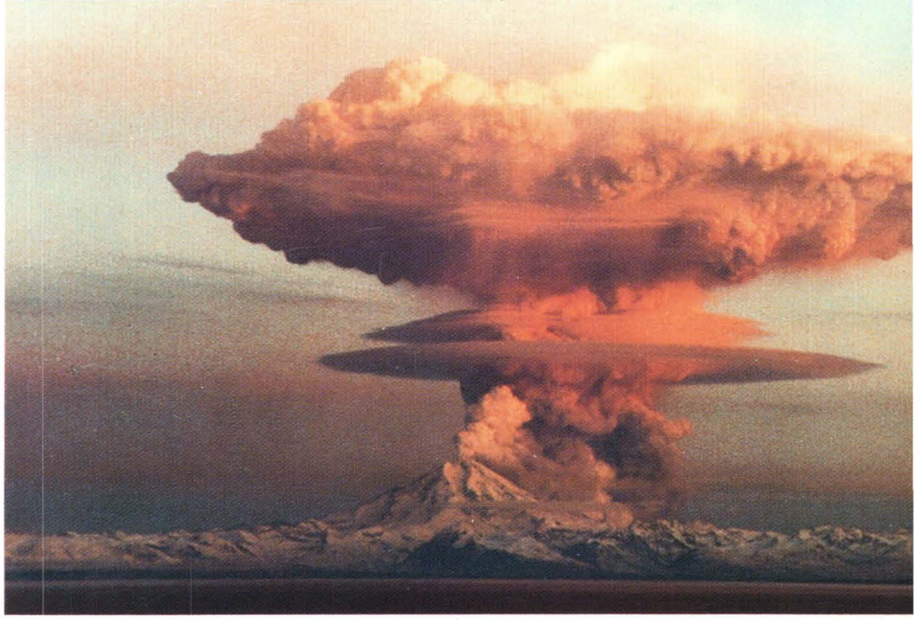

USGS 1990

Cover—Clockwise from top left:

Reeds and duckweed on the Milwaukee River, Campbellsport, Wis. (Mark A. Hardy; see articles p. 19–26).

Mount Redoubt volcano eruption on the morning of April 21, 1990 (copyright 1990, Robert J. Clucas, reprinted by permission; see articles p. 12 and 18).

Brooks Falls, Wyo. (Mark A. Hardy; see articles p. 19–26).

Major roads lead to Atlantic City on this portion of the newly digitized New Jersey State base map (see article p. 66).

Close up of sand boils (from underlying loose, saturated sand deposits) at eastern end of Marina Green, San Francisco, Calif., caused by the October 17, 1989, Loma Prieta earthquake (Michael J. Bennett; see article p. 3).

United States Geological Survey Yearbook Fiscal Year 1990

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, Jr., Secretary

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

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Message from the Director

The forces of nature, tragically evident in fiscal year 1990, added a host of new challenges for the U.S. Geological Survey. This year also marked significant accomplishments and advancements in our mission of providing "Earth Science in the Public Service."

The "World Series" Loma Prieta earthquake of October 17, 1989, was one that will long be remembered for the devastation it caused in northern California and for the scientific lessons that it taught. The earthquake followed close after the destruction from Hurricane Hugo, which affected our citizens from the Virgin Islands and Puerto Rico to the coastal areas of North and South Carolina. Just after the hurricane we were able to use our hydrologic knowledge to assist in restoring water resources to the citizens of St. Croix. Then, in December, Mount Redoubt volcano in Alaska awoke from a dormant period and began periodic eruptions that drastically affected air travel and caused concern for oil transport and public safety. In Hawaii, Kilauea volcano continued its longest lived eruption in this century throughout the year.

Such natural hazards are sobering reminders that we will never control nature. By understanding better the mechanisms of these hazards, we can mitigate the severity of their impacts. The theme of preparedness is the emphasis of the International Decade for Natural Disaster Reduction (IDNDR), which began in January 1990. As one of the signatory nations to the United Nations resolution that authorized the IDNDR, the United States is developing a national program to prepare for natural hazards. Through scientific research, social planning and preparedness, and proper emergency response, we can, as a Nation and as a global community, work to lessen the effects of natural hazards and reduce the economic and social losses from natural disasters.

