of Mineral Resources) hold a gold bar produced by the ceremonial gold pour.

that can be mined because of their proximity to the larger Hamdah deposit.

Cooperation with the DGMR is continuing on other gold properties and is expected to lead to additional significant deposits in the near future.

New Zealand Antarctic Mapping Program

By Jerry L. Mullins

The New Zealand Department of Survey and Land Information and the USGS are producing 1:50,000-scale topographic maps for areas of the Dry Valleys in the Antarctic. Five of 33 quadrangles will be published in 1993. In accordance with U.S. policy, the maps will show no territorial claims in Antarctica.

Under this cooperative program, the United States has been obtaining aerial photographs and establishing geodetic control in cooperation with New Zealand, performing aerotriangulation, and producing the standard map collar layout. New Zealand is performing the stereocompilation, collecting the digital cartographic data, preparing the shaded-relief and place names overlays, and providing the color separates. The USGS will print the maps.

The McMurdo Dry Valleys are generally snow-free valleys in the Transantarctic mountains located in the McMurdo Sound region. The area is comprised of three major valleys, the Wright, Taylor, and Victoria Valleys, each of which contain glaciers. The valleys are separated by mountains ranging to approximately 2,400 meters (7,874 feet).

The project includes the revision of eight maps that were produced by the USGS in 1977. These 15-minute topographic maps are at 1:50,000 scale with a 50-meter (164-foot) contour interval and 25-meter (82-foot) supplemental contours. They cover the Taylor and Wright Valleys in the Dry Valleys area of northern Victoria Land. The revision includes converting the maps from the local geodetic datum to World Geodetic System 84 datum, preparing a shaded-relief version, and updating the maps with new place names approved since the last printing.

The USGS has a long-standing commitment to cooperative mapping and scientific research in Antarctica as part of the United States Antarctic Program that maintains a permanent technical and scientific preserve at the South Pole. The Antarctic Mapping Program has produced more than 150 maps of the 5,374,000-square mile (13,918,660-square kilometer) continent. The newest maps in this series will be particularly beneficial to the U.S. and to New Zealand for Antarctic research.

Holes of Opportunity—Continental Scientific Drilling

By David P. Russ and Kurt Dodd

Continental scientific drilling is an exciting frontier area of geologic research involving national and international efforts to improve the scientific knowledge of the Earth's continental crust. The USGS, through the multiagency U.S. Continental Scientific Drilling Program, is working with the Department of Energy and the National Science Foundation to coordinate activities with international and foreign geoscience agencies.

Current knowledge of the Earth's subsurface is limited largely to inferences based on geophysical measurements (such as seismic, gravity, and magnetic surveys), studies of certain rocks that are exposed at the surface but that formed or were altered deep within the Earth, and laboratory experiments at high

pressures and temperatures similar to those found in the Earth's interior. Continental scientific drilling greatly expands our knowledge of the Earth's crust by providing direct fundamental data concerning subsurface rocks, temperature and pressure conditions, crustal fluid characteristics, changes in crustal densities and stresses, and the occurrence of deep crustal structures.

Drilling is a well-established technique for developing onshore water, petroleum, and other natural resources; most of this drilling is relatively shallow and is confined to sedimentary basins. The USGS Continental Scientific Drilling Program strives to reach much greater depths where earthquakes and volcanoes originate and where mineral and energy deposits actually form. Cutting-edge technology is being systematically developed domestically and internationally to allow drilling at elevated temperatures and pressures through dense rocks and corrosive fluids. The increased industrial competitiveness provided by this new technology is a major benefit of continental scientific drilling that is particularly critical for natural resource industries, which are being forced to drill deeper in order to replenish their declining reserves.

An important cost-effective way the United States and the USGS contribute to and benefit from continental scientific drilling is through the sharing of information and the pooling of expertise and resources with international and foreign geoscience agencies. Collaborative projects between USGS and foreign scientists at international drilling sites provide access to "holes of opportunity" where experiments and deep-earth measurements can be carried out without having to bear the high costs of drilling.

The USGS conducts several cooperative projects with countries such as Germany and Russia, which have strong drilling programs. Germany's Kontinentales Tiefbohrprogramme der Bundesrepublik Deutschland (KTB) is drilling a very deep borehole (about 10 kilometers (33,000 feet)) by using a specially designed, highly automated drill rig with state-of-the-art laboratory facilities for analyzing borehole data, core samples, and drilling records.

A joint study of thermal conductivity by USGS and KTB scientists was recently expanded to include measurements at elevated temperatures. Thermal conductivity measurements are necessary for determining heat flow in the crust but are difficult to make at high temperatures. This cooperative study is providing critical information on the most efficient, accurate, and cost-effective methods for investigating deep thermal processes.

In addition, high-temperature downhole fluid samplers were recently deployed cooperatively in the KTB deep hole at depths greater than 6 kilometers (3.7 miles) where temperatures are greater than 150 °C (302 °F). Hydrothermal and isotopic data from these analyses, coupled with rock-composition and geochemical analyses, are providing previously unattainable information on rock-fluid interactions in a deep crustal environment that has experienced intense pressure.

Russia is the world leader in deep drilling of the continental crust in the number of research wells cored, the great depths reached in the boreholes, and new and innovative technology developed for drilling. At Russia's deep well site in the Caucasus Mountains, the USGS is working to improve the procedures to measure deep earth stresses and to learn how these stresses relate to the generation of earthquakes, the production of heat for geothermal energy, and the processes that drive the motion of the Earth's crustal plates.

The USGS also has a cooperative project with Russia at the deep-hole site in northwestern Russia near Finland. At approximately 13 kilometers (8 miles) depth, the Kola well in northwestern Russia is the deepest drill hole in the world; it was drilled to learn more about ore-forming processes and to test subsurface geophysical models. The USGS has been studying subsurface stress and fluid migration pathways in the Kola well to improve understanding of fluid behavior in the deep crust. This information is important to modeling the formation of mineral deposits, to determining mechanisms of oil and gas origin and migration, and to understanding the processes that initiate and control fault rupture and earthquakes.

The basic information on the subsurface of the Earth's continents gained through these cooperative drilling efforts yields important economic, technological, and societal benefits through applications in other ongoing efforts, such as mitigating earthquake and volcanic hazards, responsibly managing radioactive and other hazardous wastes, ensuring adequate supplies of natural resources, and expanding educational opportunities in science and engineering.

Continental scientific drilling greatly expands our knowledge of the Earth's crust. . .

Russia is the world leader in deep drilling of the continental crust. . .

Cooperation with Hungary

By Paul Teleki

At the request of the Hungarian Government, bureaus of the U.S. Department of the Interior (DOI), led by the USGS, have been providing technical assistance since the autumn of 1990 to the Hungarian Ministry of Industry and Trade. Mining, geology, and energy resources are the main concerns of the

assistance, which is part of U.S. efforts to revitalize the economies and sponsor increased scientific cooperation in Eastern Europe.

The USGS and other DOI bureaus have provided advice and assistance in restructuring the legal and regulatory framework for the mining and energy sector in Hungary. They have developed new regulations and defined regulatory oversight functions related to mining and energy development and production. In addition, experts of the USGS and the British and Swedish Geological Surveys provided review and advice in the reorganization of Hungary's geological and geophysical institutions; that reorganization is still in progress.

A new mining law was written with the participation of DOI's Office of Policy Analysis, the Solicitor's Office, the USGS, the Bureau of Land Management, the Minerals Management Service, and the U.S. Bureau of Mines along with Hungarian, Canadian, and Norwegian Government counterparts. The legislation covers concession-based exploration, development, and production of oil and gas, minerals, and geothermal energy, as well as pipelines, surface and subsurface storage, and the utilization of abandoned mines. It also sets royalty rates and prescribes occupational health, safety, and environmental protection. This bill also established the Hungarian Mining Office as the regulatory agency of the mining sector with minerals management inspection and enforcement responsibilities as well as royalty collection and management. The bill is being debated in the Hungarian Parliament.

Under a separate agreement between the U.S. Department of Energy and the Hungarian Ministry of Industry and Trade, the USGS has provided technical assistance to the Hungarian Atomic Energy Commission in reviewing disposal options for radioactive waste in Hungary. The goal of this program is to find suitable disposal locations, including geologically and hydrologically acceptable deep disposal sites for high- to low-level wastes from Hungary's nuclear powerplant. The project is one aspect of a broader set of cooperative activities between the U.S. Department of Energy and Hungary that includes assistance in preparing new legislation for electricity, devising a regulatory framework for the electricity sector, and developing energy information systems. The USGS has provided in-country technical support to the Hungarian Government to coordinate and administer the agreements with the Ministry of Industry and Trade.

EXPOMIN '92

By A.T. Ovenshine

A new exhibit by the Department of the Interior debuted at EXPOMIN '92, a major South American mining exposition held in Santiago, Chile, May 12–15, 1992. Organized by the Minerals Management Service, Bureau of Land Management (BLM), and USGS, the exhibit focused on the search for

and management of minerals on lands in the national domain.

At the meeting, Spanish-speaking officials from BLM and USGS greeted thousands of interested visitors, collected hundreds of requests for more information, and explained the exhibits, which included interactive computer files from BLM and USGS. Public officials from Bolivia asked the USGS to display the exhibit at a similar exhibition in Santa Cruz, Bolivia, in September 1992.

Major International Mapping Meetings Held in Washington, D.C.

By Alan R. Stevens

More than 10,000 participants from 85 nations attended the American Society for Photogrammetry and Remote Sensing 17th International Society for Photogrammetry and Remote Sensing (ISPRS) Congress, and the concurrent 27th International Geographical Congress (IGC) in Washington, D.C., August 2–14, 1992. A joint scientific and commercial exhibit was also open throughout the 2 weeks.

"Visual Geography," a new traveling, museum-quality exhibit produced by the USGS with cooperation from the National Geographic Society, made its debut at the ISPRS–IGC exhibits. The exhibit features more than 400 images showing the diversity and beauty of cartographic products. Topics range from "Charting the Heavens" and "Moments in Mapping," to "Beyond Geography." Presently, the exhibit is on a 5-year tour in the United States monitored by the Association of Science-Technology Centers.

Additionally, other domestic and international organizations such as Resource Technology '92, the International Cartographic Association, the International Union of Surveying and Mapping Organizations, the United Nations, and the U.S. Agency for International Development held meetings in conjunction with ISPRS.

The opening address was presented by Mr. Daniel S. Goldin, the Administrator of NASA, and the keynote address was presented by Dr. Roy Gibson, former Director General of the European Space Agency. Dallas Peck, the Director of the USGS, moderated a plenary session entitled "The Challenge of Global Change," and Doyle Frederick, the Associate Director, moderated a session entitled "Federal Geographic Data Committee Activities." The Congress included over 1,500 technical papers, 160 exhibitors, 5 workshops, and 26 technical tours. Committee volunteers included many scientists and technicians, from the USGS, who assisted with translating, interpreting, monitoring technical sessions, and scheduling tours.

The technical program of the concurrent meetings focused on the mapping and geographic sciences with special issues such as automated cartography, computer vision, geographic data coordination and standards, geographic information systems, education and training, robot vision and navigation, expert systems and artificial intelligence, image analysis, extraterrestrial mapping, and many more.

Mexico and U.S. Sign Cooperative Mapping Agreement

By Alan R. Stevens

The joint meeting of the ISPRS–IGC was also the venue for the signing of an agreement for cooperation in mapping and earth sciences between the United States and Mexico.

The agreement was signed by Dr. Carlos Jarque, Director of Mexico's National Institute of Statistics, Geography, and Information (INEGI) and Dallas L. Peck, Director, USGS. The INEGI promotes the development and coordination of Mexico's National System of Geographic Information.

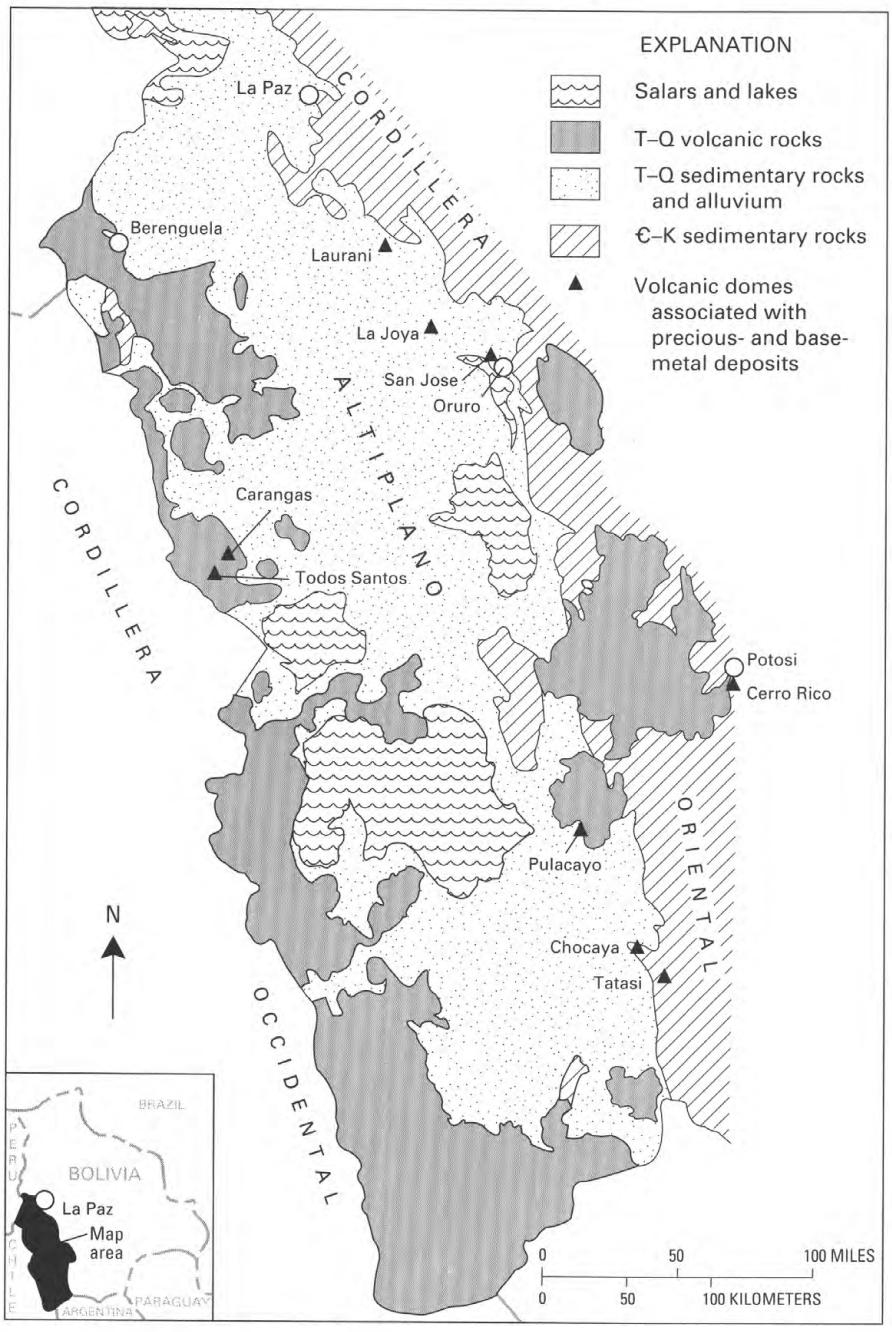
The agreement allows for cooperation among the two agencies in cartography, geographic information systems, remote sensing, and related fields. Activities under the agreement may include cooperative projects among technicians, engineers, and scientists, as well as technical information exchanges. One area of cooperation will be border map revision implementation and data base generation pilot projects in the El Paso, Texas, and Ciudad Juarez, Mexico, areas.

Since 1974, the USGS and agencies of the Mexican government have cooperated in several mapping activities, many of them in border areas. All of these activities were in keeping with the 1972 Scientific and Technical Cooperation Treaty between the United States and Mexico.

Mineral Resource Studies in Bolivia

By Steve Ludington

Bolivia has been famous for its mineral wealth since prehistoric times. The Quechua, Aymara, and other Native American peoples had been mining precious metals for hundreds of years when Spanish explorers first arrived in the 16th century. Unparalleled production of precious metals from the New World, including the silver mines of Bolivia, supported the Spanish Empire for the next 200 years. Native uprising, followed by the wars for independence that culminated in the founding of Bolivia in 1823, interrupted production of silver in the area. After independence, interest in mining was renewed, and tin began to gain importance on world markets. Today, mining continues to be a mainstay of the Bolivian economy.



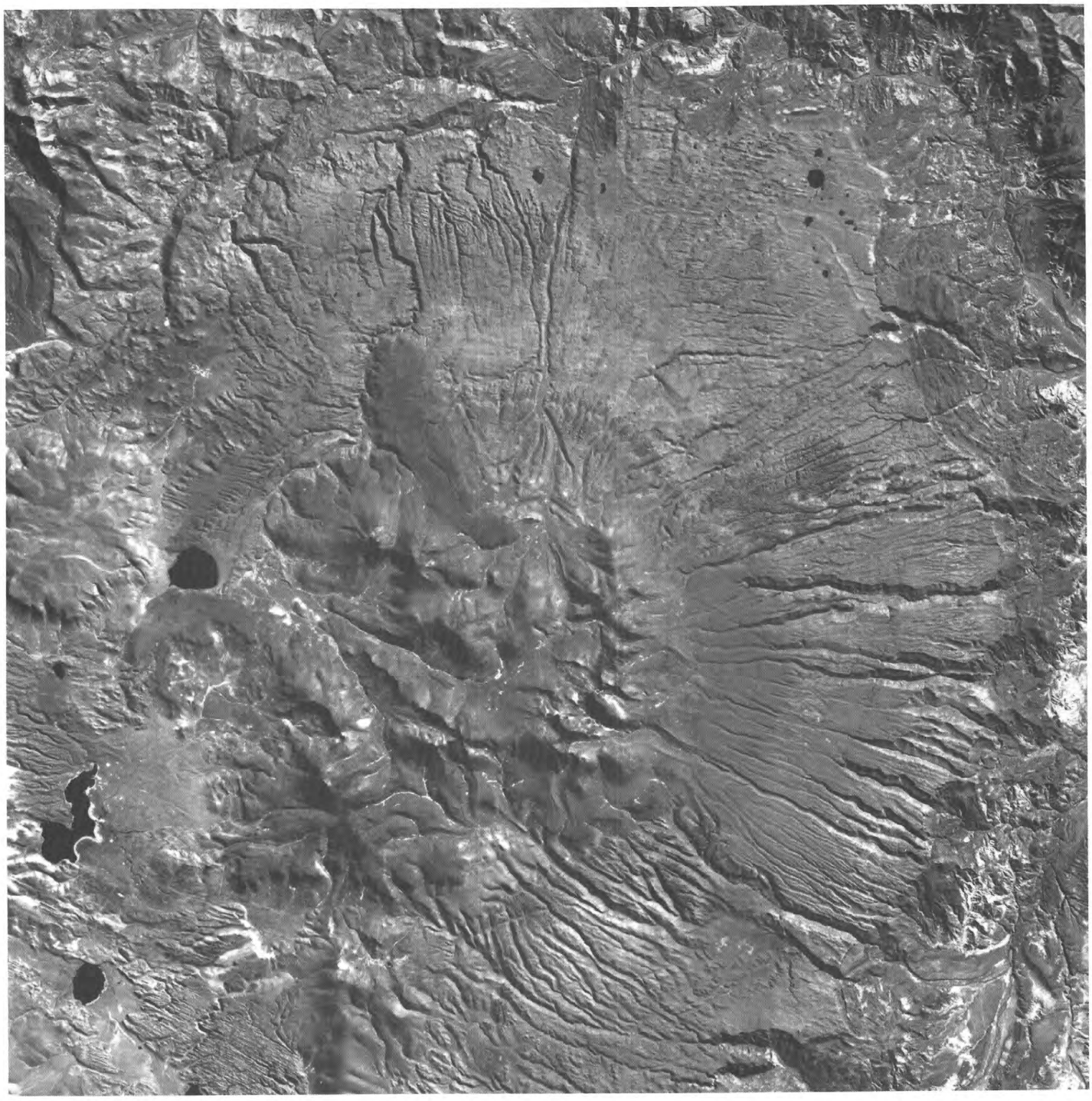
Simplified geologic map of southwestern Bolivia, including the Cordillera Occidental and Altiplano. T-Q (Tertiary and Quaternary) rocks were deposited in the last 65 million years; Є-K (Cambrian to Cretaceous) rocks were deposited between 570 and 65 million years ago.

For more than 50 years, the USGS has worked with Bolivian earth science agencies in a series of cooperative projects. The USGS recently completed a study of the mineral resources of the Altiplano and Cordillera Occidental, in cooperation with the U.S. Bureau of Mines (USBM) and the Servicio Geológico de Bolivia (GEOBOL). The project resulted from Bolivian requests for USGS technical assistance in the revitalization and redirection of Bolivia's national mining industry, which had fallen into sharp decline by 1987.

In early 1989, the two countries agreed to initiate a national mineral-resource assessment by beginning with the mineral-rich Altiplano and Cordillera Occidental. In July 1989, the U.S. Trade and Development Program signed an agreement with the Ministerio de Minas y Metalurgia to help strengthen the mining industry of Bolivia. The agreement provided for a USGS–GEOBOL cooperative assessment of the known and undiscovered mineral resources of the Bolivian Altiplano and the adjoining Cordillera Occidental. The joint assessment began in January 1990 and concluded 2 years later with the publication of USGS Bulletin 1975, *Geology and Mineral Resources of the Altiplano and Cordillera Occidental, Bolivia.*

Important results of the joint assessment include (1) new descriptions of the sediment-hosted copper deposits in the Corocoro and other areas, (2) a detailed description of the La Joya gold-bearing polymetallic district, (3) descriptions of the relatively unexplored polymetallic deposits in the southernmost part of the Altiplano, in the Sud Lípez area, and (4) first descriptions of many saline, alkaline lakes on the southern Altiplano that may contain undiscovered resources of lithium, potassium, boron, zeolites, diatomite, and other materials.