While the effects of nature's forces can be intense and often severe, they are nonetheless short-term events. Other issues of concern to the environment are longer term and are thus also a challenge to the earth scientist. The cumulative impact of human activities on our water resources can result in changes to the quality of those resources. Nature itself can affect water resources so that the water is not of sufficient quality to meet human needs. To address pressing national questions, to determine the long-term trends, and to identify, describe, and explain the major factors that affect water quality, the USGS has undertaken a first-time-ever comprehensive assessment of the quality of the Nation's surface- and groundwater resources. This ambitious task, which was tested in 7 pilot studies, and begun at 20 study sites in fiscal year 1991, will provide the Nation with the information necessary for addressing policy and scientific issues related to water quality.

A long-term environmental issue challenging earth scientists throughout the world is that of interdisciplinary research on global change. The Earth is a dynamic planet, and change is occurring always around us. As yet science does not have the finite answers to many of the questions concerning the changing environment of our planet. We must develop a sound understanding of the cycles of natural change and the impacts of human activities on Earth systems and develop the capability to predict changes. The mission-oriented geologic, hydrologic, geographic, and data management activities of the USGS provide a sound basis of information with which to investigate this intriguing area of longer term environmental change.

Among this year's significant accomplishments was the completion of primary topographic mapping of the conterminous United States. With that milestone achieved, the USGS is continuing its work to develop more sophisticated technology to update existing maps and to make them available in digital form. During this year we also completed the Louisiana Barrier Island Erosion Study. The maps from this study will be key to making accurate and reliable predictions of future conditions along the coast and adjacent wetland environments.

The USGS also completed, in cooperation with the Bureau of Mines, an initial assessment of the mineral potential of the Bureau of Land Management wilderness areas and is continuing our cooperative efforts with the U.S. Forest Service to assess the mineral resources of National Forests. Water resources investigations, conducted in every State, were supported by State agencies to increase our understanding of the Nation's water resources. Also this year, USGS outreach programs answered the call from Interior Secretary Manuel Lujan to address the earth science educational needs of the Nation, the role of volunteerism, and the interests of women, minorities, and persons with disabilities. We are strongly committed to enhancing our support in these areas as part of the conduct of our mandated mission in the geologic, hydrologic, and mapping sciences.

As earth scientists we have the opportunity to be the first line of defense in meeting present and future environmental challenges. We are committed to meeting those challenges and in providing the best science possible to meet the needs of the Nation we serve. It is with great pleasure that I present to you the accomplishments of the USGS for 1990.

Dallas L. Peck

Natural Hazards Research and Response

International Decade for Reducing Loss from Natural Disasters

By Walter W. Hays

The United States is planning a balanced and comprehensive program of research and applications for the 1990's as a part of the United Nations International Decade for Natural Disaster Reduction (IDNDR). The U.S. program is designed to reduce the loss of life and damage to property from natural disasters. Worldwide loss from such disasters is increasing rapidly due to population growth, urbanization, and the concentration of industry and infrastructure in areas prone to recurrent natural hazards. The U.S. program will complement the programs of 154 other signatory nations of the December 1989 IDNDR resolution of the 44th General Assembly of the United Nations. The resolution calls for all nations to develop programs to achieve the IDNDR goal of reducing the loss of life, economic impact, and human suffering resulting from natural disasters.

The IDNDR is both an unprecedented opportunity and a challenge. The opportunity is to apply new understanding of natural forces to regions at risk to minimize loss of life. The challenge is that such a multidisciplinary effort must be taken on a global scale, an undertaking never before attempted.

The task of the IDNDR is great. Statistics compiled in 1989 by the United Nations International Ad Hoc Group of Experts show that, by the year 2000, the surface of the Earth will be subjected to

- One million thunderstorms,
- 100,000 floods,
- Tens of thousands of damaging landslides, earthquakes, wildfires, and tornadoes, and
- Several hundred to several thousand tropical cyclones and hurricanes, tsunamis, droughts, insect infestations, and volcanic eruptions.

Some of these recurrent natural hazards will cause a disaster. A disaster occurs when people are killed or property is destroyed, but, for purposes of planning for assistance, a disaster is defined as a disruption of human activity that prevents a community from functioning normally. The consequences of disasters are grave.