The Altiplano is a series of high basins in the Andes Mountains formed by folding and thrusting. Beginning about 30 million years ago, a wide variety of volcanic and intrusive rocks was deposited in the Altiplano. Many of these volcanic-rock complexes are associated with deposits of metallic minerals. During the last great ice age, most of the Altiplano was covered by large glacial lakes. The Cordillera Occidental consists of volcanic rocks that have erupted during the last 15 million years as the Nazca tectonic plate plunges beneath the continent of South America. Several of the volcanoes that form

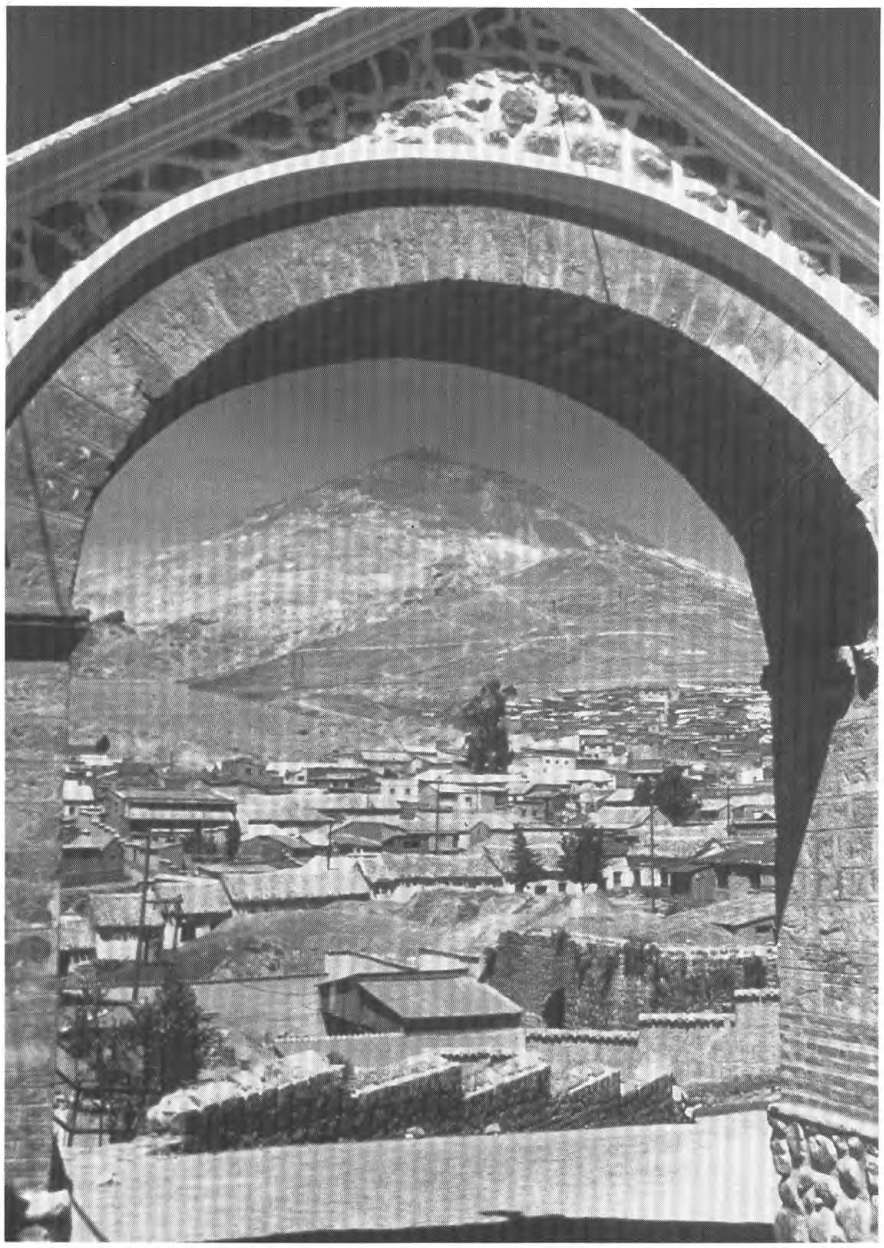


the crest of the Andes and mark the international border with Chile are presently active.

In addition to studies in the field, a new 1:500,000-scale geologic map was compiled from Bolivian sources; the map units were chosen specifically to support the delineation of areas that may contain mineral deposits.

The team analyzed Thematic Mapper satellite images and identified more than 130 areas of hydrothermally altered rocks, which typically accompany metallic mineral deposits. Many of the identified altered areas are clearly related to known mining districts, but others are in remote and poorly mapped

The Panizos caldera is the result of a large volcanic eruption on the Bolivia-Argentina border, in the southern part of the study area. The circular sheet of volcanic rocks is nearly 35 kilometers (22 miles) across. The extremely well preserved volcanic landforms of this area are a testament to the aridity of the region and the slow rate of erosion, for the eruptions that formed this feature happened more than 8 million years ago. The area is especially interesting because it contains some unusual gold occurrences. According to studies by GEOBOL geologists, gold is found widely distributed in drainage sediment throughout the volcanic field. Microscopic study of the gold particles, recovered by panning of sediment, revealed many textural features that suggest that the particles have not been transported a great distance; indeed, much of the gold may be nearly in place. To find gold like this in volcanic rocks is extremely unusual, and continuing studies are underway to determine the origin of the gold.



CHARLES G. CUNNINGHAM

Cerro Rico de Potosi, the conical hill shown in the photograph, is the world's largest silver deposit. The brown, silicified summit of this volcanic dome is seen here from the city of Potosi, Bolivia. The light-colored mine dumps in the middle distance are the result of centuries of mining silver and tin. Mining of rich veins containing as much as 40 percent silver began before 1545 and has resulted in production of an estimated 30,000 to 60,000 metric tons (33,000 to 66,000 short tons) of fine silver. In the 20th century, tin production became dominant when the high-grade silver ores were largely mined out. The deposit is currently being evaluated as a bulk minable source of low-grade silver and tin ores. It is estimated that the amount of silver remaining in low-grade ore is equal to all the silver produced to date.

locations and may indicate undiscovered mineral deposits.

Existing data on the magnetic properties of rocks in the area enabled researchers to create an aeromagnetic map. The map shows that much of the western part of the area has a distinctive, high-relief magnetic signature that is similar to magnetic signatures in many mineralized areas throughout the world.

Mineral deposits were classified according to deposit type, and, because of the unique geologic character of the central Andes in Bolivia, some new deposit types were devised. Twenty-eight specific mineral deposit types were identified, and the geologic factors that control their occurrence and distribution were outlined. All identified mineral occurrences were plotted on a map, and areas that may contain many of the deposit types delineated. USGS geologists made probabilistic estimates of numbers of undiscovered deposits for several selected deposit types to quantify our knowledge about the mineral resources of the study area.

Sediment-hosted copper deposits are the most widespread deposit type in the study area, although the Bolivian deposits are smaller than those in other parts of the world. Gold may occur in the study area in a wide variety of types of mineral deposits, including sediment-hosted gold deposits, antimony deposits, and low-sulfide gold-quartz vein deposits.

Bolivian polymetallic vein deposits have provided most of the mineral resources of the study area in the past. Silver and tin were the principal commodities, but copper, lead, zinc, antimony, bismuth, and tungsten also were mined. These deposits are closely related to volcanic-rock complexes. In the future, gold may be an increasingly important product of these deposits, as exemplified by the newly developed Kori Kollo deposit in the La Joya district.

The study area contains large areas that exhibit geologic characteristics associated with other types of precious-metal deposits, similar to those found in the western part of the United States. The present level of exploration is insufficient, however, to differentiate the specific environments, but the remote-sensing study revealed many areas that may represent the upper parts of any of these deposits.

The study area also contains an environment that may host very large evaporite deposits of lithium and boron. Two great salars (salt flats) on the Altiplano, Uyuni and Coipasa, and many smaller ones may contain large resources of these materials, as well as sodium carbonate, sodium sulfate, and potash. Zeolites, diatomite, and other materials also may be important.

29th International Geological Congress Meets in Kyoto, Japan

By John R. Keith and A.T. Ovenshine

Almost 5,000 earth scientists, exhibitors, and guests from 90 countries around the world met in Kyoto, Japan, August 24 through September 3, 1992, for the 29th International Geological Congress (IGC). The Congress was sponsored by more than 50 Japanese institutions, including the Japanese Ministry of International Trade and Industry, the Japan National Oil Company, the Metal Mining Agency of Japan, and the Geological Survey of Japan in cooperation with numerous other scientific societies, governmental bodies, universities, industrial organizations, and individuals.

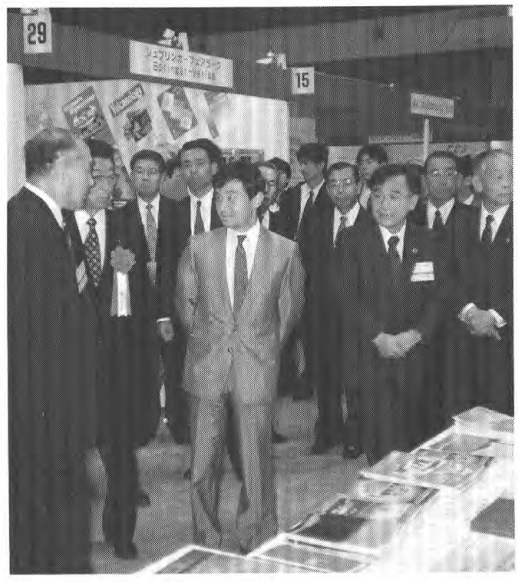
Since its first meeting in 1878, the Congress has been held every 4 years on the average, and the location is rotated among different member countries. The most recent meeting was held in Washington, D.C., in 1989, and the USGS was a major sponsor of that event. The Congress is one of the largest regularly scheduled international meetings of scientists.

This year's IGC in Kyoto featured more than 3,800 oral and poster presentations at the Kyoto International Conference Center. In addition, 12 workshops and short courses were offered to participants. Over 50 field trips rounded out a very full menu of scientific activities. The field trips, as well as many of the papers, dealt with the geologic processes and history of island arcs.

The principal theme of the Congress stressed the strong relation between the earth sciences and human survival. Crown Prince Naruhito, in his opening address as Honorary President, stressed the obligation of earth scientists to provide governments with essential scientific data on which to base wise decisions about resource management, natural hazards, and global environmental problems. The scientific program of the meeting expanded on this principal theme. A major symposium was devoted to frontier earth science research related to the environment, and numerous papers dealt with global climate change, natural hazards, energy use, and environmental aspects of mineral resource extraction. USGS researchers presented papers and convened symposia on a wide range of topics, including mineral and energy resources in the 21st century, heat and mass transport of magma in areas of active volcanism, climate and paleogeography of the Pacific region, and volcanic calderas and their tectonic setting.

In addition to the scientific program, the Congress included business meetings of more than 85 associated societies and specialty groups, a major program of scientific exhibits, a youth congress, a science theater, and cultural programs for those accompanying members. The Organizing Committee was pleased with the number of registrants from outside Japan (57 percent). About 300 delegates attended from the states of the former Soviet Union. Of 400 U.S. attendees, about 40 were from the USGS. Director Dallas Peck led the U.S. delegation. The overall effect of the Congress was well summarized by a Japanese newspaper, which gave the meeting a banner headline: "IGC is the Olympics of Earth Science!"

The General Information booth.



Crown Prince Naruhito (center), Honorary President of the IGC, visits the USGS booth.

JOHN R. KEITH

USGS Director Dallas Peck (holding pen) and Office of International Geology Chief A.T. Ovenshine sign a new Memorandum of Understanding with Russian scientists.

International Agreements of the U.S. Geological Survey

[Bold type denotes agreements that began during fiscal year 1992]

Country	Counterpart organization	Description
Argentina	Instituto Nacional de Prevencíon Sísmica	Establish global telemetered seismic network station.
Bolivia	Ministry of Mines and Metallurgy	Scientific and technical cooperation in the earth sciences.
Bolivia	Academia Nacional de Ciencias de Bolivia/Observatorio San Calixto	Establish global telemetered seismic network station.
Botswana	Geological Survey of Botswana	Establish global telemetered seismic network station.
Brazil	University of Brasilia	Establish global telemetered seismic network station.
Cameroon	Institute for Geology and Mining Research	Scientific and technical cooperation in the earth sciences.
Canada	**Canadian Surveys, Mapping, & Remote Sensing Sector of the Department of Energy, Mines and Resources**	**Cooperation in surveys, mapping, and remote sensing activities in the areas of international border mapping and the accessing of global change data.**
Central African Republic	French Office of Scientific and Technical Research Overseas	Seismic research observatory station in Bangui.
China, People's Republic of	State Seismological Bureau	Scientific and technical cooperation in earthquake studies.
China, People's Republic of	Chinese Academy of Geological Sciences	Scientific and technical cooperation in earth sciences.
China, People's Republic of	Bureau of Hydrology of the Ministry of Water Resources	Scientific and technical cooperation in surface-water hydrology.
China, People's Republic of	Bureau of Surveying and Mapping	Scientific and technical cooperation in surveying and mapping studies in the development of geographic information systems, the application of remote-sensing information, and the development of map-production management systems.
Côte D'Ivoire	Côte D'Ivoire Lamto Geophysical Station	Establish global telemetered seismic network station.
Czechoslovakia	**Geological Surveys of Czech and Slovak Federal Republic**	**Scientific and technical cooperation in the earth sciences.**
Finland	Geological Survey of Finland	Scientific and technical cooperation in the earth sciences.
France	Bureau de Recherches Géologiques et Minières	Cooperation in the geological sciences.
Honduras	Ministry of Natural Resources	Scientific, technical, and policy cooperation in the earth and mapping sciences.
Iceland	Icelandic Council of Science	Scientific and technical cooperation in the earth sciences.
Israel	Earth Science Research Administration	Establish global telemetered seismic network station.
Italy	Istituto Nazionale di Geofisica	Regional digital seismic studies.
Italy	Osservatorio Geofisico Sperimentale Ministry of Universities and Scientific Research	Scientific and technical cooperation in the earth sciences.
Italy	Istituto Sperimentale Modelli e Strutture	Cooperation in the geological sciences.
Japan	**Public Works Research Institute, Ministry of Construction**	**Cooperation in hydrology, water resources, and global climate change.**

International Agreements of the U.S. Geological Survey—Continued

[Bold type denotes agreements that began during fiscal year 1992]

Country	Counterpart organization	Description
Kuwait	Kuwait Institute for Scientific Research	Cooperation in the earth sciences.
Mexico	Instituto de Investigaciónes Eléctricas	Cooperation in geothermal and related volcanic investigations.
Mexico	Institute of Statistics, Geography, and Information	Technical cooperation in cartography, geographic information systems, and remote sensing.
New Zealand	Department of Lands and Surveys	Scientific and technical cooperation in topographic mapping of parts of Antarctica.
Norway	Norwegian Institute of Technology	Cooperation in the geological sciences.
Norway	Geological Survey of Norway	Scientific and technical cooperation in the earth sciences.
Norway	**University of Bergen**	**Scientific and technical cooperation in the earth sciences.**
Paraguay	Comisión Nacional de Desarrollo Regional Integrado del Chaco and the National University of Asunción	Establish global telemetered seismic network station.
Peru	Ministry of Energy and Mines	Scientific and technical cooperation in the earth and mapping sciences.
Poland	Ministry of Environmental Protection and Natural Resources	Cooperation in geoscience research.
Saudi Arabia	Ministry of Petroleum and Mineral Resources	Tenth extension work agreement related to geology, geophysics, and mineral resources.
South Africa	Department of Mineral and Energy Affairs	Installation and operation of an integrated realtime system to acquire global seismic data.
former Soviet Union	Committee on Geology of Russian Federation and Russian Academy of Sciences	Cooperation in geoscience (studies in energy, mineral, and water resources, mapping science, global climate change, marine geology, deep scientific drilling, and earthquake research).
former Soviet Union	Russian Committee of Geodesy and Cartography of the Ministry of Ecology and Natural Resources	Cooperation in the mapping sciences.
United Arab Emirates	National Drilling Company	Scientific and technical cooperation in the earth sciences.
United Kingdom	Natural Environmental Research Council	Cooperation in earth sciences and environmental studies.
Venezuela	**Ministry of Energy and Mines**	**Scientific and technical cooperation in the earth and mapping sciences.**
Worldwide	Unesco (United Nations Educational, Scientific, and Cultural Organization)	Cooperation in the International Decade for Natural Disaster Reduction.
Worldwide	United Nations Environmental Program and U.S. National Aeronautics and Space Administration	Establishment and operation of a global resource data base facility.

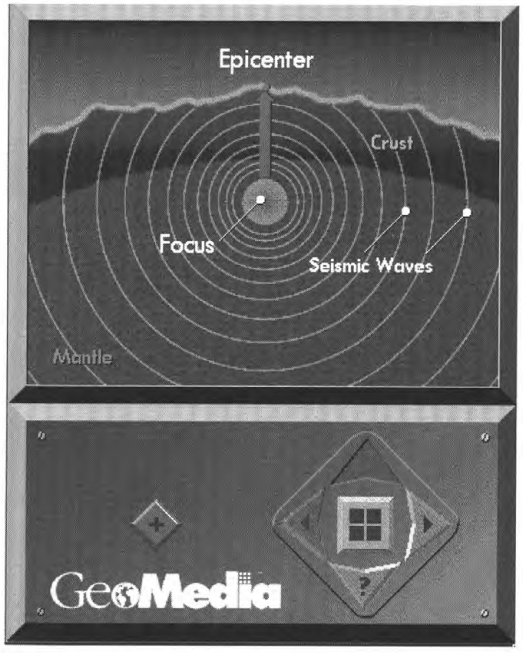
INFORMATION SYSTEMS ACTIVITIES

EARTH-QUAKES

Earth Forces

Earthquakes occur when energy is released in the Earth's crust. This energy can be caused by a sudden movement or dislocation of segments of the Earth's crust ◆ **(plates)** beneath the ground surface. When the stress and strain of forces deep within the Earth are greater than the strength of the crust, it breaks along a fault.

Click on the text above for more information.



MISSION

The Information Systems Division provides support and services to the Director of the U.S. Geological Survey, to major programs in each division of the USGS, the U.S. Department of the Interior, and to other government agencies on information technology and automated data processing (ADP). The Division operates the USGS mainframe computer located in Reston, Va., and Technology Information Centers and minicomputers in four ADP service centers nationwide.

The Division assists users in acquiring ADP and telecommunications hardware, software, and services; coordinates and improves information systems through systems analysis and design; provides user education and assistance; and conducts research into better ways to use computer technology to solve mission-related problems. The Division manages and operates voice, data, and video communications for the USGS, including GEONET, the data communications network of the Interior Department, from which gateways provide access to other national networks and supercomputer systems.

Message from the Assistant Director for Information Systems

Partnerships. Networking. Teamwork. Nearly every noteworthy USGS accomplishment in computing involves two or more people, computers, networks, organizations, or locations joining forces in a partnership. Working together, we use information resources technology to meet important earth science objectives that are beyond the resources or talents of a single individual or computer.

The ground motion from the 1989 Loma Prieta earthquake, for example, which was felt so strongly at USGS offices in Menlo Park, Calif., reminded people about the importance and vulnerability of our own telecommunications. Realizing that the USGS provides crucial earthquake information to the world, we joined forces with local and regional disaster-relief organizations to develop a recovery plan that would quickly and reliably reconnect our voice and data networks with the "outside world."

In other examples, several dozen USGS earth and computer scientists collaborated with colleagues at NASA's Jet Propulsion Laboratory to share experiences and techniques in the new field of scientific visualization to create animations that allow scientists to simulate earth science processes and envision solutions. The exchange of ideas and products from computer-generated visuals is already stimulating a new generation of applications that raise the understanding of earth processes to a new level.

With leadership from the USGS, Wide Area Information Servers are being adopted throughout the earth science and library communities as an easy and inexpensive way to share access to data and information located in many agencies and countries. In the field of education, GeoMedia builds on a partnership with teachers, scientists, and students to give students an understanding of fundamental earth science processes through the use of multimedia.

Clearly, the USGS is committed to joining forces with other organizations to share in the fast-changing world of earth science computing. After all, it helps us, and it helps our partners. Information resources technology provides an innovative arena to capitalize on the creativity and growth fostered by partnerships.

J.E. Biesecker

Telecommunications and Emergency Response

By Carol Lawson and Carl Mortensen

Located in the heart of the San Francisco Bay region, the USGS Western Region headquarters in Menlo Park, Calif., is susceptible to the effects of a damaging earthquake along one or more of the many faults that traverse the area. The Loma Prieta earthquake of 1989, served as a reminder to USGS employees, both as scientists and as members of the local community, of the need for effective emergency planning in the wake of a natural disaster.

Responding to an emergency, which affects people as employees, as scientists, and as providers of vital earth science information, is an important part of ongoing planning at the Menlo Park facility. While emergency response has long been a reality for the USGS, the Loma Prieta earthquake made the bureau realize that its own facility in Menlo Park needed to refine its existing plans into a more coordinated approach to deal with effective communications in the event of inevitable earthquakes and other disasters in the area that would hamper or severely curtail conventional telecommunications. With over 1,700 local employees, the USGS must be prepared to address the safety and welfare of its employees during a crisis. Seismologists and geologists must be ready to provide scientific information to Federal, State, and local emergency services agencies to help ensure that emergency response plans are effective. That information must also be made available quickly and in an understandable format for the news media to transmit to the public. To support these functions, telecommunications systems have been developed that serve to coordinate the management, scientific, and public outreach components of USGS emergency response plans.

Management Response Plan.—An effective communications network enables local USGS officials to easily coordinate with one another across the Western Region's Headquarter's 25-acre, campuslike facility. Command centers have been established in each of the division level managers' offices that offer

three independent methods of communication: the internal telephone system, a backup telephone system, and walkie-talkies. The internal telephone system has a backup power provision designed to maintain continuity of service in the event of a major power outage. It also provides outgoing trunk lines that have been elevated to *essential service status* by the local telephone carrier, which guarantees the USGS priority access to available lines, under most circumstances. Also in emergency circumstances, the telephone system services contractor recognizes the USGS as a priority customer. Should the Menlo Park facility's telephone system experience an equipment failure during an emergency, the contractor's service department is instructed to offer immediate support.

In the event that the internal telephone system experiences an unforeseen problem that disrupts service, a backup telephone capability has been installed in each of the command centers and in the offices of key scientists. This backup capability is provided by a major telephone carrier's switch located off-site with facilities designed to withstand a magnitude 8.5 earthquake. The phones tying into this off-site switch also carry *essential service status* and have several useful features including intercom, conferencing, and forwarding capabilities that enable management and scientists to effectively communicate with each other and with others off-site.

Should a disaster necessitate the evacuation of the office buildings, each manager also has a walkie-talkie. These portable walkie-talkies are used outside to allow for continued communications among the widespread buildings. All three of these communication systems exist to ensure effective coordination during the execution of the management response plan. Additionally, public telephones having *essential service status* have been strategically located throughout the facility. These telephones enable 911 emergency calls to be placed in the event other telephone systems experience circuit overload. These essential service pay telephones carry the highest possible priority of all of the established telephone services; therefore, they have the greatest likelihood of being able to access a dial tone during a disaster or emergency.

Scientific Response Plan.—USGS scientists are key players in the Federal Response Plan in the event of a catastrophic earthquake. Authority for actions taken under this plan derives from Public Law 93–288 (as amended), also known as the Robert T. Stafford Disaster Relief and Emergency Assistance Act. USGS scientists provide continuously updated information, hazard warnings, and technical advice (including the extent, distribution, and nature of shaking, ground failure, and damage and estimates of risk from aftershocks and progressive ground failure) to State and Federal response organizations immediately following a major earthquake. In the event of a Bay Area earthquake, the USGS can provide initial estimates of shaking intensities and likely damage distribution, as well as the likely distribution of surface faulting, liquefaction, and landslides. The accuracy and speed of these initial estimates can assist State and Federal authorities in directing local and regional response actions such as establishing staging areas and deploying resources. The USGS plan for the Bay Area will establish channels for effectively and rapidly transferring technical and scientific estimates, data, hazard warnings, and other information to help formulate and guide State and Federal responses. This plan serves as a model for the development of similar plans for USGS response to earthquakes in other regions.

Telecommunications Response Plan.—Telecommunications requirements for this plan are largely met by a communications command center that is designed to provide easy-to-use telephone based communications with access to the California State Office of Emergency Services (OES), the Federal Emergency Management Agency (FEMA), and USGS officials. Five different phone-based systems are available—the internal phone system, the backup external phone system, a microwave-based telephone system, a very high frequency (VHF) radio telephone system, and a satellite telephone system. The internal and external backup phone systems are the same as those used by managers in the center management response plan. Both systems allow scientists and managers to easily and conveniently communicate with each other, as well as with individuals off-site. The microwave-based system enables telephone access to area codes outside of the immediately affected area by passing the call through a series of microwave stations shared with the U.S. Army Corps of Engineers. A typical requirement of this system would be the need to directly access a dial tone in the 916 area code, about 90 miles (145 kilometers) from the Menlo Park Center and where State emergency offices are located. This capability is important because telephone lines into and out of an area that has experienced a widespread disaster typically experience a severe overload, hence access to local telephone services commonly results in the receipt of a busy signal. The VHF radio phone systems allow the scientists to use radio capabilities to establish an independent access link to a 916 area code telephone using a series of relay stations (different than those used by

microwave). In compliance with established radio regulations, this capability is used only by USGS scientists. In the event that a large enough earthquake (or other disaster) strikes and renders conventional, microwave, and radio communications inoperable (for example, telephone company, central offices, microwave towers, and repeater stations are brought down), the command center can use its satellite telephone system. This system ties into the global International Maritime Satellite Organization (Inmarsat) satellite network, which operates a system of satellites in geostationary orbit over the Atlantic, Pacific, and Indian Oceans. It provides worldwide land, air, and sea coverage with access to land stations providing international telephone networking. The USGS's satellite telephone system is fully portable and can be deployed in clear locations outside of the communications command center building in the event conditions are severe enough to require the evacuation of buildings. This is the same technology that was deployed extensively during Operation Desert Storm. Each of these communication systems is available to facilitate the USGS role in the Federal Response Plan and to enable communications with key personnel within the USGS. These systems are available to help the USGS support the improved effectiveness of the Federal, State, and local emergency response and recovery plans, and to also benefit earth science investigators by incorporating immediate reconnaissance and other postearthquake investigations into the total Federal effort.

Public Outreach Plan.—During an earthquake, a joint information center is set up at the Menlo Park facility, using the facilities of the communications command center and staffed by public affairs professionals from the USGS and other agencies, along with scientific personnel. This joint information center disseminates information that can help response agencies and the public address what has happened, as well as the unknown and unexpected. Using first-hand field and instrumental information, the USGS can release factual information to the public, through the news media, in an orderly and understandable fashion. The communications command center adjacent to the joint information center is available to continuously provide information and updates on conditions to the public through news media sources throughout the State and country.

With managers, scientists, telecommunications personnel, and public affairs specialists working in concert, the USGS is prepared to serve the public and the Government and its employees in the event of a major earthquake in the San Francisco Bay Area. Through the use of effective communications links, they will be able to furnish information that can play a vital role in the response and recovery processes outlined in State and regional emergency plans.

Video Aspects of Scientific Visualization

By Richard A. MacDonald and Carmelo F. Ferrigno

By adding a visual dimension, the USGS is marketing its earth science data to new users and showcasing exciting new applications in land use-land cover planning, natural hazard forecasting, and natural resources management. This new arena of scientific visualization is making it possible to produce and disseminate USGS data more effectively.

Increasing volumes of data demand new techniques for such applications as pattern detection and analysis. With the added clarity of a visual component, scientists can discover meaning in data patterns that would not otherwise be apparent or easily detected. An example is the detection of ocean currents through the use of time-dependent models where changes can be observed by animation. Interactive modeling and simulations using visualizations enable scientists to alter models if their first attempts do not validate these hypotheses. Animations are yet another way in which visualization can provide additional insights to existing data.

Scientific visualization also makes it easier to present and distribute research results. Quality audiovisual products of scientific visualizations provide a universal medium for disseminating earth science applications at reasonable cost, thereby enhancing presentations for professional and educational users.

Recording computer-generated animations on videotape requires specialized computer hardware because the signals used to generate the images on computer monitors and television monitors are very different. To convert between these signal types, a special video graphics adapter is used in the computer. This special adapter performs two functions: First, to record a computer-generated animation to videotape, this adapter converts the computer signal (called RGB for Red-Green-Blue) to a television signal (called National Television Standard Code or NTSC). Second, the opposite process, called frame grabbing, stores frames from a videotape in the computer. Once stored in the computer, these video frames can be manipulated as if they were originally created on the computer.

. . .scientific visualization is making it possible to produce and disseminate USGS data more effectively.

A mechanism is also needed to control the video cassette recorder (VCR) from the computer. VCR's used to record scientific animations are usually higher quality than the typical consumer VCR. Typically, the VCR is connected to the computer in the same way that a printer is connected to a computer. The VCR controller may be a combination of hardware (for example, an adapter in the computer) and software or software only, all of which enable the operator to control standard functions of the VCR (stop, rewind, record, and so forth.) by using the computer display and keyboard or mouse.

Two basic methods are used to record computer-based animations: realtime and frame-by-frame recording. In realtime recording, the animated sequence of images is recorded to videotape as the images appear. If an animation displayed on the computer monitor correctly portrays the information to the viewer, it can be recorded in realtime. However, depending on the power of the computer and the complexity of the images in the animation, there are situations where the computer will be unable to generate the video frames in realtime because each image can take up to several minutes to be displayed on the monitor, which is too slow to be properly recorded to videotape. In this case, the computer generates one animation frame, that frame is recorded to videotape, and this process continues until all frames have been recorded. This is called frame-by-frame recording.

The recording of the animation is only the first step. Video editing, adding sound, narration, titles, and word overlap, requires additional computer software and hardware.

The USGS is evaluating various computer-based video recording and editing systems for scientific visualization applications, including small desktop computers and UNIX workstations. A Macintosh-based video production system is currently being tested, and videos have been produced using a PC-based system.

One of the problems with both PC- and Macintosh-based video systems is that the computers do not have sufficient processing power to produce animations for many complicated earth science processes. Because of this, the USGS is planning several pilot projects to produce and record animations created on high performance UNIX workstations.

The USGS is working with the Jet Propulsion Laboratory (JPL) in Pasadena, Calif., to test and use software developed at JPL. This software will be used to generate animated sequences, such as terrain fly-bys, which are used by scientists to analyze data that can be overlaid on a terrain surface such as geophysical, geographic, and hydrologic data. Some of the animations created in this testing will be recorded to tape by using VCR's directly controlled from the workstation.

Plans for pilot projects that would provide visualization of earth science data are underway. One project is a study of the potential contamination of a bay, located near a major metropolitan area, from a discharge pipe for a sewage treatment plant. In developing other projects, USGS and other computer specialists and scientists are working together to target pressing environmental issues that can be solved more readily through the use of scientific visualization.

GeoMedia—Teaching Earth Science Through New Technology

By Denise A. Wiltshire and Mary E. Powell

GeoMedia is an earth science educational system that uses multimedia technology to teach middle-school students about the hydrologic cycle, earthquakes, and maps. Multimedia computer technology offers students exciting new possibilities for navigating through multiple layers of information. GeoMedia is based on a newly emerging software programming technology known as hypermedia. Hypermedia techniques are used in GeoMedia to create a computer system that allows students to make associations between a mix of information, such as graphics, text, animations, and sound.

GeoMedia was originally designed for use by USGS personnel when making presentations to students visiting USGS offices. However, to fulfill the many requests made by teachers to obtain copies of the software, the USGS decided to distribute the multimedia system on digital compact disc (CD-ROM) for use in the classroom. An accompanying package, the Teachers' Developer Version, is designed to give teachers and students the ability to create additional educational material for the earth sciences.

GeoMedia contains animations that show natural processes such as the hydrologic cycle and plate tectonics. The three subject modules also include color images and sounds to further illustrate the topics. Glossaries and reading lists are included for each of the modules.

Tour Selections.—The basic metaphor of GeoMedia is essentially a tour through earth-science topics—browsing through the multimedia system is like taking a journey through information. The GeoMedia graphical user interface allows students to navigate through the information by "clicking" icons, or symbols, with the computer mouse. The icons are located on a portion of the screen that resembles a control panel of an imaginary moving vehicle. The tour selections section is the main table of contents. The student is given the option to select one of three earth science topics: water cycle, earthquakes, or understanding maps. By clicking icons in the shapes of diamonds, triangles, and squares, students can navigate through the GeoMedia tour.

The "help" option is always available as students navigate through GeoMedia by selecting the question mark from the control panel. The help screen also contains audible instructions. The audible instructions describe how to move forward and backward through GeoMedia and how to find definitions of words or additional earth science facts.

Each of the three tour selections contains four sections: animation, elements, glossary, and further reading. Links between these sections allow students to plot their personal paths through the information. A description of each of the tour selections is given below.

Water Cycle.—The water cycle is shown as a motion picture or animation. It explains the relation between the water-cycle elements such as evaporation, condensation, precipitation, and runoff.

The animation section is composed of the components of the water cycle. As noted above, links exist between the animation and the elements sections of the water cycle tour selection. For example, if students click the cloud icon at any point during the animation, they will link to a more detailed description of clouds in the elements section.

The elements section contains text and images that describe the components of the water cycle in further detail than in the animation section. The selections available on the GeoMedia control panel offer options for additional information on water facts and the geographic location of the photographic images that appear on the screen.

Earthquakes.—After selecting earthquakes from the tour selections screen, the introductory scene for the earthquakes module appears accompanied by the roar of an earthquake sound.

The animation section of this module presents a series of images showing the Earth forces that cause earthquakes. The image and audio portions of the system explain the relation between plate tectonics and earthquake activity.

The animation is composed of some of the same elements discussed in more detail within the elements section of the earthquakes module. Links exist between the animation and the elements sections of the earthquakes tour selection. For example, by clicking on the images of the dip-slip or strike-slip faults at any point during the animation, students are

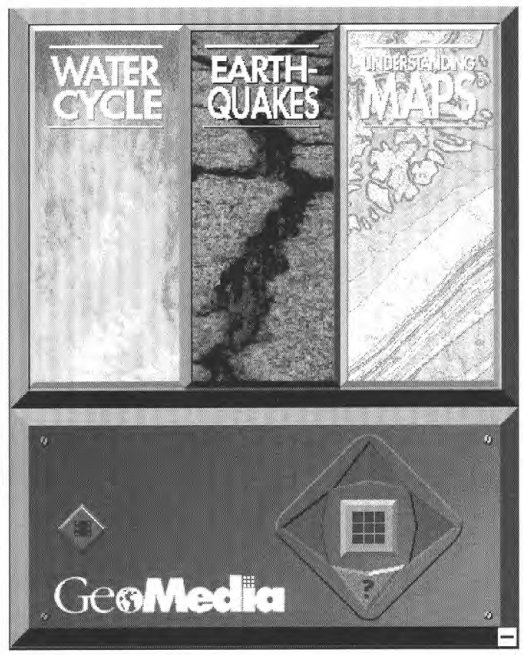
TOUR SELECTIONS

On a Journey

GeoMedia is a multimedia tour of science topics. By using the computer mouse, you can explore earth science concepts through a series of images. *GeoMedia* is both fun and easy to use.

Have you ever wondered about the movement of water on Earth through an unending cycle? Do you know how to read a map? Do you know why there are earthquakes? The answers to these questions are at your fingertips.

Select a Tour — *Click on one of the three flashing panels.*



WATER CYCLE

Animation

This part of the tour shows the water cycle as a moving picture or animation. The animation explains the relationship between the water cycle elements such as evaporation, condensation, and precipitation.

Start Animation — *Click on flashing red triangle.*
More Information — *Click on animation elements. GeoMedia hint: click on sun or ocean.*
Forward and Reverse — *Click on red triangles.*

Computer screens from the GeoMedia educational system showing table of contents (top) and illustration from the water cycle animation (bottom). MacroMind® Director™ (version 3.1), produced by Macromedia, Inc., was the primary software package used to develop GeoMedia.

Creating Your Own GeoMedia Modules

The GeoMedia Teachers' Developer Version is comprised of a HyperCard® Program named *GeoDeveloper*. It provides sample art work for screen designs and navigation buttons for creating a new GeoMedia educational system. The control panel icons have associated HyperCard scripts and programming instructions for navigation. GeoDeveloper is a base to build upon when designing a hypermedia system. Scanned images, text, and sounds may be added to present additional information on the earth sciences.

linked to a more detailed description of these faults in the elements section.

The elements section contains text and images that describe the components of earthquakes in further detail than in the animation section. In this section, students learn more about earth forces, plate tectonics, and monitoring seismic activity. Disaster photographs that show the destruction earthquakes can cause are part of the element on Pacific epicenters. Additional information on earthquake facts is available by clicking the plus symbol icon on the GeoMedia control panel.

Understanding Maps.—This part of the tour presents a series of animations that explain the concept of elevation and the use of contour lines as map symbols. An animated three-dimensional model of a map explains the relation between contour lines and elevation. A link exists between the three-dimensional map model of a mountainous region in Southern California and a series of satellite images shown in a perspective view near the same area.

The elements section contains text and images that further describe map scale and the types of maps produced by the USGS. Examples of planimetric, topographic, and thematic (geologic, hydrologic, and land use) maps are presented in this section. Also shown are scanned images of aerial photographs and satellite imagery.

Glossaries and Further Reading Lists.—Throughout GeoMedia, the gray diamond icons embedded in the text link the reader to the glossary for the definition of the marked word. Each module contains a glossary. The glossary for each module can also be viewed by selecting it directly from the table of contents.

Each of the three modules contains a further reading section to encourage students to learn more about the given topic by visiting their school or public libraries. The reading lists include references to periodicals, books, posters, and maps.

Summary.—The USGS plans to continue developing prototype computer systems to promote earth science literacy among the Nation's schoolchildren. Through the use of computer technology, we hope to inspire children who might not necessarily respond to traditional teaching methods. In addition, computer technology continues to play an important role in most scientific research. Teaching earth science through computer technology offers new opportunities to give students a better understanding of scientific methods and investigative techniques, including data analysis.

WAIS—Improved Access to Information

By Eliot J. Christian and Timothy L. Gauslin

In many instances, scientists, policy makers, and educators—as well as the general public—would make better use of computerized information if it were easier to access. What can be done to simplify access to data and information?

In the late 1980's, the library and information services community reached consensus on an access standard. This open standard, known in the United States as the Information Retrieval Service Definition and Protocol Specification (Z39.50), defines a uniform method for access to data and information. The idea is that an open standard permits data and information to be stored on computer systems having very different hardware and software, yet a user can retrieve information from any computer in the same way.

The USGS is working with a consortium including several major corporations and about 150 universities to develop a version of Z39.50 that is available as public domain software, known as Wide Area Information Servers (WAIS). WAIS is targeted to users who have limited computer skills and need a powerful search and retrieval mechanism. This approach is already being used extensively in the USGS and is gaining wide acceptance in the Federal Government as a whole.

In a typical WAIS search, the user selects information servers or searches directories of servers, using familiar English words. That search is formatted to the Z39.50 standard, and the information servers match the search words to the server contents. The user sees a list of titles found and then views those of interest.

Since users do not know which words would be key to finding everything that may be relevant, WAIS provides an approach known as "relevance feedback." When a user designates any retrieved text as relevance feedback, WAIS uses the words in that portion as another search request.

The USGS began its involvement with WAIS through an initiative to enhance the Earth Science Data Directory (ESDD). ESDD is a useful source for references to earth science data, including many at the State level, and is also a comprehensive list of data holdings relevant to Arctic research. WAIS is especially appropriate for ESDD because the ESDD user community ranges from local citizens to international global change researchers. The ability of WAIS to place the ESDD in the context of other information sources is

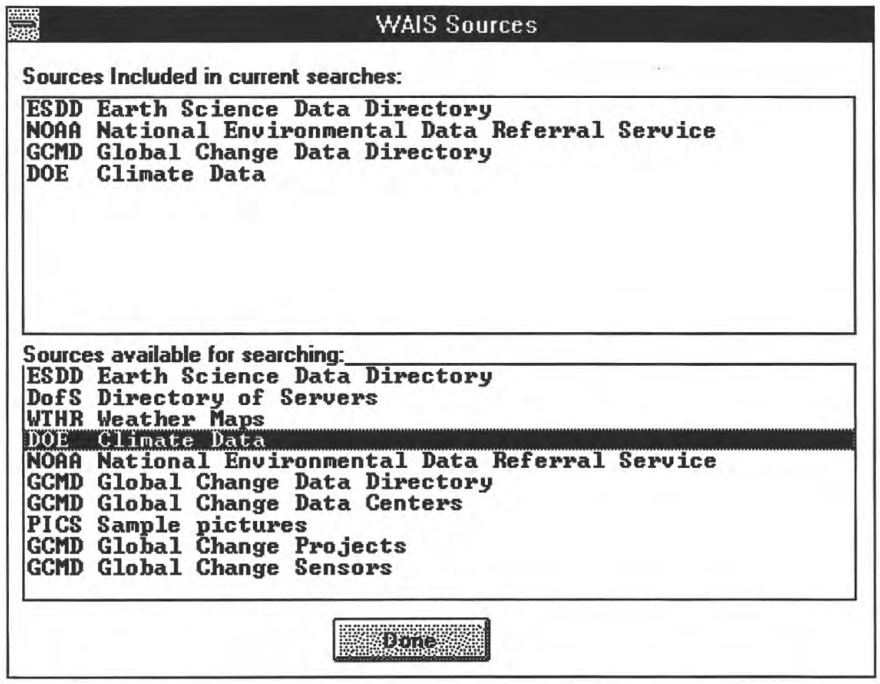
especially powerful for these users. WAIS is also expected to be used by the USGS and others for directories of spatial data and for information related to water and geologic data.

The USGS has added features to WAIS that are useful for ESDD users (for example, location searching, phrase searching, and keyword searching within fields) in a manner compliant with the Z39.50 standard and in concert with the network of WAIS developers. In fact, the WAIS software has many examples of contributed parts from hundreds of developers worldwide. By maintaining compliance with the standard, users of the USGS/WAIS software can access any Z39.50 server but have additional capabilities when accessing the USGS server. Conversely, the USGS information servers are accessible to all users of Z39.50, whether they received software from USGS or not.

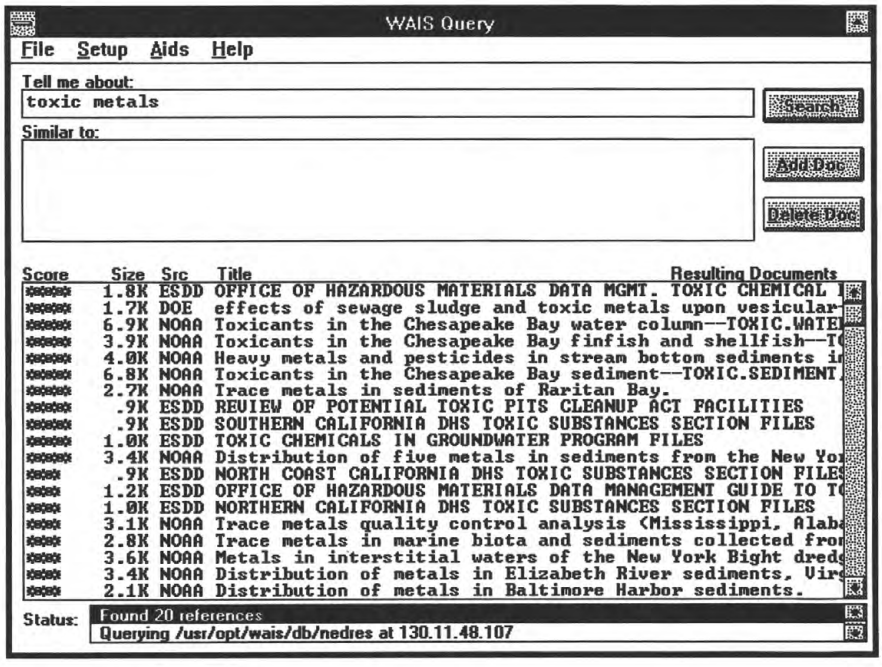
For the location searching feature, the USGS developed the software to map the latitude/longitude referenced in the text and to allow a user to search by drawing a polygon on a map. The University of North Carolina developed the server software that accepts the polygon vertices and matches them to source entries.