Recall these recent U.S. disasters: floods in Arkansas, Texas, and Ohio; tornadoes in New York, Alabama, and Indiana; wildfires in Wyoming, California, and Oregon; earthquakes in California; hurricanes along the Gulf and Atlantic Coasts; volcanic eruptions in Hawaii and Alaska; and droughts in the Midwest, Southeast, and California. The worldwide consequences of disasters, taken as a whole, are alarming. For example, the World Health Organization reports that worldwide natural disasters occurring between 1964 and 1983 killed more than 2 million people and left almost 750 million people homeless, orphaned, sick, or injured.

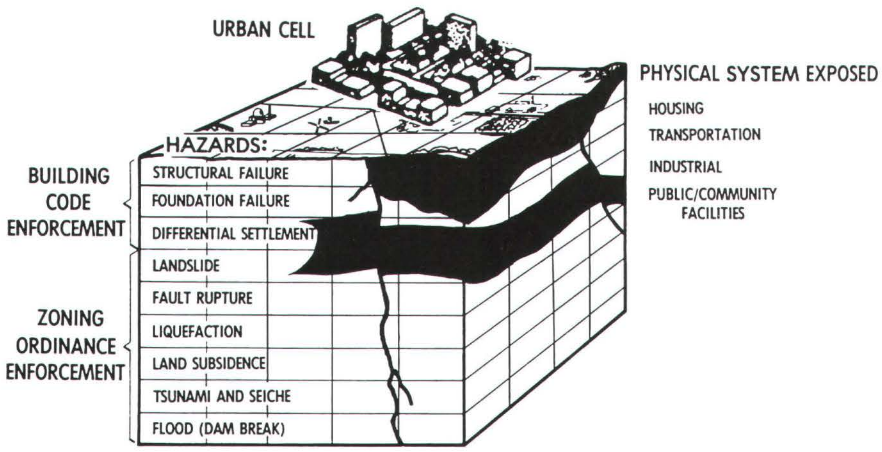
The United States has accepted the challenge of the IDNDR because of its great potential to assist in achieving the specified goals and because every U.S. State and Territory has communities that are at risk. Some are at risk from natural hazards that recur at intervals ranging from every year for floods, landslides, tornadoes, hurricanes, and wildfires to once every few years for damaging earthquakes and drought. Others face risks once every century or more for major earthquakes, such as those in Alaska, California, and the Mississippi Valley area, and for large volcanic eruptions, such as those in the Pacific Northwest and Alaska.

However infrequently these natural hazards occur, they cause direct economic losses of more than $20 billion per year. At risk economically is the multitrillion dollar inventory of dwellings, office buildings, government facilities and military installations, industrial complexes, schools, hospitals, utility and communication systems, and other facilities that are located throughout the Nation in hazard-prone regions such as

- In or adjacent to fault zones capable of generating damaging earthquakes,
- Along coasts where hurricanes, storm surges, or tsunami flood waves strike,
- Near active volcanoes,
- On unstable slopes susceptible to landslides,
- In flood plains subject to inundation,
- In regions prone to tornadoes,
- Along wilderness-urban interfaces vulnerable to wildfires, and
- In regions subject to drought or insect infestation.

Earthquake Fatalities of the 20th Century

1990	Philippines (M=7.7)	3,100
1960	Agadir, Morocco (M=5.9)	12,000
1968	Dasht-i Biyaz, Iran (M=7.3)	12,000
1962	Buyin Zhara, Iran (M=7.3)	12,225
1917	Indonesia (M=7.0+)	15,000
1978	Tabas, Iran (M=7.7)	18,200
1905	Kangra, India (M=8.6)	19,000
1948	Ashkhabad, USSR (M=7.3)	19,800
1974	China (M=6.8)	20,000
1976	Guatemala City (M=7.5)	23,000
1988	Armenia, USSR (M=6.8)	24,944
1935	Quetta, Pakistan (M=7.5)	25,000
1939	Chillán, Chile (M=8.3)	28,000
1915	Avezzano, Italy (M=7.5)	32,610
1939	Erzincan, Turkey (M=8.0)	32,700
1990	Iran (M=7.7)	40,000
1927	Tsinghai, China (M=8.0)	40,912
1908	Messina, Italy (M=7.5)	58,000
1970	Ankash, Peru (M=8.3)	66,794
1923	Kanto, Japan (M=8.3)	142,807
1920	Kansu, China (M=8.5)	200,000
1976	Tangshan, China (M=7.8)	242,469



Types of actions that local jurisdictions throughout the Nation will take during the 1990's to make their communities more resilient to natural hazards.