As WAIS becomes widely used, opportunities arise to simplify interaction with data and information repositories. For example, Apple Computers created a dynamic version of WAIS that periodically retrieves requested information automatically and prepares a "personalized newspaper" showing updated information that the user requested. The USGS has also added a simple way for a user to suspend the WAIS session and access an existing data system such as the USGS Global Land Information System. Another idea is to give the WAIS user an option to contribute data and information products online. WAIS would help the contributor to document the product appropriately and would then route the document and product electronically through peer review.

Versions of WAIS are already available for most computers, and there are hundreds of information servers freely accessible. WAIS is being used not only for bibliographic information but also for providing online access to data. As an integrating technology, WAIS promises to vastly simplify the problems of access to scientific and technical data and information.



Multiple sources can be selected for searching, regardless of their different formats.



Document titles found on a search for "toxic metals," showing examples from multiple sources.

ADMINISTRATION

MISSION

The Administrative Division provides administrative direction and coordination in support of the scientific and technical programs of the U.S. Geological Survey. This support includes policy guidance and program direction and provides leadership and authority for various administrative management and technical support functions, including personnel, manpower utilization, finance, administrative management systems, management analysis, records management, procurement and contract negotiation, property and facilities management, security, safety, and motor vehicle management.

The Division also manages the development, maintenance, and operation of the financial management system for the entire U.S. Department of the Interior. These functions are carried out at the National Center in Reston, Va., and through Regional Management Offices in Denver, Colo., and Menlo Park, Calif.

Message from the Assistant Director for Administration

Through enhanced use of new technology, automation, and innovative administrative programs in fiscal year 1992, we continued to provide the USGS with cost-effective and responsive administrative support. Examples of new technologies and automation activities included replacing microfilm storage of financial records with electronic archival, retrieval, and research technology for records management and adding electronic bulletin board and a toll-free telephone number to our automated vacancy announcement system. An innovative personnel program implemented this past year includes the use of On-the-Spot Awards, to enable supervisors to grant immediate small-amount financial awards to deserving employees. Other innovations include conversion to a direct accountability mail system, remote input of financial transactions, and streamlining of fiscal data processing through expanded use of alternative payment mechanisms.

Effective partnerships include internal bureau committees that ensure that recommendations of managers and the workforce are considered in decisions affecting administrative programs, as well as departmental committees and task forces, where bureau concerns are considered in the formulation of departmental administrative policies. Continued representation on intergovernmental committees and working groups also provides opportunities to exchange viewpoints on personnel and on financial, facilities, and property management. Finally, partnerships with the educational community and public service groups paved the way for increased participation in the Volunteer for Science Program, as well as a greater number of women and minorities employed under student and other appointment authorities.

Looking to the future, the competition for scarce financial resources will continue to be a challenge that the Administrative Division will address through state-of-the-art tools, technology, and innovative ideas to ensure that the administrative support that we provide is both cost effective and responsive to bureau needs.

Jack J. Stassi

Highlights of Administrative Activities

Highlights of administrative direction and coordination in support of USGS scientific and technical programs for fiscal year 1992 include

Financial Management.—In fiscal year 1992, improvements in the bureau's management of fiscal resources included expansion of the use of Automatic Teller Machines for travel advances and extension of remote data entry to 88 sites, thereby expediting fiscal transactions.

Facilities and Management Services.—Accomplishments in fiscal year 1992 included the start of construction for the new Reston mapping facility, clearance for construction at the EROS Data Center in Sioux Falls, S. Dak., completion of the new rock processing facility at the Menlo Park, Calif., facility, and smooth conversion to the U.S. Postal Service direct accountability system, which achieved economies in postal costs. Numerous proactive safety management initiatives earned the USGS the Secretary of the Interior's annual award for the best departmental safety program.

Procurement and Contracts.—For the fifth year, procurement transactions grew substantially. The bureau's commitment to the goals and objectives of the Department's Minority Business Enterprise Programs was reflected in the USGS receipt of the Secretary's Award for Excellence, the second award the USGS has won in this area in the past 3 years.

Personnel.—In fiscal year 1992, the USGS expanded participation in minority-organization-sponsored career fairs and recruitment visits to targeted minority schools and universities, which resulted in increased USGS employment of women and minorities (see p. 105). Issuance of a Career Planning Manual for clerical, administrative, and secretarial employees provided enhanced career development opportunities. Implementation of an innovative On-the-Spot Award program provided a vehicle to give employees immediate financial recognition for their accomplishments.

Administrative Systems Management.—Fiscal year 1992 administrative system improvements included a new property management system; software to electronically

report excess property; automated tracking of performance standards and appraisals, supervisory/managerial training, and volunteer activities; and production of new and enhanced automated financial reports tailored to the needs of USGS financial managers.

Systems Partnerships

By Kory K. Lee

Building upon its success with the Department of the Interior's (DOI) standard financial management system—the Federal Financial System (FFS)—the USGS is now leading the effort to acquire and implement a DOI standard procurement system—the Interior Department Electronic Acquisition System (IDEAS)—and has developed and coordinated the implementation of a departmentwide job vacancy announcement system, known as the Automated Vacancy Announcement and Distribution System (AVADS). In a partnership outside the Department of the Interior, the USGS provided support to implement and service the Department of Education's use of the USGS automated Personnel Actions System.

Federal Financial System.—In fiscal year 1992, the USGS Washington Administrative Service Center (WASC) coordinated the implementation of the FFS in two organizations. The Bureau of Indian Affairs (BIA) presented DOI's most challenging FFS implementation to date. Complicating factors of this implementation included BIA's decentralized approach to financial management and a variety of challenging accounting and reconciliation issues. BIA successfully converted to the FFS in October of 1991, and the WASC assisted BIA in stabilizing operations and reducing financial-document backlogs during its first few months of production under the new system. With BIA now onboard, 7 of the 10 DOI bureaus are now using FFS. This represents over 97 percent of the 20 million annual financial transactions within the DOI, as the three bureaus yet to use FFS are comparatively small in terms of accounting volume. Also in fiscal year 1992, a non-DOI organization, the Patent and Trademark Office (PTO) of the Department of Commerce, also began use of the FFS. The PTO sought and received special authority from the Department of Commerce to replace its existing financial system with FFS. The WASC worked extensively with PTO during fiscal year 1991 to prepare the organization for its FFS implementation. These efforts paid off as PTO began FFS production in October of 1991. This was a significant accomplishment in many respects. PTO was the largest non-DOI organization ($282 million in budget authority and 3,900 full-time employees) to implement the DOI version of FFS, and PTO used many FFS features that were not being used by any DOI bureau, such as printing of purchase orders and travel orders in FFS, requisition approvals on-line, and commodity orders.

The WASC continues to maintain the DOI version of the FFS software, which is used by seven DOI bureaus and four non-DOI bureaus. Weekly meetings or conference calls are conducted by the WASC with all the DOI FFS customers to coordinate issues associated with the FFS and its operation at these organizations. The National Park Service, USGS, BIA, and PTO process their FFS transactions on the mainframe computer at the USGS in Reston, Va. In addition, the WASC also services the Administrative Office of the U.S. Courts on its version of FFS. The Denver Administrative Service Center (DASC) provides FFS computer services to the DOI bureaus and cross-serviced agencies located in the Denver, Colo., area.

Interior Department Electronic Acquisition System.—The USGS is also managing the departmentwide implementation and maintenance of the Department of the Interior's standardized automated procurement system, IDEAS. The IDEAS project, which began in FY 1991, is a major component of the Department's overall efforts to streamline administrative systems and to eliminate costly and duplicative systems development and maintenance, and will also serve to improve DOI management controls over procurement data. Implementation of IDEAS throughout the Department will proceed on an incremental basis over a multiyear period.

During fiscal year 1992, the WASC implemented the first module of this multiphase project. The Interior Procurement Data System (IPDS) was placed in production and made available to all bureaus as the first portion of IDEAS. The IPDS provides both the capability for all of the bureaus to input and retrieve individual and summary contract action information, as well as the capability for the Department to examine and aggregate all contractual actions and report them to the Federal Procurement Data System (FPDS). Reporting requirements for both IPDS and FPDS are legislatively mandated.

The WASC and other USGS staff, assisted by representatives of the Department and bureaus, also continued its efforts to competitively acquire the balance of the IDEAS software. A market review identified commercially available software as providing a significant portion of DOI's requirements. The acquisition of an existing commercially

available system and customizing it to meet the remaining functionality requirements was validated through a benefit/cost analysis. A Request For Comment was circulated for Department and industry review and comment, and led to the issuance by the USGS of a Request For Proposal for IDEAS. Proposals were received, and the evaluation process began prior to the end of fiscal year 1992. Award of the IDEAS contract and initial implementation at the USGS's Office of Procurement and Contracts is anticipated during fiscal year 1993.

Automated Personnel Processing for the Department of Education.—This year, the USGS and the Department of Education (ED) worked together to implement a modified version of the USGS Automated Personnel Actions System throughout the ED. Since both agencies are customers of the DOI payroll/personnel (Pay/Pers) system, many similar information processes simplified the modification effort.

In use at USGS for a number of years, the system completely automates processing of the Government's Standard Form (SF) 52, the Request for Personnel Action. The application features two main subsystems: Requesting Office Subsystem (SF–52) and the Personnel Processing Subsystem (PERS). Users of SF–52 may initiate requests for personnel actions, track the progress of the action as it is routed through the appropriate levels of approval, and then print reports of pending and completed actions. Users of PERS are within the personnel office. They process the requests by routing the action through the appropriate section (Classification, Recruitment and Placement, and Processing). The entire system provides for electronic paperless routing—ranging from the signature of the approving official to the circulation through proper channels of the personnel office.

The collaborative effort to implement the system for ED consisted of a three-stage plan: preparation, pilot operation, and full production. Under the preparation stage, key personnel specialists worked together to analyze ED's flow of information and customize the system to meet their needs. At the same time, computer specialists identified equipment and facilities to support full operations, worked out a training plan, and established procedures to quickly answer user's questions (system hotline). Pilot operations, designed to test the system before full implementation, began in September 1991, and consisted of a successful trial run for 600 employees at ED headquarters in Washington, D.C. Scheduled to be fully implemented by the end of 1992, the system will support over 5,000 personnel at ED.

Departmental AVADS.—During 1992, the USGS formally established partnerships with all DOI bureaus to develop and implement a departmentwide Automated Vacancy Announcement and Distribution System (AVADS). AVADS provides flexible and widespread electronic access to job information for all DOI vacancy announcements, both within the Department and for external job applicants. The USGS first implemented its own AVADS 4 years ago. This earlier version has been modified to meet the general requirements of all DOI bureaus, and the USGS is now assisting them in their efforts to bring the system into operation. To carry out this effort, the USGS has entered into interagency agreements with the DOI bureaus, which outline a program for technical assistance, comprehensive hands-on training, registration of users, and a coordinated implementation schedule.

AVADS is extremely flexible. Job information can be directly accessed from the mainframe computer, distributed through automated downloads to personal-computer networks, or retrieved from stand-alone personal computers. AVADS consists of components that run on the USGS mainframe computer in Reston, Va., and IBM-compatible personal computers. On the mainframe computer, DOI personnel specialists enter vacancy announcements into a centralized data base. On a weekly basis, the information is electronically transferred across a computer network to several hundred personnel offices and designated distribution sites throughout the Department, where it can be accessed or further redistributed to employees.

The entire system provides for electronic paperless routing. . .

On the personal computer, a program called MicroAVADS provides a method for an applicant to search for and print vacancies based on bureau, geographical location, job series and (or) grade, without the need for access to the mainframe computer. The easy-to-use program, along with the vacancy information, is distributed to the DOI personnel office locations.

The primary strength of AVADS lies in its ability to distribute job vacancy information to a large number of potential job applicants. During a typical year, an estimated 10,000 positions are open within the Department. The system assists applicants, who have more vacancies available to them, and hiring officials who have more applicants to choose from. In addition to a more widespread distribution of job information, the process is much faster than mailing and reproducing paper documents.

Job opening information through AVADS is available to the general public, special interest minority and women's groups,

college placement offices, and campus recruitment centers at Historically Black Colleges and Universities (HBCU), Hispanic Association of Colleges and Universities (HACU), Hispanic-Serving Institutions, Tribally Controlled Community Colleges, and other schools of higher training. With a personal computer and modem, anyone can access the AVADS Bulletin Board System by dialing 1–800–368–3321. This part of AVADS allows non-DOI job applicants to view and copy all DOI vacancy information, using selection criteria such as organization, location, job title, and salary range.

At present, all USGS vacancies are included in the DOI AVADS, and three other bureaus have begun entering vacancies into the system; the remaining bureaus are at various stages of implementation. By the end of calendar 1992, all DOI bureaus are expected to have begun use of the system. This system is a major improvement in the Department's ability to reach its own employees, other Federal employees, and other applicants with current information on employment opportunities.

Partnerships with Other DOI Bureaus

By Joseph L. Murphy, John Walbert, and Deborah L. Burton

In its leadership role to implement and operate DOI's standard financial management system—the Federal Financial System (FFS)—the USGS has created an effective partnership with other DOI bureaus through the establishment of a departmental users group to guide the direction of systems development and implementation efforts for FFS.

The FFS User Group serves as a communications forum among FFS users, the Washington Administrative Service Center (WASC), the Denver Administrative Service Center (DASC), and the Department's Office of Financial Management (PFM). It provides FFS users a means of regularly sharing information and a structure through which they may develop agreements on FFS matters. The FFS User Group also serves as a forum for users to make recommendations to PFM regarding FFS policies, and to the WASC, DASC, and other DOI bureaus regarding FFS procedures. The goal of the group is to promote and coordinate the continued development and operational improvement of FFS. Each DOI bureau using FFS, the WASC, the DASC, and PFM have one User Group member. In addition, any DOI bureau not using FFS is invited to attend the meetings.

The USGS, together with DOI, initiated the action to establish a DOI FFS User Group during fiscal year 1989, with the initial FFS implementations at USGS and the Bureau of Reclamation (BOR). Initially, the WASC and the departmental Office of Financial Management served as co-chairs of the User Group. Beginning in fiscal year 1990, responsibility for chairing the group rotates among the DOI bureaus. As each bureau prepared for its own FFS implementation, they built upon the lessons learned from the experiences of USGS and BOR. At this stage, much time was spent in dealing with unique needs of individual bureaus and directing efforts to incorporate their requirements into FFS. As can be expected with any major change of this nature, the bureaus' primary concerns were to ensure that their needs would be adequately addressed. The WASC and the DASC worked with the other DOI bureaus to accomplish the successful implementation of FFS in subsequent fiscal years. As the number of FFS production bureaus has grown, so has the size of the User Group. As of fiscal year 1992, 7 of the 10 DOI bureaus were in production operations on FFS and active participants in the group, as well as one of the three remaining DOI bureaus yet to implement FFS. The primary functions of the User Group include identifying and prioritizing enhancements needed in FFS, determining how available enhancement funding should be applied, and reviewing proposed enhancement designs in terms of the bureaus' needs. The group also provides a mechanism for sharing the result of new software testing and determines the timing for installing each new FFS release.

As the FFS operational community expanded, the agenda of technical issues also grew, and a separate group was established to act as the technical advisory arm of the User Group, the DOI Software Advisory Board (SAB). The SAB is composed of representatives from all of the DOI production bureaus, the DASC, and the WASC. The SAB provides technical support to the User Group in the areas of FFS software design development, testing, and implementation; develops a standard schedule for the installation of new releases of FFS software; recommends how available funding should be allocated to approved software modifications; and prepares consolidated recommendations on FFS design documents for approval of the FFS User Group. The SAB is also responsible for sharing the results of WASC, DASC, and bureau testing among the DOI bureaus and for quickly notifying all bureaus of a critical software problem. A charter for the SAB, written by the USGS, established a process for dealing with FFS software installations, as well as a process for evaluating, prioritizing, and

designing enhancements to FFS. The bureaus adopted these processes as operating procedures. The SAB chairmanship rotates among the bureaus, the DASC, and the WASC.

In fiscal year 1992, another departmentwide working group—the External Reports Committee—was formed to address numerous issues pertaining to FFS reports required by organizations outside of the DOI, for example, the Department of Treasury and the Office of Management and Budget (OMB). The External Reports Committee was formed with key personnel from each participating Interior Department FFS bureau. One of the challenges facing the committee was the different interpretations each bureau brought to the table regarding the system requirements for external reports. The WASC chaired this committee and facilitated the effort to reach agreement among the bureaus on how to handle all of the issues identified with each external report. Major enhancements were identified for the FFS version of the SF–133 (Report on Budget Execution) and the SF–225 (Report on Obligations). The bureaus also agreed upon a design to improve the efficiency of all FFS external reporting. All of these enhancements are now under development for DOI's FY 1993 release of the FFS. The USGS took a lead role in providing input and test results to the group on Treasury's 220-series of annual reports, as well as the TFS–2108 Year-End Closing Report.

The governmentwide FFS User Group also formed a similar committee to address these issues for all FFS Federal agency users. The DOI was represented by the WASC on this committee and provided leadership in documenting recommended designs for the enhancement of the FFS in this area.

Employment Outreach

By Richard C. Williams

In 1992, the USGS took steps to provide an enhanced and coordinated approach to recruitment through development of a plan for affirmative outreach to women, minorities, and the disabled. In concert with Workforce 2000 initiatives, the plan supports the formation of recruitment teams made up of managers, scientists, personnel specialists and role models to attend selected job fairs and college career days, visit with faculty and placement officials on targeted campuses, and host site visits from college and university representatives.

Women, Minorities, and Persons with Disabilities.—The USGS continued to show progress in attracting women, minorities, and persons with disabilities to employment with the bureau through expanded outreach programs. The number of minority employees in the permanent work force increased 2.9 percent and the number of women increased 2.5 percent during the year. The number of persons with disabilities in the USGS work force increased by 6.1 percent.

A significant element of the USGS recruitment program continues to be its presence at national, regional, and local career fairs in support of women, minorities, and persons with disabilities. In 1992, USGS representatives attended and presented exhibits at numerous conferences including: the High Technology Minority and Women's Job Fair in Albuquerque, New Mex.; the Environmental Careers Organization Minority Conference in Atlanta, Ga.; the Federal Asian Pacific American Council (FAPAC) Conference in Bethesda, Md.; and the Organization of Chinese Americans National Convention in San Jose, Calif., as well as other HBCU and HACU sponsored activities.

The USGS also participated in joint outreach programs with "sister" bureaus in the Department of the Interior, including the National IMAGE Conference in Albuquerque, New Mex.; the National Association for Equal Opportunity in Higher Education (NAFEO) Conference in Washington, D.C.; and the Blacks in Government Conference, also in Washington, D.C. These efforts represent the beginning of new initiatives designed to encourage the "pooling" of shared resources by bureaus in conducting recruitment.

The USGS continued to expand its relations with the Environmental Careers Organization, Inc., a nonprofit organization involved with establishing work-study partnerships for students pursuing degrees in the environmental and earth sciences. In 1992, the bureau used the services of eight women and minority students under this program.

With the expansion of the USGS Automated Vacancy Announcement Distribution System (AVADS) and the addition of its companion feature, the AVADS Bulletin Board System (see p. 103), USGS vacancy information may now be accessed by non-Federal groups and individuals across the Nation by dialing 1–800–368–3321. The telephone number is listed on all recruitment brochures, displays, and literature, and has been distributed to special-interest minority and women's groups, college placement offices, and campus recruitment centers at HBCU's, HACU's, Hispanic-Serving Institutions, Tribally Controlled Community Colleges, and other schools of higher learning.

As Workforce 2000 approaches, the USGS recognizes the need for strategic recruitment plans and expanded recruiting

. . .USGS vacancy information may now be accessed by non-Federal groups and individuals across the Nation. . .

efforts to attract qualified individuals who share a commitment to cultural diversity in the work force.

Specialized Equipment and Services for Disabled Employees.—The bureau's Selective Placement Program Advisory Committee, composed of representatives from each division, identifies and implements initiatives designed to meet the equipment and service needs of disabled employees within the USGS. During the year, the committee approved a variety of funding requests in support of disabled employees, including purchase of the following:

- Equipment designed to provide or enhance the mobility of individuals at their work station;
- Ergo-arms for use by employees with wrist impairments who use computers to perform work assignments;
- Additional Telecommunications Devices for the Deaf (TDD), including compact TDD's for use by disabled employees while on official travel;
- New software that allows hearing impaired employees to utilize their computers as TDD's for communication purposes;
- A computer system with sophisticated visual enhancements for visually impaired employees;
- Sign language interpreting services for employees attending training courses;
- "Teacher-aid" equipment for instructors who are hearing impaired; and
- Microcomputer equipment, which allows hearing impaired employees to fully participate with hearing employees in training courses provided at the National Training Center.

The committee also approved funding in support of a Conference on Accessible Technology in October 1992. This conference, the first of its kind within the Department of the Interior, provided information to managers and other attendees on state-of-the-art technology, electronics, and computerization for people with disabilities. Guest speakers and panelists addressed issues concerning the development and use of technology that enables persons with disabilities to function, compete, and excel in the work place. Vendors showcased a wide variety of equipment and computers designed to assist disabled employees. Plans are underway to convene similar conferences at other USGS centers in coming years.

. . .USGS student employment programs provided opportunities for over 850 students. . .