Moreover, the Nation's building wealth is growing at a rate of $400 billion per year as new public and private construction adds to the number of buildings and lifeline systems. The total value of new construction during the 1990's will reach approximately $4 trillion. Earthquakes and hurricanes alone have the potential for causing greater average annual loss to structures than that for all other hazards combined. Two 1989 events, Hurricane Hugo and the Loma Prieta, Calif., earthquake, illustrate the devastating effects of a category 4 hurricane (see Saffir-Simpson hurricane scale, p. 8) and a magnitude 7.1 earthquake. Together they caused direct losses of $15 billion and indirect losses of $30 to $45 billion, resulted in the deaths of more than 100 people and injured several thousand more, rendered tens of thousands homeless or jobless, and left communities facing a long, complex recovery process.

The U.S. program for the IDNDR has been prepared through a 17-member national committee convened in 1989 by the National Research Council of the National Academy of Sciences and Engineering and the Federal science and disaster-reduction agencies. The Federal agencies work as the Subcommittee on Natural Disaster Reduction under the direction of the President's Office of Science and Technology Policy.

Action at the local and State level will rally as many as 30,000 local jurisdictions and several million people. Local jurisdiction will be encouraged to adopt and enforce policies that will reduce losses from natural hazards through

- Hazard and risk assessments,
- Preparedness and mitigation measures,
- Prediction and warnings for all natural hazards,
- Improved planning, siting, design, and construction practices,
- Awareness and education for all sectors of the society,
- Loss reduction based on lessons learned from disasters throughout the world, and
- Cooperative national and international endeavors designed to collect, analyze, and share data, experiences, and mitigation techniques for specific natural hazards.

In each local jurisdiction, three demonstration studies will serve as the means to integrate and coordinate hazard reduction efforts:

- Disaster Prevention Resource Network—A national multihazards information system available to fulfill local and national needs for natural disaster data.
- Natural Hazard Prediction Experiments—Specific hazard-prone locations that will be used as natural laboratories to advance prediction techniques for each type of natural hazard that jurisdictions are exposed to.
- Hazard-Reduction Regions—Selected geographic regions having jurisdictions that take specific action to reduce hazards. This action will result in hazard resistant schools, hospitals, and other essential facilities within those jurisdictions.

The progress of each jurisdiction will be monitored as the U.S. program unfolds. Each jurisdiction is free to choose those program elements that best suit their needs. Some of the hoped-for changes that will help to measure the success of the IDNDR are increased understanding of the physical and social aspects of natural disaster reduction, improved risk assessment and emergency response and recovery plans, and increased awareness by the public, policymakers,

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

When a community is prepared, disaster is reduced.

emergency planners, and the media of natural disasters, preparedness, and mitigation.