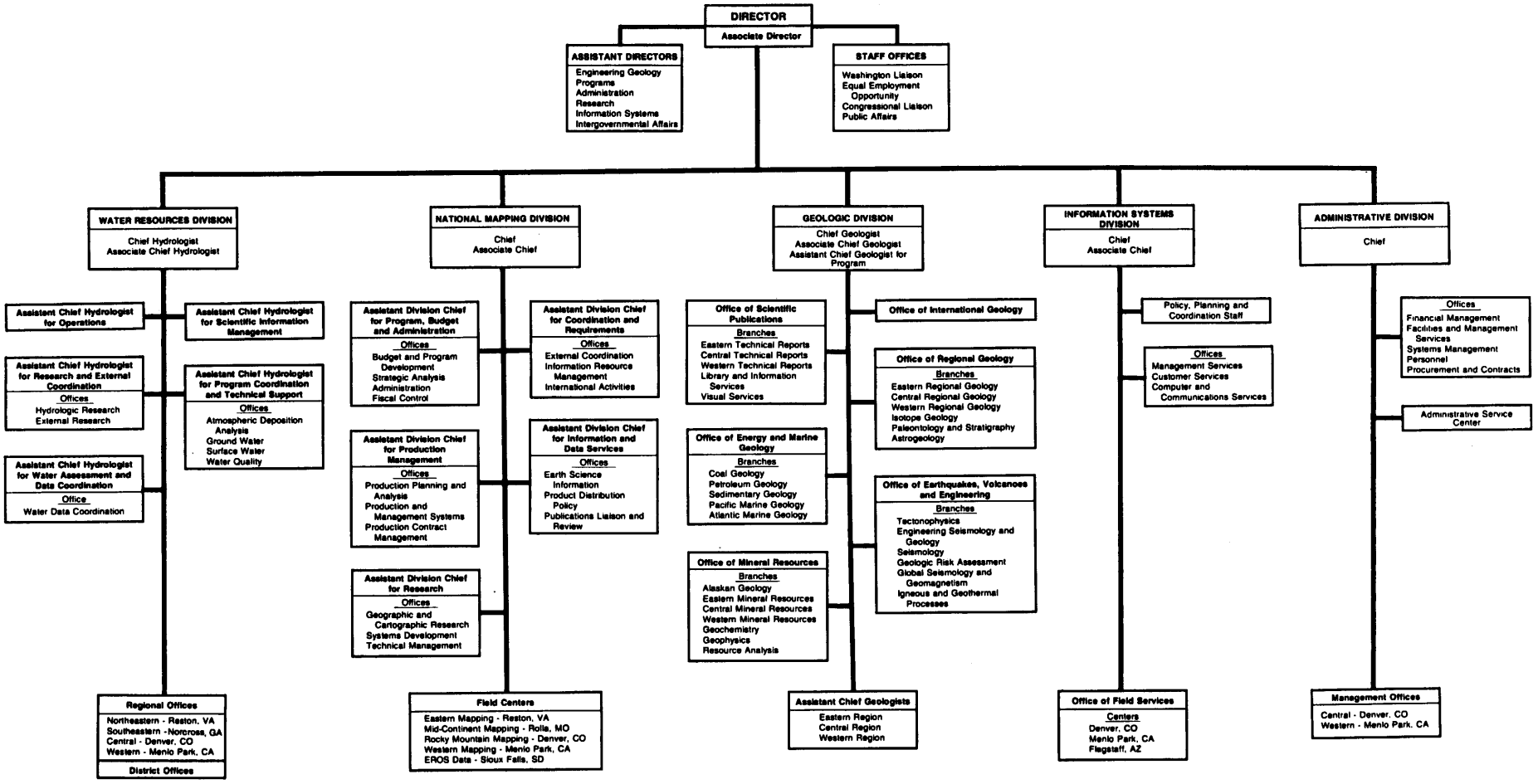
Students as Partners.—Student employment programs continue to provide high-quality temporary staff in support of USGS mission requirements. Through cooperative education, disadvantaged-youth, and related employment programs, students have the opportunity to apply their academic skills in the real-world setting of scientific laboratories, field sites, and offices while earning money to continue their studies.

In 1992, USGS student employment programs provided opportunities for over 850 students to perform work assignments in a wide variety of activities, including the collection of geologic samples at geographically remote field locations, obtaining water samples and hydrologic data for laboratory analysis, and gathering other information about natural and manmade features, used in making topographic and geologic maps.

About 300 students participated in the Stay-in-School and Federal Junior Fellowship Programs, which are designed to provide opportunities for financially needy youth to work and earn income so that they can continue their education. Over one-third of these students are minorities and over one-half are women. There were also significant increases in the number of individuals, including minorities and women, participating in cooperative education and other postsecondary student employment programs. Many of these students received permanent appointments with the USGS upon graduating from high school or college.

In an effort to strengthen student as well as faculty employment programs and enhance cooperative partnerships in educational initiatives, the USGS has more than 150 partnership agreements with colleges and universities located nationwide, including schools which belong to the HACU as well as HBCU.

ORGANIZATION OF THE U.S. GEOLOGICAL SURVEY
U.S. Department of the Interior



Budget Information

USGS budget authority for fiscal year 1992, by appropriation, for surveys, investigations, and research (SIR)
[Dollars in thousands]

Activity/Subactivity/Program element	Fiscal year 1992 enacted
National Mapping, Geography, and Surveys	**$132,612**
National Map and Digital Data Production	49,647
Cartographic Data and Map Revision	41,629
Thematic and Special Data	5,050
National Map and Digital Data Cooperative Program	2,228
SLAR (Side-Looking Airborne Radar)	740
Information and Data Systems	19,091
National Data Base Management	7,170
Information Dissemination Services	4,427
Global Change Data Systems	7,494
Research and Technology	18,892
Cartographic and Geographic Research	8,557
National Cartographic Requirements, Coordination, and Standards	4,589
Geographic and Spatial Information Analysis	5,746
Advanced Cartographic Systems	44,982
Geologic and Mineral Resource Surveys and Mapping	**223,543**
Geologic Hazards Surveys	68,040
Earthquake Hazards Reduction	50,336
Volcano Hazards	15,348
Landslide Hazards	2,356
Geologic Framework and Processes	36,006
National Geologic Mapping	21,993
Deep Continental Studies	3,239
Geomagnetism	1,828
Coastal and Wetlands Processes	8,946
Global Change Research	11,021
Global Change and Climate History	11,021
Offshore Geologic Surveys	28,031
Offshore Geologic Framework	28,031
Mineral Resource Surveys	50,296
National Mineral Resource Assessment Program	25,914
Strategic and Critical Minerals	10,320
Development of Assessment Techniques	14,062
Energy Geologic Surveys	30,149
Evolution of Sedimentary Basins	6,979
Coal Investigations	8,397
Oil and Gas Investigations	6,034
Oil Shale Investigations	598
Uranium and Radon Investigations	1,976
Geothermal Investigations	5,336
World Energy Resource Assessment	829
Water Resources Investigations	**$183,915**
National Water Resources Research and Information System—Federal Program	112,629
Data Collection and Analysis	24,355
National Water Information Clearinghouse	3,251
Coordination of National Water Data Activities	1,060
Regional Aquifer System Analysis	8,593
Core Program Hydrologic Research	10,261
Improved Instrumentation	1,731
Water Resources Assessment	1,652
Toxic Substances Hydrology	14,949
Nuclear Waste Hydrology	3,594
Acid Rain	3,196
Scientific and Technical Publications	2,346
National Water-Quality Assessment Program	28,463
Global Change Hydrology	7,727
Truckee-Carson Program	1,451
National Water Resources Research and Information System—Federal-State Cooperative Program	63,269
Data Collection and Analysis, Areal Appraisals, and Special Studies	59,210
Water Use	4,059
National Water Resources Research and Information System—State Research Institutes and Research Grants Program	8,017
State Water Resources Research Institutes	5,576
National Water Resources Research Grants Program	1,765
Program Administration	676
General Administration	**23,883**
Executive Direction	7,184
Administrative Operations	14,247
Reimbursements to the Department of Labor	2,452
Facilities	**20,241**
National Center—Rental Payments to GSA	17,100
National Center—Facilities Management	3,141
Total, SIR	**$584,194**

USGS budget for fiscal years 1989 to 1992, by activity and sources of funds[1]

[Dollars in thousands; totals may not add because of rounding]

Budget activity	1989	1990	1991	1992
Total	**$670,897**	**$ 723,137**	**$802,538**	**$851,979**
Direct program	451,988	[1]501,510	575,044	586,699
Reimbursable program	218,909	221,628	227,494	265,280
States, counties, and municipalities	69,577	74,113	87,415	89,950
Miscellaneous non-Federal sources	14,194	15,151	13,499	14,609
Other Federal agencies	135,138	132,363	126,580	160,721
National Mapping, Geography, and Surveys	**126,457**	**141,069**	**162,421**	**164,981**
Direct program	94,235	111,528	132,395	132,612
Reimbursable program	32,222	29,542	30,026	32,369
States, counties, and municipalities	1,520	2,132	2,366	3,028
Miscellaneous non-Federal sources	10,804	10,278	9,722	10,633
Other Federal agencies	19,898	17,131	17,938	18,708
Geologic and Mineral Resource Surveys and Mapping	**215,882**	**241,739**	**261,513**	**267,642**
Direct program	178,329	200,472	225,112	225,383
Reimbursable program	37,553	41,267	36,401	42,259
States, counties, and municipalities	961	1,917	2,661	3,077
Miscellaneous non-Federal sources	682	2,022	1,260	536
Other Federal agencies	35,910	37,328	32,480	38,646
Water Resources Investigations	**287,154**	**295,128**	**333,238**	**363,287**
Direct program	145,635	152,904	177,969	184,489
Reimbursable program	141,520	142,224	155,269	178,798
States, counties, and municipalities	67,095	70,064	82,388	83,845
Miscellaneous non-Federal sources	2,700	2,839	2,503	3,424
Other Federal agencies	71,725	69,321	70,378	91,529
General Administration	**19,059**	**21,493**	**21,528**	**25,028**
Direct program	16,330	18,081	21,206	23,883
Reimbursable program	2,729	3,412	322	1,145
Miscellaneous non-Federal sources	0	1	1	1
Other Federal agencies	2,729	3,411	321	1,144
Facilities	**17,450**	**18,502**	**18,314**	**20,304**
Direct program	17,421	18,502	18,314	20,304
Reimbursable program	29	0	0	0
Computer and Administrative Services	**4,856**	**5,183**	**5,476**	**10,709**
Reimbursable program	4,856	5,183	5,476	10,709
Miscellaneous non-Federal sources	7	11	13	15
Other Federal agencies	4,849	5,172	5,463	10,694
Operation and Maintenance of Quarters	**38**	**23**	**48**	**28**
Direct program	38	23	48	28

[1] Direct program includes $584,194 for current year, $2,292 for no year, $185 for Contributed Funds, and $28 for Operation and Maintenance of Quarters.

USGS reimbursable funds from other Federal agencies for fiscal years 1989 to 1992, by agency

[Dollars in thousands; figures in parentheses are included in Department of the Interior totals]

Budget activity	1989	1990	1991	1992
Department of Agriculture	$ 3,638	$ 3,379	$ 3,464	$ 3,714
Department of Commerce	0	281	323	9
National Oceanic and Atmospheric Administration	5,327	1,448	2,258	5,146
Department of Defense	40,478	41,257	42,002	56,461
Department of Energy	31,630	29,574	28,521	30,679
Bonneville Power Administration	311	358	159	217
Department of the Interior	14,076	12,728	12,533	12,451
Bureau of Indian Affairs	(2,190)	(2,018)	(1,834)	(1,347)
Bureau of Land Management	(1,317)	(1,239)	(1,256)	(1,508)
Bureau of Mines	(0)	(24)	(0)	(0)
Bureau of Reclamation	(5,926)	(6,119)	(6,259)	(5,990)
Minerals Management Service	(222)	(32)	(76)	(207)
National Park Service	(1,304)	(883)	(1,036)	(1,107)
Office of the Secretary	(2,206)	(1,343)	(1,549)	(1,551)
Office of Surface Mining	(264)	(106)	(67)	(8)
U.S. Fish and Wildlife Service	(648)	(964)	(456)	(733)
Department of State	10,082	8,144	8,279	10,524
Department of Transportation	1,479	362	299	661
Environmental Protection Agency	3,096	5,279	4,302	6,414
National Aeronautics and Space Administration	4,952	5,607	6,270	9,589
National Science Foundation	630	2,328	625	1,838
Nuclear Regulatory Commission	1,797	1,917	1,441	539
Tennessee Valley Authority	170	217	200	275
Miscellaneous Federal agencies	17,472	19,484	15,904	22,204
Total	**$135,139**	**$132,363**	**$126,580**	**$160,721**

Guide to Information and Publications

Earth Science Information Centers

To obtain information on cartographic data and on earth science programs, publications, and services, or to obtain copies of reports and maps, write or visit U.S. Geological Survey Earth Science Information Centers at the following addresses:

Alaska:
Room 101
4230 University Dr.
Anchorage, AK 99508

Box 12, New Federal Bldg.
101 12th Ave.
Fairbanks, AK 99701

California:
Bldg. 3, Room 3128
345 Middlefield Rd., Mail Stop 532
Menlo Park, CA 94025

Colorado:
Bldg. 25, Room 1813
Box 25046
Denver Federal Center, Mail Stop 504
Denver, CO 80225

District of Columbia:
Main Interior Bldg., Room 2650
1849 C St., NW.
Washington, DC 20240
(When visiting, use E St. entrance.)

Mississippi:
Bldg. 3101
Stennis Space Center
Bay St. Louis, MS 39529

Missouri:
Room 231
1400 Independence Rd.
Rolla, MO 65401

South Dakota:
EROS Data Center
Sioux Falls, SD 57198

Utah:
8105 Federal Bldg.
125 S. State St.
Salt Lake City, UT 84138

Virginia:
Room 1C–402
507 National Center
12201 Sunrise Valley Dr.
Reston, VA 22092

Washington:
U.S. Post Office Bldg., Room 135
W. 904 Riverside Ave.
Spokane, WA 99201

USGS Library System

The USGS Library system is one of the largest earth science collections in the world and contains more than one million monographs, serial publications, maps, and microforms. The collection covers all aspects of the geological sciences and related subjects. An online catalog provides public access. The library honors the standard interlibrary loan request forms as well as requests received online from the Interlibrary Loan System of the On-Line Computer Library Center. Information and reference services are available from the following library locations:

USGS Library
950 National Center
Reston, VA 22092

USGS Library
Mail Stop 955 (Bldg. 5, Room 507)
345 Middlefield Rd.
Menlo Park, CA 94025

USGS Library
2255 N. Gemini Dr.
Flagstaff, AZ 86001

USGS Library
Mail Stop 914, Box 25046
Denver Federal Center
Denver, CO 80225

Water Information

Sources of Water Data

To obtain assistance in locating sources of water data, identifying sites at which data have been collected, and obtaining specific information, write:

National Water Data Exchange
U.S. Geological Survey
421 National Center
Reston, VA 22092

Water-Data Aquisition Activities

To obtain information on ongoing and planned water-data acquisition activities of all Federal agencies and many non-Federal organizations, write:

Office of Water Data Coordination
U.S. Geological Survey
417 National Center
Reston, VA 22092

Water Resources of Specific Areas

To obtain information on water resources in general and about the water resources of specific areas of the United States, write:

Hydrologic Information Unit
U.S. Geological Survey
419 National Center
Reston, VA 22092

Geologic Information

General Geology

To obtain information on geologic topics such as earthquakes and volcanoes, energy and mineral resources, the geology of specific areas, and geologic maps and mapping, write:

Geologic Inquiries Group
U.S. Geological Survey
907 National Center
Reston, VA 22092

Mineral Resources

To obtain information on mineral resources, write or visit:

Minerals Information Office*
Main Interior Bldg., Room 2647
1849 C St., NW.
Washington, DC 20240

*Joint venture of the USGS and the U.S. Bureau of Mines.

Minerals Information Office, USGS
340 N. 6th Ave.
Tucson, AZ 85705

Minerals Information Office, USGS
c/o Mackay School of Mines
University of Nevada, Reno
Reno, NV 89557–0047

Minerals Information Office, USGS
Post Office Bldg., Room 133
W. 904 Riverside Dr.
Spokane, WA 99201

Maps and Books

To buy topographic and thematic maps of all areas of the United States, to request USGS catalogs, pamphlets, leaflets, and circulars (limited quantities free), and to buy USGS book publications, write or visit:

USGS Map Distribution
Box 25286, Bldg. 810
Denver Federal Center
Denver, CO 80225

To buy Alaska maps, residents of Alaska may write or visit:

Earth Science Information Center
Box 12, New Federal Bldg.
101 12th Ave.
Fairbanks, AK 99701

Open-File Reports

To buy USGS open-file reports or to obtain information on the availability of microfiche or paper-duplicate copies of open-file reports, write:

ESIC Open-File Report Sales
Box 25286, Bldg. 810
Denver Federal Center, Mail Stop 517
Denver, CO 80225

Periodicals

New Publications

To get on the mailing list for the monthly list of *New Publications of the U.S. Geological Survey* (free), write:

Distribution Support Section
U.S. Geological Survey
582 National Center
Reston, VA 22092

Earthquakes & Volcanoes

To subscribe to *Earthquakes & Volcanoes*, a bimonthly, nontechnical digest that provides up-to-date information on earthquakes, volcanoes, and related natural hazards around the world, write:

Superintendent of Documents
Government Printing Office
Washington, DC 20402

U.S. Geological Survey Offices

[Information current as of April 1993]

Headquarters Offices	Central Region	Western Region
National Center **12201 Sunrise Valley Drive** **Reston, VA 22092**	**Denver Federal Center** **Box 25046** **Denver, CO 80225**	**345 Middlefield Rd.** **Menlo Park, CA 94025**

Office of the Director

Director	Dallas L. Peck	(703) 648–7411	101 National Center
Associate Director	Doyle G. Frederick	(703) 648–7412	102 National Center
Special Assistant (Washington Liaison) and Deputy Ethics Counselor	Jane H. Wallace	(202) 343–3888	Rm. 2648, Interior Bldg. Washington, DC 20240
Assistant Director for Research	Stephen E. Ragone	(703) 648–4450	104 National Center
Assistant Director for Engineering Geology	James F. Devine	(703) 648–4423	106 National Center
Assistant Director for Administration	Jack J. Stassi	(703) 648–7200	201 National Center
Assistant Director for Programs	Peter F. Bermel	(703) 648–4430	105 National Center
Assistant Director for Intergovernmental Affairs	John J. Dragonetti	(703) 648–4427	109 National Center
Assistant Director for Information Systems	James E. Biesecker	(703) 648–7108	801 National Center
Congressional Liaison Officer	Talmadge W. Reed	(703) 648–4457	112 National Center
Chief, Public Affairs Office	Donovan B. Kelly	(703) 648–4460	119 National Center
Equal Employment Opportunity Officer	Bruce D. Palmer	(703) 648–4417	116 National Center
Special Assistant to the Director for Human Resources	J. Lynn Smith	(703) 648–7111	115 National Center
Director's Representative—Central Region	Harry A. Tourtelot	(303) 236–5438	911 Denver Federal Center
Director's Representative—Western Region	George Gryc	(415) 329–4002	Western Region, Stop 144
Special Assistant to the Director for Alaska	Paul D. Brooks	(907) 271–4138	4230 University Drive, Suite 120 Anchorage, AK 99508

Administrative Division

Chief	Jack J. Stassi	(703) 648–7200	201 National Center
Administrative Officer	Louie Pectol	(703) 648–7204	203 National Center
Office of Personnel, Chief	Maxine C. Millard	(703) 648–7442	215 National Center
Office of Procurement and Contracts, Chief	John K. Peterson	(703) 648–7373	205 National Center
Office of Financial Management, Chief	Vacant	(703) 648–7604	270 National Center
Office of Facilities and Management Services, Chief	William F. Gossman, Jr.	(703) 648–7338	207 National Center
Office of Systems Management, Chief	Phillip L. McKinney	(703) 648–7256	206 National Center
Washington Administrative Service Center, Chief	Phillip L. McKinney	(703) 648–7256	206 National Center
Central Regional Management Officer	F.B. Sower	(303) 236–5900	201 Denver Federal Center
Western Regional Management Officer	George F. Hargrove, Jr.	(415) 329–4150	Western Region, Stop 211

Information Systems Division

Chief	James E. Biesecker	(703) 648–7108	801 National Center
Deputy Chief	Wendy A. Budd	(703) 648–7103	801 National Center
Office of Customer Services, Chief	Virginia L. Ross	(703) 648–7178	805 National Center
Office of Computer and Communications Services, Chief	Charles D. Nethaway	(703) 648–7077	807 National Center
Office of Management Services, Chief	Eliot Christian	(703) 648–7245	802 National Center
Office of Field Services, Chief	Doug R. Posson	(303) 236–4944	801 Denver Federal Center

National Mapping Division

Chief	Allen H. Watkins	(703) 648–5748	516 National Center
Associate Chief	Roy R. Mullen	(703) 648–5745	516 National Center
Assistant Division Chief for Research	Joel L. Morrison	(703) 648–4640	519 National Center
Assistant Division Chief for Program, Budget and Administration	Richard E. Witmer	(703) 648–4611	514 National Center
Assistant Division Chief for Information and Data Services	Gary W. North	(703) 648–5780	508 National Center
Assistant Division Chief for Coordination and Requirements	Gene A. Thorley	(703) 648–5742	590 National Center
Assistant Division Chief for Production Management	James R. Plasker	(703) 648–4146	511 National Center
Eastern Mapping Center, Chief	K. Eric Anderson	(703) 648–6002	567 National Center

National Mapping Division—Continued

Mid-Continent Mapping Center, Chief	Merle E. Southern	(314) 341–0880	1400 Independence Rd., Rolla, MO 65401
Rocky Mountain Mapping Center, Chief	Randle W. Olsen	(303) 236–5825	510 Denver Federal Center
Western Mapping Center, Chief	John R. Swinnerton	(415) 329–4254	Western Region, Stop 531
Earth Resources Observation Systems Data Center, Chief	Donald T. Lauer	(605) 594–6123	EROS Data Center Sioux Falls, SD 57198

Geologic Division

Chief Geologist	Benjamin A. Morgan	(703) 648–6600	911 National Center
Associate Chief Geologist	David P. Russ	(703) 648–6601	911 National Center
Assistant Chief Geologist for Program	Bonnie McGregor	(703) 648–6640	910 National Center
Administrative Officer	Elwood H. Like	(703) 648–6611	912 National Center
Human Resources Officer	John D. McGurk	(703) 648–6628	911 National Center
Office of Scientific Publications, Chief	John M. Aaron	(703) 648–6077	904 National Center
Office of Regional Geology, Chief	Mitchell W. Reynolds	(703) 648–6959	908 National Center
Office of Earthquakes, Volcanoes, and Engineering, Chief	Robert L. Wesson	(703) 648–6714	905 National Center
Office of Energy and Marine Geology, Chief	Gary W. Hill	(703) 648–6470	915 National Center
Office of Mineral Resources, Chief, Acting	Willis H. White	(703) 648–6100	913 National Center
Office of International Geology, Chief	A. Thomas Ovenshine	(703) 648–6047	917 National Center
Assistant Chief Geologist, Eastern Region	Nancy Milton	(703) 648–6660	953 National Center
Assistant Chief Geologist, Central Region	Harry A. Tourtelot	(303) 236–5438	911 Denver Federal Center
Assistant Chief Geologist, Western Region	William R. Normark	(415) 329–5101	Western Region, Stop 19

Water Resources Division

Chief Hydrologist	Philip Cohen	(703) 648–5215	409 National Center
Associate Chief Hydrologist	John N. Fischer	(703) 648–5216	408 National Center
Assistant Chief Hydrologist for Scientific Information Management	James F. Daniel	(703) 648–5699	440 National Center
Assistant Chief Hydrologist for Operations	William B. Mann IV	(703) 648–5031	441 National Center
Assistant Chief Hydrologist for Research and External Coordination	Robert M. Hirsch	(703) 648–5041	436 National Center
Office of Hydrologic Research, Chief	Roger G. Wolff	(703) 648–5043	436 National Center
Office of External Research, Chief	John E. Schefter	(703) 648–6800	424 National Center
Assistant Chief Hydrologist for Program Coordination and Technical Support	Verne R. Schneider	(703) 648–5229	414 National Center
Office of Atmospheric Deposition Analysis, Chief	Ranard J. Pickering	(703) 648–6874	416 National Center
Office of Ground Water, Chief	William M. Alley	(703) 648–5001	411 National Center
Office of Surface Water, Chief	Charles W. Boning	(703) 648–5301	415 National Center
Office of Water Quality, Chief	David A. Rickert	(703) 648–6862	412 National Center
Assistant Chief Hydrologist for Water Assessment and Data Coordination	David W. Moody	(703) 648–6856	407 National Center
Office of Water Data Coordination, Chief	Nancy C. Lopez	(703) 648–5019	417 National Center
Northeastern Region, Chief	Stanley P. Sauer	(703) 648–5817	433 National Center
New England Programs, Chief	Ivan C. James II	(508) 490–5002	28 Lord Rd., Suite 280 Marlborough, MA 01752
Mid-Atlantic Programs, Chief	Herbert J. Freiberger	(410) 828–1535	208 Carroll Bldg. 8600 La Salle Rd. Towson, MD 21204
Mid-East Programs, Chief	Donald E. Vaupel	(609) 771–3902	810 Bear Tavern Rd., Suite 206 West Trenton, NJ 08628
Ohio Valley Programs, Chief	Catherine L. Hill	(317) 290–3333	5957 Lakeside Blvd. Indianapolis, IN 46278
Western Great Lakes Programs, Chief	Daniel P. Bauer	(608) 274–3535	6417 Normandy Ln. Madison, WI 53719
Southeastern Region, Chief	James L. Cook	(404) 409–7700	Suite 160 Spalding Woods Office Park Norcross, GA 30092
Southeast Programs, Chief	Michael W. Gaydos	(404) 409–7700	Suite 160 Spalding Woods Office Park Norcross, GA 30092

Water Resources Division—Continued

Southeastern Region—Continued			
Lower Mississippi Programs, Chief	Wanda C. Meeks	(501) 378–6391	2301 Federal Office Bldg. 700 W. Capitol Ave. Little Rock, AR 72201
Florida-Caribbean Programs, Chief	Irwin H. Kantrowitz	(904) 681–7631	227 N. Bronough St., Suite 3015 Tallahassee, FL 32301
Central Region, Chief	James F. Blakey	(303) 236–5920	406 Denver Federal Center
Midwest Programs, Chief	James E. Kircher	(913) 832–3567	4821 Quail Crest Pl. Lawrence, KS 66049
North Central Programs, Chief	William J. Herb	(612) 783–3107	2280 Woodale Dr. Mounds View, MN 55112
Rocky Mountain Programs, Chief	Charles A. Pascale	(303) 236–4882	415 Denver Federal Center Box 25046 Denver, CO 80225
Southwest Programs, Chief	Charles R. Burchett	(512) 873–3004	8011 Cameron Rd., Bldg. 1 Austin, TX 78753
Western Region, Chief	T. John Conomos	(415) 329–4403	Western Region, Stop 470
Pacific Northwest Programs, Chief	Marvin O. Fretwell	(206) 593–6510	1201 Pacific Ave., Suite 600 Tacoma, WA 98402
Great Basin Programs, Chief	William J. Carswell, Jr.	(702) 887–7600	333 W. Nye Ln., Room 203 Carson City, NV 89706
California-Pacific Programs, Chief	John M. Klein	(916) 978–5529	Rm. W–2234 Federal Bldg. 2800 Cottage Way Sacramento, CA 95825
District Offices			
Alabama	Hillary H. Jeffcoat	(205) 752–8104	520 19th Ave. Tuscaloosa, AL 35401
Alaska	Philip J. Carpenter	(907) 786–7110	4230 University Dr., Suite 201 Anchorage, AK 99508
Arizona	Robert D. MacNish	(602) 670–6671	375 S. Euclid Ave. Tucson, AZ 85719
Arkansas	Ector E. Gann	(501) 324–6391	2301 Federal Office Bldg. 700 W. Capitol Ave. Little Rock, AR 72201
California	John M. Klein	(916) 978–5529	Rm. W–2234 Federal Bldg. 2800 Cottage Way Sacramento, CA 95825
Colorado	David J. Lystrom	(303) 236–4882	415 Denver Federal Center Box 25046 Denver, CO 80225
Connecticut	Chester E. Thomas, Jr.	(203) 240–3060	Rm. 525 Abraham A. Ribicoff Federal Bldg. 450 Main St. Hartford, CT 06103
Delaware (See Maryland)			
District of Columbia (See Maryland)			
Florida	John Vecchioli	(904) 681–7631	227 N. Bronough St., Suite 3015 Tallahassee, FL 32301
Georgia	Timothy W. Hale	(404) 903–9100	Suite 130, Peachtree Business Center 3039 Amwiler Rd. Atlanta, GA 30360
Hawaii	William Meyer	(808) 541–2653	677 Ala Moana Blvd., Suite 415 Honolulu, HI 96813
Idaho	Jerry L. Hughes	(208) 334–1750	230 Collins Rd. Boise, ID 83702
Illinois	Stephen F. Blanchard	(217) 398–5350	102 E. Main St., 4th Floor Urbana, IL 61801
Indiana	Jo Ann Macy	(317) 290–3333	5957 Lakeside Blvd. Indianapolis, IN 46278
Iowa	Norwood B. Melcher	(319) 337–4191	P.O. Box 1230 Rm. 269, Federal Bldg. 400 S. Clinton St. Iowa City, IA 52244
Kansas	Richard A. Herbert	(913) 832–3505	4821 Quail Crest Pl. Lawrence, KS 66049

Water Resources Division—Continued

District Offices—Continued

Kentucky	Alfred L. Knight	(502) 582–5241	2301 Bradley Ave. Louisville, KY 40217
Louisiana	Darwin D. Knochenmus	(504) 389–0281	3535 S. Sherwood Blvd., Suite 120 Baton Rouge, LA 70816
Maine	Derrill J. Cowing	(207) 622–8201	26 Ganneston Dr. Augusta, ME 04330
Maryland	James G. Peters	(410) 828–1535	208 Carroll Bldg. 8600 La Salle Rd. Towson, MD 21204
Massachusetts	Michael C. Yurewicz	(508) 490–5003	28 Lord Rd., Suite 280 Marlborough, MA 01752
Michigan	Cynthia Barton	(517) 377–1608	6520 Mercantile Way, Suite 5 Lansing, MI 48911
Minnesota	George Garklavs	(612) 783–3100	2280 Woodale Dr. Mounds View, MN 55112
Mississippi	Gerald L. Ryan	(601) 965–4600	Suite 710, Federal Bldg. 100 W. Capitol St. Jackson, MS 39269
Missouri	Marvin G. Sherrill	(314) 341–0825	1400 Independence Rd., Stop 200 Rolla, MO 65401
Montana	Joe A. Moreland	(406) 449–5302	Drawer 10076, Rm. 428, Federal Bldg. 301 S. Park Ave. Helena, MT 59626
Nebraska	Michael V. Shulters	(402) 437–5082	Rm. 406, Federal Bldg. 100 Centennial Mall, North Lincoln, NE 68508
Nevada	Jon O. Nowlin	(702) 887–7600	333 W. Nye Ln., Rm. 224 Carson City, NV 89706
New Hampshire	Brian Mrazik	(603) 225–1611	525 Clinton St. Bow, NH 03304
New Jersey	Janice R. Ward	(609) 771–3931	810 Bear Tavern Rd., Suite 206 West Trenton, NJ 08628
New Mexico	Russell K. Livingston	(505) 262–5301	Pinetree Office Park, Suite 200 4501 Indian School Rd., NE. Albuquerque, NM 87110
New York	L. Grady Moore	(518) 472–6567	P.O. Box 1669 343 U.S. Post Office and Courthouse Albany, NY 12201
North Carolina	James F. Turner	(919) 571–4044	3916 Sunset Rd. P.O. Box 30728 Raleigh, NC 27622
North Dakota	William F. Horak, Jr.	(701) 250–4601	821 E. Interstate Ave. Bismarck, ND 58501
Ohio	Steven M. Hindall	(614) 469–5553	975 W. Third Ave. Columbus, OH 43212
Oklahoma	Kathy D. Peter	(405) 231–4256	202 N.W. 66th, Bldg. 7 Oklahoma City, OK 73116
Oregon	Marvin O. Fretwell	(503) 251–3200	10615 S.E. Cherry Blossom Dr. Portland, OR 97216
Pennsylvania	David E. Click	(717) 730–6910	840 Market St. Lemoyne, PA 17043
Puerto Rico	Allen L. Zack	(809) 749–4433	P.O. Box 364424 GSA Center, Bldg. 652 Hwy. 28, Km. 7.2, Pueblo Viejo San Juan, PR 00936
Rhode Island (See Massachusetts)			
South Carolina	Glenn G. Patterson	(803) 750–6100	Stephenson Center, Suite 129 720 Gracern Rd. Columbia, SC 29210
South Dakota	Kenneth L. Lindskov	(605) 394–1781	1608 Mountain View Rd. Rapid City, SD 57702
Tennessee	Ferdinand Quinones-Marquez	(615) 736–5424	810 Broadway, Suite 500 Nashville, TN 37203

Water Resources Division—Continued

District Offices—Continued

Texas	Richard O. Hawkinson	(512) 873–3028	8011 Cameron Rd., Bldg. A Austin, TX 78754
Utah	Harvey L. Case III	(801) 975–3405	Rm. 1016, Administration Bldg. 1745 W. 1700 South Salt Lake City, UT 84104
Vermont (See New Hampshire)			
Virginia	Gary S. Anderson	(804) 771–2427	3600 W. Broad St., Rm. 606 Richmond, VA 23230
Washington	Carl R. Goodwin	(206) 593–6510	1201 Pacific Ave., Suite 600 Tacoma, WA 98402
West Virginia	David P. Brown	(304) 347–5131	603 Morris St. Charleston, WV 25301
Wisconsin	Warren A. Gebert	(608) 276–3801	6417 Normandy Ln. Madison, WI 53719
Wyoming	Barney D. Lewis	(307) 772–2728	2617 E. Lincolnway, Suite B Cheyenne, WY 82001

Cooperators and Other Financial Contributors

Cooperators listed are those with whom the USGS had a written agreement cosigned by USGS officials and officials of the cooperating agency for financial cooperation in fiscal year 1992. Parent agencies are listed separately from their subdivisions whenever there are separate cooperative agreements for different projects with a parent agency and with a subdivision of it. Agencies are listed in alphabetical order under the State or territory where they have cooperative agreements with the USGS. Agencies with whom the USGS has research contracts and to whom it supplied research funds are not listed.

Cooperating office of the U.S. Geological Survey
g—Geologic Division
n—National Mapping Division
w—Water Resources Division

Alabama
Alabama Department of—
Economic and Community Affairs (w),
Emergency Management (w),
Environmental Management (w),
Highways, Departments No. 1, 2, and 6 (w);
Anniston, City of (w);
Birmingham, City of (w);
Blountsville, Town of (w);
Covington, County of (w);
Geological Survey of Alabama (n,w);
Huntsville, City of (w);
Jefferson County Commission (w);
Mobile, City of (w);
Montgomery, City of (w);
Parrish, Town of (w);
Sumter, County of (w);
Tuscaloosa, City of (w);
University of Alabama—Tuscaloosa (w)

Alaska
Alaska Department of—
Fish and Game (w),
Natural Resources, Division of Water (w),
Transportation (w);
Alaska Energy Authority (w);
Alaska Industrial Development and Export Authority (w);
Alaska Mineral Appraisal Program (g);
Anchorage, Municipality of (w);
Annette Islands Reserve Tribal Government (g);
Cordova, City of (w);
Juneau, City and Borough of (w);
Kenai Peninsula Borough (w);
Sitka, City and Borough of (w);
University of Alaska, Fairbanks (g,w)

American Samoa
Environmental Protection Agency of American Samoa (w);
Power Authority (w)

Arizona
Arizona Department of—
Environmental Quality (w),
Water Resources (w);
Arizona State University (g);
Cochise County Flood Control District (w);
Gila Valley Irrigation District (w);
Gila Water Commissioner, Office of (w);
Hualapai Indian Tribe (w);
Hopi Tribe Department of Natural Resources (w);
Maricopa County—
Flood Control District (w),
Water District (w);
Metropolitan Water District of Southern California (w);
Navajo Nation (w);
Pima County Department of Transportation (w);
Safford, City of, Water, Gas, and Sewer Department (w);
Salt River Project (w);
Scottsdale, City of, Water Resources Department (w);
Show Low Irrigation Company (w);
Tucson, City of (w)

Arkansas
Arkansas Department of—
Parks and Tourism (w),
Pollution Control and Ecology (w);
Arkansas Game and Fish Commission, Fisheries Division (w);
Arkansas Geological Commission (n,w);
Arkansas Soil and Water Conservation Commission (w);
Arkansas State Highway and Transportation Department (w);
Arkansas-Oklahoma: Arkansas River Compact Commission (w);
Fort Smith, City of (w);
Independence, County of (w);
Little Rock—
Municipal Water Works (w),
Public Works Department (w);
Rogers, City of, Water Utilities Department (w);
Saline County Rural Development Authority (w);
University of Arkansas—
at Fayetteville (w),
at Little Rock (w)

California
Adelanto, City of (w);
Alameda County—
Flood Control and Water Conservation District (Hayward) (w),
Water District (w);
Antelope Valley-East Kern Water Agency (w);
California Department of—
Boating and Waterways (w),
Fish and Game (w),
Parks and Recreation (w),
Pesticide Regulation (w),
Transportation (w),
Water Resources (w);
California Water Resources Control Board (w);
Calleguas Municipal Water District (w);
Carpinteria County Water District (w);
Casitas Municipal Water District (w);
Channel Islands Beach Community Services (w);
Coachella Valley Water District (w);
Contra Costa County Flood Control and Water Conservation District (w);
Crestline-Lake Arrowhead Water Agency (w);
Desert Water Agency (w);
East Bay Municipal Utility District (w);
Eastern Municipal Water District (w);
Georgetown Divide Public Utility District (w);
Great Basin Unified Air Pollution Control District (g);
Humboldt Bay Municipal Water District (w);
Imperial County Department of Public Works (w);
Imperial Irrigation District (w);
Indian Wells Valley Water District (w);
Los Angeles, County of (w);
Louisiana State University and A&M College (w);
Madera Irrigation District (w);
Marin Municipal Water District (w);
Mendocino County Water Agency (w);
Merced, City of (w);
Merced Irrigation District (w);
Metropolitan Water District (w);
Mojave Water Agency (w);
Mono, County of (w);
Montecito Water District (w);
Monterey County Water Resources Agency (w);
Monterey Peninsula Water Management District (w);
Orange County Water District (w);
Pala Band of the Mission Indians (w);
Palmdale, City of (w);
Palo Alto, City of (w);
Pechanga Indian Reservation (w);
Riverside County Flood Control and Water Conservation District (w);
Sacramento Municipal Utility District (w);
Sacramento County Department of Public Works (w);
San Benito County Water District (w);
San Bernardino County Flood Control District (w);
San Bernardino Valley Municipal Water District (w);
San Diego, City of (w);
San Diego County Department of Public Works (w);
San Francisco, City and County of (w);
San Francisco Water Department (w);
San Luis Obispo County Engineering Department (w);
San Mateo County Department of Public Works (w);
Santa Barbara, City of, Department of Public Works (w);
Santa Barbara County—
Flood Control and Water Conservation District (w),
Water Agency (w);
Santa Clara Valley Water District (w);
Santa Cruz, City of (w);
Santa Cruz County Flood Control and Water Conservation District (w);
Santa Maria Valley Water Conservation District (w);
Santa Ynez River Water Conservation District (w);
Scotts Valley Water District (w);
Sonoma County—
Planning Department (w),
Water Agency (w);
Tahoe Regional Planning Agency (w);
Tulare County Flood Control District (w);
Turlock Irrigation District (w);
United Water Conservation District (w);
University of California—
at Berkeley (g),
at Davis (g),
at Santa Barbara (g),
Lawrence Livermore National Laboratory (g);
Ventura County Public Works Agency (w);
Water Master—Santa Margarita (w);
Water Replenishment District of Southern California (w);
Woodbridge Irrigation District (w);
Yolo County Flood Control and Water Conservation District (w);
Yuba County Water Agency (w)

Colorado
Arapahoe County Water and Wastewater (w);
Arkansas River Compact Administration (w);
Aspen, City of (w);
Aurora, City of (w);
Bent, County of (w);
Boulder, City of (w);
Boulder, County of (w);
Breckenridge, Town of (w);
Centennial Water and Sanitation District (w);
Cherokee Water and Sanitation District (w);

Colorado Department of—
Health (w),
Natural Resources, Oil and Gas Conservation Commission (w),
Transportation (w);
Colorado Division of—
Water Resources, Office of the State Engineer (w),
Wildlife (w);
Colorado River Water Conservation District (w);
Colorado School of Mines (g);
Colorado Springs, City of—
Department of Public Utilities (w),
Engineering Division (w);
Colorado Water Conservation Board (w);
Delta County Board of Commissioners (w);
Denver Board of Water Commissioners (w);
Eagle County Board of Commissioners (w);
East Grand County Water Quality Board (w);
Englewood, City of (w);
Evergreen Metropolitan District (w);
Fort Collins, City of, Water and Wastewater (w);
Fountain Valley Authority (w);
Fremont Sanitation District (w);
Garfield, County of (w);
Glendale, City of (w);
Glenwood Springs, City of (w);
Lakewood, City of (w);
Lamar, City of (w);
Las Animas, City of (w);
Longmont, City of (w);
Loveland, City of (w);
Lower Fountain Water-Quality Management Association (w);
Metropolitan Wastewater Reclamation District (w);
Moffat, County of (w);
Northern Colorado Water Conservation District (w);
Pueblo Board of Water Works (w);
Pueblo, City of, Department of Utilities (w);
Pueblo County Commissioners (w);
Pueblo West Metropolitan District (w);
Rio Blanco, County of (w);
Rio Blanco Water Conservation District (w);
Rio Grande Water Conservation District (w);
Rocky Ford, City of (w);
St. Charles Mesa Water District (w);
San Juan Basin Oil and Gas Coordinating Committee (g);
Southern Ute Indian Tribe (g,w);
Southwestern Colorado Water Conservation District (w);
Steamboat Springs, City of, Public Works Department (w);
Teller-Park Soil Conservation District (w);
Thornton, City of (w);
Trinchera Water Conservation District (w);
Uncompahgre Valley Water Users Association (w);
University of Colorado (g);
Upper Arkansas Council of Governments (w);
Upper Arkansas River Water Conservation District (w);
Upper Eagle Regional Water Authority (w);
Upper Gunnison River (w);
Upper Yampa Water Conservancy District (w);
Urban Drainage and Flood Control District (w);
Ute Mountain Indian Tribe (w);
Vail Valley Conservation Water District (w);
Westminster, City of (w);
Yellow Jacket Water Conservancy District (w)

Connecticut

Connecticut Department of—
Environmental Protection (g,n,w);
Fairfield, Town of, Conservation Department (w);
Meriden, City of (w);
New Britain, City of, Board of Water Commissioners (w);
South Central Connecticut Regional Water Authority (w);
Torrington, City of (w)

Delaware

Geological Survey (n,w)

District of Columbia

Department of Public Works (w)

Florida

Bay County Utilities (w);
Boca Raton, City of (w);
Bradenton, City of (w);
Broward, County of (w);
Cape Coral, City of (w);
Cocoa, City of (w);
Daytona Beach, City of (w);
Deerfield Beach, City of (w);
Florida Department of—
Environmental Regulation (n,w),
Natural Resources (w)–
Bureau of Marine Resource and Evaluation (w),
Division of Survey and Mapping (n),
Transportation (n,w);
Florida Institute of Phosphate Research (w);
Florida Keys Aqueduct Authority (w);
Fort Lauderdale, City of (w);
Game and Freshwater Fish Commission (w);
Hallandale, City of (w);
Highland Beach, Town of (w);
Hillsborough, County of (w);
Hollywood, City of (w);
Jacksonville, City of, Department of Public Utilities (w);
Jacksonville Electric Authority (w);
Joshua Water Control District (w);
Lake, County of, Water Authority (w);
Lake Mary, City of (w);
Lee, County of (w);
Manatee County—
Board of County Commissioners (w),
Environmental Action Commission (w);
Metropolitan Dade County (w);
Miami-Dade Water and Sewer Authority (w);
Northwest Florida Water Management District (w);
Perry, City of (w);
Pinellas, County of (w);
Polk, County of (w);
Pompano Beach, City of (w);
Port Orange, City of (w);
Quincy, City of (w);
Reedy Creek Improvement District (w);
Sarasota, City of (w);
Sarasota, County of (w);
South Florida Water Management District, Department of Research and Evaluation (w);
South Indian River Water Control District (w);
St. Johns River Water Management District (w);
St. Petersburg, City of (w);
Stuart, City of (w);
Suwannee River Water Management District (w);
Tallahassee, City of—
Electric Department (w),
Water Quality Laboratory (w);
Tampa, City of (w);
Tampa Bay Regional Planning Council (w);
Tampa Port Authority (w);
University of Miami (g);
University of Florida (g);
Volusia, County of (w);
Walton, County of (w);
West Coast Regional Water Supply Authority (w);
Winter Park, City of (w)

Georgia

Albany, City of (w);
Albany Water, Gas, and Light Commission (w);
Attapulgus, City of (w);
Bibb, County of (w);
Blairsville, Town of (w);
Brunswick, City of (w);
Chatham County-Savannah Metropolitan Planning Commission (w);
Chestatee-Chattahoochee Resource Conservation and Development Center (w);
Clayton County Water Authority (w);
Covington, City of (w);
De Kalb County Public Works Department (w);
Georgia Department of—
Natural Resources—
Water Quality Support Program (w),
Geologic Survey (w),
Transportation (w)—
at Atlanta (w),
at Forest Park (w);
Gwinnett, County of, Preconstruction Division (w);
Helena, City of (w);
Macon-Bibb County Water and Sewage Authority (w);
Monroe Water, Light, and Gas Commission (w);
Moultrie, City of (w);
Springfield, City of (w);
Thomaston, City of (w);
Thomasville, City of (w);
Tift County Commission (w);
Tifton, City of (w);
Valdosta, City of (w);
Zebulon, City of (w)

Guam

Guam, Government of, Environmental Protection Agency (w)

Hawaii

Hawaii, County of, Department of Water Supply (w);
Hawaii Department of—
Agriculture, Division of Agriculture Resource Management (w),
Hawaiian Home Lands (w),
Land and Natural Resources (g)—
Commission on Water Resources Management (w),
Division of—
Forestry and Wildlife (n,w),
Water Resource Management (w),
Transportation (w);
Honolulu, City and County of, Department of Public Works (g,w);
Kauai, County of, Department of Water Supply (w);
Maui, County of, Department of Water Supply (w)

Idaho

Bonner County Commissioners (w);
Coeur d'Alene Tribe of Idaho (w);
Idaho Department of—
Health and Welfare (w),
Water Resources (w);
Salmon River Canal Co., Ltd. (w);
Shoshone, County of (w);
Southwest Irrigation District (w);
Teton, County of (w);
Water District No. 01 (Idaho Falls) (w);
Water District No. 31 (Dubois) (w);
Water District No. 32D (Dubois) (w)

Illinois

Bloomington and Normal Sanitary District (w);
Cook County Forest Preserve District (w);
Danville Sanitary District (w);
Decatur, City of (w);
DeKalb, City of, Public Works Department (w);
DuPage County Forest Preserve, Planning and Development Section (w);
DuPage County Department of Environmental Concerns (w);

Illinois Department of—
Energy and Natural Resources—
Geological Survey Division (n),
State Water Survey (w),
Transportation—
Division of Highways (n),
Division of Water Resources (n,w);
Illinois Environmental Protection Agency (w);
Lake County Department of Planning, Zoning, and Environmental Quality (w);
Metropolitan Water Reclamation District of Greater Chicago (w);
Northern Illinois University (w);
Springfield, City of (w);
Wisconsin Department of Natural Resources (w)

Indiana

Carmel, Town of, Utilities (w);
Elkhart, City of, Water Works (w);
Indiana Department of—
Environmental Management (g,w),
Natural Resources (n)—
Division of—
Transportation (w),
Water (w);
Indianapolis, City of, Department of Public Works (w);
Muncie Sanitary District, Bureau of Water Quality (w)

Iowa

Ames, City of (w);
Cedar Rapids, City of, Engineering Department (w);
Clinton, City of (w);
Davenport, City of (w);
Des Moines, City of (w);
Fort Dodge, City of (w);
Iowa Department of—
Transportation, Highway Division (w),
Natural Resources, Geological Survey Bureau (n,w);
Iowa State University (w);
Muscatane Water and Light Board (w);
University of Iowa—
Institute of Hydraulic Research (w),
Hygienic Laboratory (w)

Kansas

Arkansas River Compact Administration (w);
Emporia, City of, Department of Public Works (w);
Franklin, County of (w);
Harvey County Conservation Distict (w);
Hays, City of (w);
Iowa Tribe of Kansas and Nebraska (w);
Kansas City-Wyandotte County Health Department (w);
Kansas Department of Transportation (w);
Kansas Geological Survey (n,w);
Kansas State Board of Agriculture, Division of Water Resources (w);
Kansas State Conservation Commission (w);
Kansas State University Department of Agronomy (w);
Kansas University Center for Research, Inc. (w);
Kansas Water Office (w);
Kickapoo Tribe of Kansas (w);
Linn, County of (w);
Olathe, City of (w);
Prairie Band of Potawatomi Tribe (w);
Sac and Fox Tribe of Missouri (w);
Wichita, City of (w)

Kentucky

Campbellsville Municipal Water (w);
Elizabethtown, City of (w);
Glasgow Water Company (w);
Kentucky Department of Natural Resources and Environmental Protection Cabinet (w);
Metropolitan Sewer District (w);
Owensboro, City of (w);
University of Kentucky, Kentucky Geological Survey (n,w);
University of Louisville (w)

Louisiana

Caddo Parish (w);
Capital-Area Groundwater Conservation Commission (w);
East Baton Rouge Parish (w);
Jefferson Parish Department of Public Utilities (w);
Louisiana Department of—
Environmental Quality (w),
Justice (w),
Transportation and Development (w), Office of Public Works (n);
Louisiana Geological Survey (n);
Minden, City of (w);
Plaquemines Parish (w);
Sabine River Compact Administration (w);
St. John the Baptist Parish (w);
Terrebonne Parish (w);
West Monroe, City of (w)

Maine

Cobbossee Watershed District (w);
Greater Portland Council of Governments (w);
Maine Department of—
Conservation—
Geological Survey (w),
State Forest Service (n);
North Kennebec Valley Regional Planning Commission (w);
Northern Maine Regional Planning Commission (w);
University of Maine (w)

Maryland

Baltimore City of, Water Quality Management (w);
Delaware Geological Survey (w);
Delaware River Basin Commission (w);
Hyndman, Borough of (w);
Maryland Department of the Environment (w);
Maryland Geological Survey (n,w);
Salisbury, City of (w);
University of Maryland (g)

Massachusetts

Cape Cod Commission (w);
Executive Office of Environmental Affairs (n);
Massachusetts Department of—
Environmental Management, Division of Resources Conservation (w),
Environmental Protection—
Division of Water Pollution Control (w),
Division of Water Supply (w),
Bureau of Waste Site Cleanup (w);
Massachusetts Highway Department (w);
Massachusetts Water Resources Authority (g);
Metropolitan District Commission—
Parks, Engineering and Construction Division (w),
Watershed Management Division (w);
Woods Hole Oceanographic Institute (g)

Michigan

Adrian, City of (w);
Ann Arbor, City of (w);
Antrim County Drain Commission (w);
Battle Creek, City of—
Board of—
Public Utilities (w),
Water and Light (w);
Beaverton, City of (w);
Cadillac, City of, Wastewater Treatment Plant (w);
Clare, City of (w);
Consumers Power Company (w);
Elsie, Village of, Department of Public Works (w);
Flint, City of, Water Plant (w);
French Paper Company (w);
Huron-Clinton Metropolitan Authority (w);
Imlay, City of (w);
Indian Lake Property Owners (w);
Kalamazoo, City of, Department of Public Works (w);
Keweenaw Bay Indian Community (w):
Macomb, County of (w);
Mead Paper Company (w);
Michigan Department of—
Natural Resources, Office of Budget and Federal Aid (w),
Transportation, Design Division (w);
Michigan Power Company (w);
Monroe County Health Department, Environmental Health Division (w);
Negaunee, City of, Water and Wastewater Treatment Plant (w);
Norway, City of (w);
Oakland County Drainage Commission (w);
Otsego County Road Commission (w);
Portage, City of (w);
Portland, City of (w);
STS Hydropower, Ltd. (w);
Tri-County Regional Planning Commission (w);
Upper Peninsula Power Company (w);
Wayne, County of, Division of Environmental Health (w);
Wisconsin Electric Power Company (w);
Wolverine Hydroelectric (w);
Wolverine Power Supply Cooperative (w);
Ypsilanti Community Utility Authority (w)

Minnesota

Beltrami County SWCD (w);
Elm Creek Conservation Management and Planning Commission (w);
Grand Portage Reservation Government (w);
Hubbard County Soil and Water (w);
Land Management Information Center (n);
Lower Red River Watershed Management Board (w);
Metropolitan Waste Control Commission (w);
Mille Lacs Reservation Band Government (w);
Minnesota Department of—
Health, Division of Environmental Health (w),
Natural Resources (g,w),
Transportation (w);
Minnesota Pollution Control Agency (w);
Minnesota State Planning Agency (n);
Northwest Minnesota Ground Water Steering Committee (w);
University of Minnesota, Department of Soil Science (w);
Whitewater Joint Powers Board (w)

Mississippi

Harrison County Development Commission (w);
Jackson, City of (w);
Jackson County Port Authority (w);
Mississippi Department of—
Agriculture and Commerce (w),
Environmental Quality—
Office of Geology (w),
Office of Land and Water Resources (w),
Office of Pollution Control (w),
Transportation (w);
Pat Harrison Waterway District (w);
Pearl River Basin Development District (w);
Pearl River Valley Water Supply District (w);
Yazoo Mississippi Delta Joint Water Management District (w)

Missouri

Cape Girardeau, City of (w);
Cass County SWCD (w);
Independence, City of (w);
Jackson County Parks and Recreation (w);
Mid-America Regional Council (w);

Missouri Department of—
Conservation (n,w),
Health (w),
Natural Resources—
Division of Environmental Quality (w),
Division of Geology and Land Survey (n,w);
Missouri Highway and Transportation Commission (w);
Rolla, City of (w);
Rolla Municipal Utilities (w);
Springfield, City of, City Utilities (w);
St. Francis County Environmental Corporation (w);
Sullivan, City of (w);
Watershed Commission of the Ozarks (w);
University of Missouri-Columbia, Department of Geology (w)

Montana

Blackfeet Nation (w);
Chippewa Creek Tribe of Rocky Boy's Reservation (g);
Fort Peck Reservation (w);
Greenfield Irrigation District (w);
Helena, City of (w);
Lower Musselshell Conservation District (w);
Montana Bureau of Mines and Geology (w);
Montana Department of—
Fish, Wildlife, and Parks (w),
Health and Environmental Sciences (w),
Natural Resources and Conservation (w),
Transportation (w);
Northern Cheyenne Tribe (w);
Salish and Kootenai Tribes of Flathead Reservation (w);
Wyoming State Engineer (w)

Nebraska

Central Platte Natural Resources District (w);
Kansas-Nebraska Big Blue River Compact Administration (w);
Lincoln, City of (w);
Little Blue Natural Resources District (w);
Lower Platte South Natural Resources District (w);
Lower Republican Natural Resources District (w);
Middle Republican Natural Resources District (w);
Nebraska Department of Water Resources (w);
Nebraska Natural Resources Commission (w);
Nemaha Natural Resources District (w);
North Platte Natural Resources District (w);
Omaha, City of (w);
Papio-Missouri River Natural Resources District (w);
South Platte Natural Resources District (w);
University of Nebraska, Conservation and Survey Division (w);
Upper Elkhorn Natural Resources District (w);
Upper Niobrara-White Natural Resources District (w);
Upper Republican Natural Resources District (w)

Nevada

Carson City/County Department of Public Works (w);
Clark County Regional Flood Control District (w);
Clark County Sanitation District (w);
Douglas, County of (w);
Duck Valley Reservation (w);
Henderson, City of (w);
Las Vegas, City of (w);
Las Vegas Valley Water District (g,w);
Nevada Bureau of Mines and Geology (g,n,w);
Nevada Department of—
Conservation and Natural Resources—
Division of Environmental Protection (w),
Division of Water Resources (w),
Transportation (w);
Wildlife (w);
Summit Lake Paiute Indian Tribe (w);
Tahoe Regional Planning Agency (w);
Washoe County Planning Department (n)

New Hampshire

New England Interstate Water Pollution Control Commission (w);
New Hampshire Department of—
Environmental Services (g,w),
Transportation (n);
Vermont Department of Environmental Conservation (w)

New Jersey

Bergen, County of (w);
Brick Township Municipal Utility Authority (w);
Gloucester County Planning Commission (w);
Mercer County Park Commission (w);
Morris County Municipal Utility Authority (w);
New Brunswick, City of (w);
New Jersey Department of Environmental Protection (n,w);
New Jersey Water Supply Authority (w);
North Jersey District Water Supply Commission (w);
Passaic Valley Water Commission (w);
Pinelands Commission (w);
Rutgers State University (w);
Somerset County Board of Chosen Freeholders (w);
Washington Township Municipal Utility Authority (w);
West Windsor, Township of (w)

New Mexico

Albuquerque, City of—
Hydrology Division (w),
Utility Planning Division (w),
Waste Water Utility (w);
Albuquerque Metropolitan Arroyo Flood Control Authority (w);
Arizona Department of Environmental Quality (w);
Bernalillo, County of (w);
Canadian River Municipal Water Authority (w);
Costilla Creek Compact Commission (w);
Elephant Butte Irrigation District (w);
La Cienega Acequia Association (w);
Las Cruces, City of (w);
Las Vegas, City of (w);
Navajo Indian Nation, Department of Environmental Protection (w);
New Mexico Department of—
Environment (w),
Highways (w),
Transportation (w);
New Mexico State University, Water Resources Research Institute (w);
Office of the State Engineer (w);
Pecos River Commission (w);
Pueblo of Zuni (w);
Raton, City of (w);
Rio Grande Compact Commission (w);
Rio San Jose Flood Control District (w);
Ruidoso, Village of (w);
Santa Rosa, City of (w);
University of New Mexico (n)

New York

Amherst, Town of, Engineering Department (w);
Auburn, City of (w);
Batavia, City of (w);
Chautauqua, County of, Department of Planning and Development (w);
Cheektowaga, Town of (w);
Columbia University (g);
Cornell University (w);
Cortland, County of (w);
Essex, County of, Planning Department (w);
Hudson-Black River Regulating District (w);
Kiryas Joel, Village of (w);
Monroe, County of, Department of Environmental Health (w);
Nassau, County of—
Department of Health (w),
Department of Public Works (w);
New England Interstate Water Pollution (w);
New York City Department of Environmental Protection, Bureau of Water Supply (w);
New York State Department of—
Environmental Conservation, Planning and Restoration (w),
Transportation (w);
New York State Power Authority (w);
Nyack, Village of, Board of Water Commissioners (w);
Onondaga, County of—
Department of Drainage and Sanitation (w),
Water Authority (w);
Orange County Water Authority (w);
Saratoga Springs, City of (w);
Schuyler County Department of Planning and Economic Development (w);
State University of New York, Syracuse (w);
Suffolk, County of—
Department of Health Services (w),
Water Authority (w);
Tompkins, County of, Department of Planning (w);
Ulster, County of (w);
Victor, Village of (w)

North Carolina

Asheville, City of (w);
Bethel, Town of (w);
Brevard, City of (w);
Chapel Hill, Town of (w);
Charlotte, City of (w);
Danville, City of (w);
Durham, City of (w);
Fayetteville, City of (w);
Greensboro, City of (w);
Lexington, City of (w);
Lumber River Council of Governments (w);
Mecklenburg, County of (w);
Morganton, City of (w);
North Carolina Cooperative Extension Service (w);
North Carolina State Department of—
Environment, Health, and Natural Resources (n,w),
Transportation (w);
North Carolina Wildlife Resources Commission (w);
Orange, County of (w);
Raleigh, City of (w);
Rocky Mount, City of (w);
Triangle Area Water Supply Monitoring, Project Steering Committee (w);
Western Piedmont Council of Governments (w)

North Dakota

Devils Lake Sioux Tribe (w);
Dickinson, City of (w);
Lower Heart Water Resources District (w);
Minot, City of (w);
North Dakota Department of—
Game and Fish (w),
Health, Water Supply, and Pollution Control (w),
Parks and Recreation (w),
Transportation (w);
North Dakota Geological Survey (n,w);
State Water Commission (w);
Three Affiliated Tribes (w)

Ohio

Akron, City of (w);
Canton, City of (w);
Columbus, City of (w);
Eastgate Development Company (w);
Franklin, County of (w);
Fremont, City of (w);
Lima, City of (w);
Madison, County of (w);
Miami Conservancy District (w);
N.E. Ohio Regional Sewer District (w);

Ohio Department of—
Natural Resources (w),
Transportation (n,w);
Ohio Environmental Protection Agency (w);
Ohio State University, Department of Agronomy (w);
Ross, County of (w);
Seneca Soil and Water District (w);
Sumit County Engineers (w);
Toledo Metropolitan Area Council of Governments (w);
University of Toledo (w)

Oklahoma

Ada, City of (w);
Cheyenne and Arapaho Tribes (w);
McGee Creek Authority (w);
Oklahoma Conservation Commission (w);
Oklahoma Department of—
Agriculture (w),
Health (w),
Transportation (n);
Oklahoma Geological Survey (w);
Oklahoma Pollution Control Board (w);
Oklahoma Water Resources Board (w);
Sac and Fox Nation (w)

Oregon

Albany, City of (w);
Ashland, City of (w);
Clark County, Wash., Intergovernmental Resources Center (w);
Confederated Tribes of the Warm Springs Reservation (w);
Coos, County of (w);
Coos Bay-North Bend Water Board (w);
Douglas, County of (w);
Eugene, City of, Water and Electric Board (w);
Gresham, City of (w);
Jackson, County of (w);
Josephine County Department of Public Works (w);
McMinnville, City of, Water and Light Department (w);
Oregon Department of—
Environmental Quality (w),
Human Resources, State Health Division (w),
Metropolitan Service District (w),
Transportation, Highway Commission (w),
Water Resources (w);
Oregon State University (g);
Portland, City of—
Bureau of—
Environmental Services (w),
Water Works (w);
Rogue Valley Council of Governments (w);
Umatilla Indian Reservation (w);
United Sewerage Agency (w);
Washington State Department of—
Ecology (w),
Wildlife (w)

Pennsylvania

Allentown, City of, Engineering Department (w);
Alliance for the Chesapeake Bay (w);
Bethlehem, City of (w);
Bucks, County of (w);
Chester, County of, Water Resources Authority (w);
Delaware County Solid Waste Authority (w);
Delaware River Basin Commission (w);
Environmental Quality Board (w);
Fairfax County Water Authority (w);
Harrisburg, City of, Department of Public Works (w);
Hazelton City Authority Water Department (w);
Letort Regional Authority (w);
Media Borough Water Department (w);
New York State Department of Environmental Conservation (w);
North Penn Water Authority (w);
North Wales Water Authority (w);
Philadelphia, City of, Water Department (w);
Pennsylvania Department of—
Environmental Resources—
Bureau of Community Environmental Control (w),
Bureau of Mining and Reclamation (w),
Bureau of Soil and Water Conservation (w),
Bureau of Topographic and Geologic Survey (n,w),
Bureau of Water Quality Management (w),
Bureau of Water Resources Management (w);
Pennsylvania State University (w);
Pike County Planning Commission (w);
Reading, City of (w);
Somerset Conservation District (w);
Susquehanna River Basin Commission (w);
Tinicum, Township of (w);
University Area Joint Authority (w);
University of Delaware, Geological Survey (w);
West Bradford, Township of (w);
Williamsport, City of (w)

Puerto Rico

Puerto Rico Aqueduct and Sewer Authority (w);
Puerto Rico Department of Natural Resources (w);
Puerto Rico Electric Power Authority (w);
Puerto Rico Environmental Quality Board (w);
Puerto Rico Industrial Development Company (w);
Puerto Rico Mineral Resources Development Corporation (g);
University of the Virgin Islands (w);
Virgin Islands Water and Power Authority (w)

Rhode Island

Providence, City of, Water Supply Board (w);
Rhode Island State Department of Environmental Management, Division of Water Resources (w);
State Water Resources Board (w)

South Carolina

Beaufort-Jasper County Water and Sewer Authority (w);
Camden, City of (w);
Charleston Harbor Project (w);
Charleston Public Works (w);
Clear/Sumter Soil and Water Conservation District (w);
Land Resources Conservation Commission (n);
Myrtle Beach, City of (w);
Oconee County Sewer Commission (w);
Pageland, Town of (w);
Pickens, County of (w);
South Carolina State—
Department of Health and Environmental Control (w),
Department of Highways and Public Transportation (w),
Public Service Authority (w),
Water Resources Commission (n,w);
South Carolina Sea Grant Consortium (w);
Spartanburg Sanitary Sewer District (w);
Spartanburg Water System (w);
University of South Carolina Department of Environmental and Health Services (w);
Waccamaw Regional Planning and Development Council (w);
West Dakota Water Development District (w);
Western Carolina Regional Sewer Authority (w)

South Dakota

Area II Minnesota River Basin (w);
Beadle Conservation District (w);
Belle Fourche Irrigation District (w);
East Dakota Water Development District (w);
Lower Brule Sioux Tribe (w);
Mellette, County of (w);
Oglala Sioux Tribe, Pine Ridge (w);
Rapid City, City of (w);
Rosebud Sioux Tribe (w);
Sioux Falls, City of—
Utilities Department (w),
Water Purification Plant (w);
South Dakota Department of—
Environment and Natural Resources—
Geological Survey Division (w),
Water Resource Management Division (w),
Water Quality Division (w),
Water Rights Division (w),
Game, Fish and Parks (w);
Transportation (w);
South Dakota School of Mines and Technology (w);
South Dakota State University (w);
Spearfish, City of (w);
Stanley County Conservation District (w);
Watertown, City of (w);
West Dakota Water Development District (w);
West River Water Development District (w);
Wyoming, State of (w)

Tennessee

Alcoa, City of (w);
Alpha Talbott Utility District (w);
Bartlett, City of (w);
Camden, City of (w);
Chattanooga, City of, Department of Public Works (w);
Clemson University Department of Environmental Toxicology (w);
Crossville, City of (w);
Dickson, City of (w);
Eastside Utility District (w);
Franklin, City of (w);
Germantown, City of (w);
Grainger County Government (w);
Hamilton County Office of Emergency Management (w);
Humphreys, County of (w);
Johnson City, City of, Public Works Department (w);
Knoxville, City of (w);
Lawrenceburg, City of (w);
Lincoln, County of, Board of Public Utilities (w);
Memphis, City of, Light, Gas, and Water Division (w);
Memphis State University (w);
Metropolitan Governments, Nashville, City of, and Davidson, County of (w);
Murfreesboro, City of, Water and Sewer Department (w);
Pigeon Forge, City of (w);
Rogersville, Town of (w);
Savannah Valley Utility District (w);
Sevierville, City of (w);
Shelby County Government (w);
Tennessee Department of—
Environment and Conservation, Office of Water Programs (w),
Transportation—
Division of Planning (w),
Division of Structures (w);
Tennessee State Planning Office (w);
Tennessee Wildlife Resources Agency (w);
Tullahoma Utilities Board (w);
Union City, City of (w);
University of Tennessee (w);
Wartrace, City of (w)

Texas

Abilene, City of (w);
Alamo Water Reuse/Conservation (w);
Arlington, City of (w);
Austin, City of (w);
Barton Springs/Edwards Aquifer (w);
Bexar-Medina-Atascosa Counties (w);
Brazos River Authority (w);
Coastal Water Authority (w);
Colorado River Municipal Water District (w);
Corpus Christi, City of (w);

Dallas, City of (w);
Dallas, City of, Public Works Department (w);
Edwards Underground Water District (w);
El Paso, City of, Public Service Board (w);
Fort Bend Subsidence District (w);
Fort Worth, City of, Water Pollution Control (w);
Gainesville, City of (w);
Galveston, County of (w);
Garland, City of, Department of Public Works (w);
Georgetown, City of (w);
Graham, City of (w);
Greenbelt Municipal and Industrial Water Authority (w);
Guadalupe-Blanco River Authority (w);
Harris, County of, Flood Control District (w);
Harris-Galveston Coastal Subsidence District (w);
Houston, City of (w);
Lavaca-Navidad River Authority (w);
Lower Colorado River Authority (w);
Lower Neches Valley Authority (w);
Lubbock, City of (w);
Nacogdoches, City of (w);
North Central Texas Council of Governments (w);
North Central Texas Municipal Water Authority (w);
North Texas Municipal Water District (w);
Northeast Texas Municipal Water Authority (w);
Orange, County of (w);
Pecos River Commission (w);
Red River Authority (w);
Sabine River Authority of Texas (w);
Sabine River Compact Administration (w);
San Angelo, City of (w);
San Antonio, City of—
Public Service Board (w),
Water Board (w);
San Antonio River Authority (w);
San Jacinto River Authority (w);
Somerville County Water District (w);
Tarrant, County of, Water Control and Improvement District No. 1 (w);
Texas Soil and Water Conservation Board (w);
Texas State Department of Highways and Transportation (w);
Texas Water Development Board (n,w);
Titus, County of, Fresh Water Supply District No. 1 (w);
Trinity River Authority (w);
Upper Guadalupe River Authority (w);
Upper Neches River Municipal Water Authority (w);
West Central Texas Municipal Water District (w);
Wichita, County of, Water Improvement District No. 2 (w);
Wichita Falls, City of (w)

Trust Territory of the Pacific Islands
Commonwealth Utilities Corp., Saipan (w);
Northern Mariana Islands, Commonwealth of (g,w),
Department of Public Health and Environmental Services (w),
Municipality of Tinian (w);
Ponape State Government (w);
Republic of Palau (w)

Utah
Bear River Commission (w);
Central Utah Water Conservation District (w);
Goshute Tribal Government (g);
Ogden River Water Users Association (w);
Salt Lake, County of, Division of Flood Control (w);
Tooele, City of (w);
University of Utah (w);
Utah Department of—
Health, Division of Environmental Health (w),
Natural Resources—
Geological and Mineral Survey (n,w),
Oil, Gas, and Mining Division (w),
Water Resources Division (w),
Water Rights Division (w);
Weber Basin Water Conservancy District (w);
Weber River Water Users Association (w)

Vermont
Agency of—
Administration (n),
Natural Resources (g,n);
Department of Environmental Conservation (w)

Virginia
Accomack-Northampton Planning District Commission (w);
Alexandria, City of (w);
Delaware Geological Survey (w);
Hampton Roads Planning District Commission (w);
James City, County of (w);
Maryland, Department of—
Environment (w),
State Highway Administration (w);
Newport News, City of (w);
Northern Virginia Planning District Commission (w);
Prince William Health District (w);
Roanoke, City of (w);
Southeastern Public Service Authority of Virginia (w);
University of Virginia, Department of Environmental Sciences (w);
Virginia Department of—
Mines, Minerals, and Energy, Division of Mineral Resources (n),
Transportation (w);
Virginia Beach, City of, Water Resources Division (w);
Virginia Institute of Marine Science (w);
Virginia State Water Control Board (w);
York, County of (w)

Washington
Aberdeen, City of (w);
Bellevue, City of (w);
Chelan, County of, Public Utility District No. 1 (w);
Confederated Tribes and Bands of the Yakima Indian Nation (w);
Douglas, County of, Public Utility District No. 1 (w);
Hoh Indian Tribe (w);
King, County of, Department of Public Works (w);
Lewis, County of, Board of Commissioners (w);
Nisqually Indian Tribe (w);
Oregon Department of Fish and Wildlife (w);
Pacific, County of (w);
Pierce, County of (w);
Quinault Indian Business Committee (w);
Seattle, City of (w);
Seattle-King County Department of Health (w);
Skagit, County of, Department of Public Works (w);
Skagit Conservation District (w);
Snohomish, County of—
Board of Commissioners (w),
Public Utilities District No. 1 (w);
Spokane County Commissioners (n);
Spokane County Engineers Office (w);
Tacoma, City of, Department of—
Public Utilities (w),
Public Works (w);
Thurston, County of, Department of—
Health (w),
Public Works (w);
Umatilla Indian Nation (w);
University of Washington (g);
Washington Department of—
Ecology (w),
Fisheries (w),
Information Services (n),
Natural Resources (n,w);
Washington State Community Development (w);
Whatcom, County of (w)

West Virginia
Morgantown, City of, Utility Board (w);
New Martinsville, City of (w);
West Virginia Department of—
Commerce, Tourism and Parks Section (w),
Highways (w),
Natural Resources, Office of Water Resources (w);
West Virginia Geological and Economic Survey (w)

Wisconsin
Alma/Moon Lake District (w);
Balsam Lake Protection and Rehabilitation District (w);
Barron, City of (w);
Bear Lake, Town of (w);
Beaver Dam, City of (w);
Big Muskego Lake District (w);
Brown County Planning Commission (w);
Dane, County of—
Department of Public Works (w),
Lakes and Watershed Management (w),
Regional Planning Commission (w);
Darboy Sanitary District (w);
Delavan, Town of (w);
Druid Lake Inland Protection and Rehabilitation District (w);
Eagle Springs Lake Sanitary District (w);
East Central Wisconsin Regional Planning Commission (w);
Fond Du Lac, City of (w);
Fowler Lake Management District (w);
Galena, City of (w);
Geological Survey (w);
Green Bay Metropolitan Sewerage District (w);
Green Lake Sanitary District (w);
Hillsboro, City of (w);
Hooker Lake District (w);
Hubbard, Township of (w);
Illinois Department of Transportation (w);
Kaukauna Electric and Water Utilities (w);
Kimberly Water Works Department (w);
Lac Du Flambeau Indians (w);
Lake Nebagamon, Village of (w);
Little Arbor Vitae Protection and Rehabilitation District (w);
Little Chute, Village of (w);
Little Green Lake Protection and Rehabilitation District (w);
Little St. Germain Lake District (w);
Loon Lake/Wescot Management District (w);
Madison Engineering Department (w);
Madison Metropolitan Sewerage District (w);
Marinette County Land Conservation (w);
Mead, Township of (w);
Menasha, Town of, Sanitary District No. 4 (w);
Menominee Indian Tribe of Wisconsin (w);
Merton, Township of (w);
Muskego, City of (w);
Norway, Town of (w);
Oconomowoc Lake, Village of (w);
Okauchee Lake Management District (w);
Oneida Indian Tribe of Wisconsin (w);
Oshkosh, City of (w);
Peshtigo, City of (w);
Powers Lake Management District (w);
Red Cliff Indians (w);
Rock, County of, Public Works Department (w);
St. Germain, Town of (w);
Southeastern Wisconsin Regional Planning Commission (w);
Sparta, City of (w);
Stockbridge-Munsee Indians (w);
Sumit, Town of (w);
Thorp, City of (w);
Troy, Town of (w);
University of Wisconsin (g), Extension, Geological and Natural History Survey (n);
Walworth County Land Conservation Commission (w);
Waupun, City of (w);

Whitewater-Rice Lake Management District (w);
Wind Lake Management District (w);
Wisconsin Department of—
Justice (w),
Natural Resources (w),
Transportation (w);
Wittenberg, Village of (w)

Wyoming
Cheyenne, City of (w);
Evanston, City of (w);
Freemont, County of (w);
Midvale Irrigation District (w);
Northern Arapahoe Tribe (w);
Sheridan Area Water Supply Joint Power Board (w);
Shoshone Tribe (g,w);
Teton, County of (w);
Water Development Commission (w);
Wyoming Department of—
Agriculture (w),
Environmental Quality (w),
Game and Fish (w),
Highways (w);
Wyoming State Engineer (w);
Wyoming Water Research Center (w)

Federal Cooperators

Central Intelligence Agency (g)

Department of Agriculture
Agricultural Research Service (w);
Forest Service (g,n,w);
Soil Conservation Service (n,w)

Department of the Air Force (w)
Air Force Academy (w);
Headquarters, AFTAC/AC (g);
Headquarters, Third Air Division (SAC) (w);
Hickham Air Force Base (w);
Hill Air Force Base (w);
Kirtland Air Force Base (w);
MacDill Air Force Base (w);
Patrick Air Force Base (g);
Tactical Air Command (w);
Vandenberg Air Force Base (w)
Warren Air Force Base (w);
Wright-Patterson Air Force Base (w)

Department of the Army (w)
Aberdeen Proving Ground (g,w);
Anniston Depot (w);
Army Construction Engineering Research Lab (w);
Army Logistics Center (w);
Army Materiel Command (w);
Belvoir RD&E Center (g);
Corps of Engineers (g,n,w);
Engineer Topographic Laboratory (g,w);
Fort Bliss Military Reservation (w);
Fort Bragg Military Reservation (w);
Fort Carson Military Reservation (w);
Picatinny Arsenal (w);
Rocky Mountain Arsenal (w);
White Sands Missile Range (w)

Department of Commerce (w)
Bureau of the Census (n);
National Institute of Standards and Technology (g);
National Marine Fish Service (w);
National Ocean Service (n);
National Oceanic and Atmospheric Administration (g,n,w);
National Weather Service (w)

Department of Defense Agencies
Defense Advanced Research Projects Agency (g,n);
Defense Logistics Agency (w);
D efense Mapping Agency (n);
Defense Nuclear Agency (g);
National Guard Bureau (w)

Department of Energy (g,n,w)
Alaska Power Administration (w);
Bonneville Power Administration (w);
Brookhaven National Laboratory (w);
Hanford Project (w);
Health and Environmental Research (g);
Idaho Falls Operations Office (g,w);
Los Alamos National Laboratory (w);
Nevada Operations Office (g,w);
Oak Ridge Operations Office (g,w);
Rocky Flats Operations Office (w);
Savannah River Operations Office (w);
Test Operations Office, Las Vegas, Nevada (g);
Yucca Mountain Project (w)

Department of the Interior
Bureau of Indian Affairs (g,n,w);
Bureau of Land Management (g,n,w);
Bureau of Mines (n);
Bureau of Reclamation (g,n,w);
Minerals Management Service (g);
National Park Service (g,n,w);
Office of the Secretary (w);
U.S. Fish and Wildlife Service (n,w)

Department of the Navy (w)
Naval Facilities Engineering Command (g)—
Atlantic Division (w),
Northern Division (w);
Naval Oceanographic Office (g);
Naval Surface Warfare Center (w);
Naval Weapons Center, China Lake (g);
Navy Engineering and Logistics Office (g);
Navy Pacific Division (w);
Northwest Engineering Activity (w);
Office of Naval Research (g);
Pacific Missile Test Center (g);
Southwest Naval Facilities Engineering Command (w);
U.S. Marine Corps (w)

Department of State (g)
Agency for International Development (g,n,w);
Foreign and Nonforeign Governments (g);
Government of Saudi Arabia (g);
International Boundary and Water Commission, U.S. and Mexico (w);
International Joint Commission, U.S. and Canada (w)

Department of Transportation
Federal Highway Administration (w)

Environmental Protection Agency (g,n,w)
Corvallis Environmental Research Laboratory (w);
Environmental Monitoring Systems Laboratory (g);
Office of Pesticides and Toxic Substances (w);
Office of Radiation Programs (g);
Office of Water (w);
Region IV, Florida Keys (g);
Robert S. Kerr Environmental Research Lab (w)

Federal Emergency Management Agency (g,w)

Federal Energy Regulating Commission Licensees (w)

National Aeronautics and Space Administration (g,n,w)

National Science Foundation (g,n,w)

Nuclear Regulatory Commission (g)

Tennessee Valley Authority (n,w)

Veterans Administration (w)

Other Cooperators and Contributors

American Society for Photogrammetry and Remote Sensing (n)

Boy Scouts of America (n)

United Arab Emirates (w)

United Nations (g,w)
Inter-America Development Bank (g);
United Nations Development Program (n);
Unesco (w);
World Bank (g)

Yearbook Staff

The staff of the USGS Yearbook appreciates comments from readers. If there are features that you particularly enjoy reading or information that you would like to have, but is not included, please let us know. Write to Managing Editor, USGS Yearbook, 119 National Center, Reston, VA 22092.

Annette Kulyk	National Mapping Division	Sunne Rinkus	Graphic Designer
Kathleen Gohn	Geologic Division	William A. Dize	Graphics Photographic Specialist
Sandye Holmes	Water Resources Division	Carolyn McQuaig	Typographer
Marti Quigley	Information Systems Division	Wilma Donald	Editor
Connie Stephenson	Administrative Division	Gail Wendt	Managing Editor
		Rebecca Phipps	Associate Editor

Please call or write to the following 1992 yearbook authors if you have questions or comments about the information in specific articles. (See the top of page 111 for full regional addresses.)

Walter J. Bawiec	(703) 648–6148	920 National Center
Ronald E. Beck	(605) 594–6551	EROS Data Center Sioux Falls, SD 57198
Stephen F. Blanchard	(217) 398–5350	102 E. Main St. Urbana, IL 61801
Charles W. Boning	(703) 648–5305	415 National Center
Mark V. Bonito	(415) 329–5106	Mail Stop 106 (Menlo Park)
Peter H. Brownell	(703) 648–7209	206 National Center
Deborah L. Burton	(703) 648–7671	270 National Center
Eurybiades Busenberg	(703) 648–5730	432 National Center
Eliot J. Christian	(703) 648–7245	802 National Center
Jim Crawforth	(602) 556–7102	2255 N. Gemini Dr. Flagstaff, AZ 86001
Kurt Dodd	(703) 648–6654	911 National Center
Paul V. Dresler	(703) 648–5020	417 National Center
Jeff Eidenshink	(605) 594–6028	EROS Data Center Sioux Falls, SD 57198
Gary L. Fairgrieve	(703) 648–4608	511 National Center
Carmelo F. Ferrigno	(703) 648–7142	804 National Center
Ellen Findley	(703) 648–7182	801 National Center
David W. Folger	(508) 457–2234	Gosnold Bldg., Quissett Campus Woods Hole, MA 02540
Timothy L. Gauslin	(703) 648–5980	802 National Center
Donald L. Gautier	(303) 236–5740	934 Denver Federal Center
Kathryn D. Gunderson	(703) 648–7144	105 National Center
Pixie A. Hamilton	(804) 771–2427	3600 W. Broad St. Richmond, VA 23230
Robert Hamilton	(703) 648–6550	922 National Center
Monty A. Hampton	(415) 354–3119	Mail Stop 999 (Menlo Park)
Trudy P. Harlow	(202) 208–3726	Dept. of the Interior 1849 C St., MS 5123 Washington, DC 20240
Wendy Hassibe	(801) 524–5652	125 S. State St. Salt Lake City, UT 84138
Maxine C. Jefferson	(703) 648–7439	215 National Center
Susan K. Jenson	(605) 594–6011	EROS Data Center Sioux Falls, SD 57198
Fred Joines	(303) 236–5434	801 Denver Federal Center
John R. Keith	(703) 648–4357	790 National Center
Margo Kingston	(703) 648–6369	927 National Center
Richard L. Kleckner	(703) 648–5741	590 National Center
Kevin S. Larson	(605) 594–6041	EROS Data Center Sioux Falls, SD 57198
Carol Lawson	(415) 329–4030	Mail Stop 870 (Menlo Park)
Robert E. Learned	(602) 670–5581	210 E. 7th Street Tucson, AZ 85705
Kory K. Lee	(703) 648–7241	206 National Center
Nancy C. Lopez	(703) 648–5015	417 National Center
Steve Ludington	(415) 329–5371	Mail Stop 984 (Menlo Park)
Richard A. MacDonald	(703) 648–7120	804 National Center
Jill McCarthy	(415) 354–3140	Mail Stop 999 (Menlo Park)
Thomas P. Miller	(907) 786–7454	4200 University Drive Anchorage, AK 99508
David W. Morganwalp	(703) 648–5720	412 National Center
Carl Mortensen	(415) 329–4856	Mail Stop 977 (Menlo Park)
Jerry L. Mullins	(703) 648–5144	515 National Center
Joseph L. Murphy	(703) 648–7603	270 National Center
Richard O'Leary	(303) 236–2493	973 Denver Federal Center
Lyndon R. Oleson	(605) 594–6164	EROS Data Center Sioux Falls, SD 57198
Mary F. Orzech	(703) 648–6631	912 National Center
A.T. Ovenshine	(703) 648–6047	917 National Center
L. Niel Plummer	(703) 648–5841	432 National Center
Mary E. Powell	(703) 648–7130	804 National Center
Mitchell W. Reynolds	(703) 648–6960	908 National Center
Bruce M. Richmond	(415) 354–3144	Mail Stop 999 (Menlo Park)
Susan Roach	(303) 236–5812	512 Denver Federal Center
David P. Russ	(703) 648–6640	911 National Center
Asbury H. Sallenger, Jr.	(813) 893–3684	600 4th St., South St. Petersburg, FL 33701
Kenneth Sargent	011–9662–667–4188 ext. 450	P.O. Box 1488 Jeddah, 21431 Saudi Arabia
Arthur R. Schmidt	(217) 398–5376	102 E. Main St. Urbana, IL 61801
William B. Scott	(305) 526–2895	9100 NW 36th St., Suite 1070 Miami, FL 33178
Mark Shasby	(907) 786–7022	EROS, 4320 University Dr. Anchorage, AK 99508
David B. Smith	(303) 236–1800	Mail Stop 973 (Menlo Park)
J. Dungan Smith	(303) 541–3004	458 Denver Federal Center
Eugene A. Stallings	(301) 713–0006	National Weather Service 1325 East-West Hwy. Room 8144 (SSMC2) Silver Spring, MD 20910
Alan R. Stevens	(703) 648–5110	515 National Center
Paul Teleki	(703) 648–4423	c/o 106 National Center
R.J. Thompson	(605) 594–6161	EROS Data Center Sioux Falls, SD 57198
Stephen J. Vandas	(303) 236–4932	414 Denver Federal Center
John Walbert	(703) 648–6934	206 National Center
Lisa Wald	(818) 405–7822	525 S. Wilson St. Pasadena, CA 91106
Laure Wallace	(703) 648–6515	912 National Center
Jean N. Weaver	(303) 236–7765	972 Denver Federal Center
Robert H. Webb	(602) 670–6821	1675 W. Anklam Road Tucson, AZ 85701
Susan Wells	(703) 648–7452	215 National Center
Steve Wilson	(303) 236–2454	973 Denver Federal Center
Richard C. Williams	(703) 648–4401	215 National Center
Jackie M. Williams	(303) 236–1203	964 Denver Federal Center
S. Jeffress Williams	(703) 648–6511	914 National Center
Denise A. Wiltshire	(703) 648–7114	801 National Center
John H. Wittmann	(703) 648–5117	510 National Center
Kathryn Wortman	(703) 648–4566	510 National Center
Harry L. Zohn	(703) 648–5928	507 National Center

Editor's note: All photographs are by USGS employees unless otherwise noted.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.