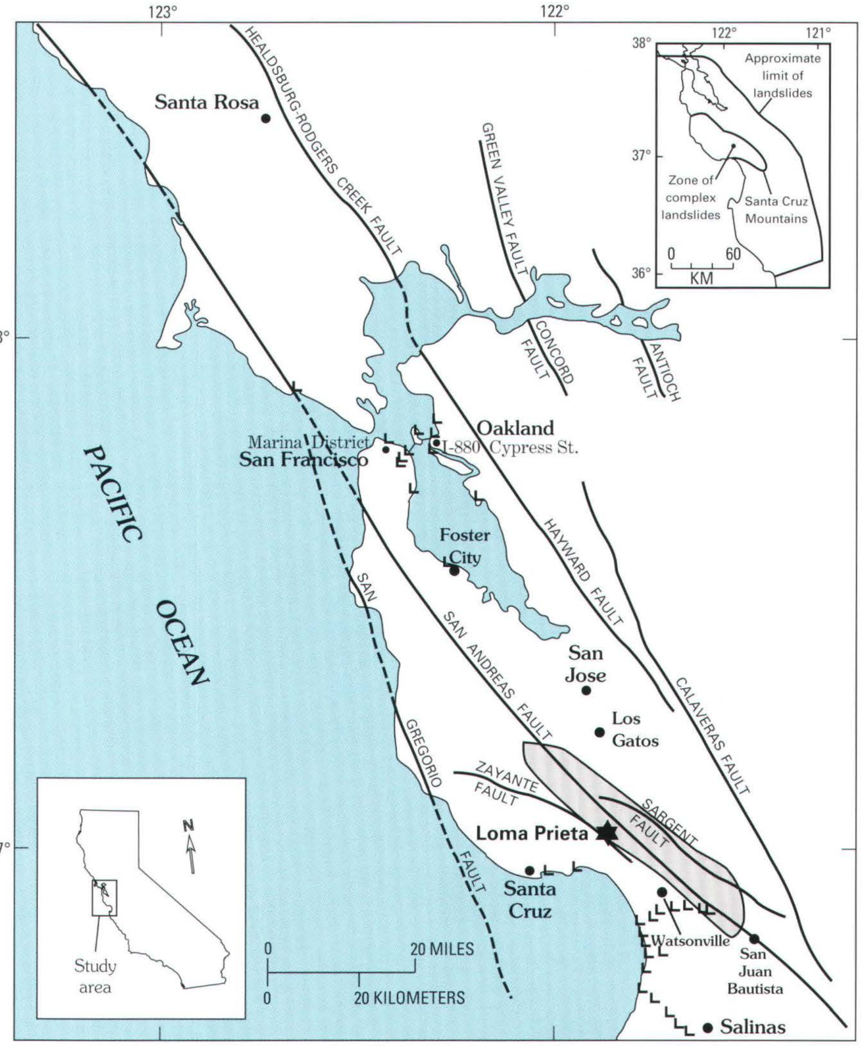
The ultimate test of the success of the IDNDR, however, will be whether or not the frequency and severity of natural disasters in the 21st century are lessened as a consequence of actions implemented during the 1990's. The key element in reducing the severity and number of natural disasters that result from natural hazards is preparedness. When a community is prepared, disaster is reduced; when a community is not prepared, disaster occurs.

The Loma Prieta Earthquake

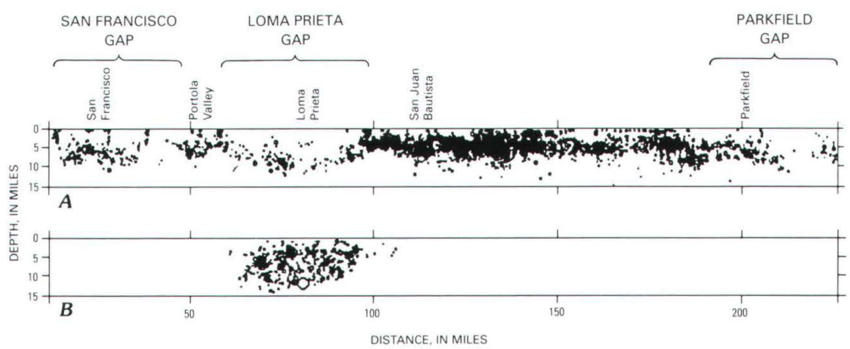
The magnitude 7.1 Loma Prieta, Calif., earthquake began suddenly and without foreshock warning at 5:04 p.m. PDT on October 17, 1989. The earthquake resulted in 62 confirmed fatalities, 3,757 injuries, more than 12,000 homeless, and property losses and recovery costs estimated to exceed $6 billion. Although larger earthquakes have affected the United States in recent decades, not since 1906 has an earthquake had such dramatic consequences. Indeed, the losses in lives and in public and private property place it among the Nation's most costly natural disasters.

The earthquake ruptured a segment of the San Andreas fault system that lies within the southern Santa Cruz Mountains. This segment had been recognized as early as 1983 as having a high probability for failure in the following few decades. The Working Group on California Earthquake Probabilities concluded in 1988 that this segment had a higher probability for producing a magnitude 6.5 to 7 earthquake than any other fault segment in Northern California.

Along certain of the crustal plate boundaries of the Earth, large active faults such as the San Andreas exist. Along some segments of these faults, no large earthquakes have occurred for long intervals of time. Scientists term these quiet segments "seismic gaps" and have forecast the time when some of these seismic gaps in the record will be filled by large earthquakes. The 7.1 Loma Prieta mainshock filled a gap in the seismicity record of the northern San Andreas fault, lending further credibility to the use of seismic gaps in earthquake forecasting. While anticipated, the earthquake had no obvious short-term seismic or strain precursors. The clearest harbinger, a marked increase in seismicity in the 16 months before the event, was recognized and widely



Region affected by the October 17, 1989, Loma Prieta earthquake (magnitude 7.1). Heavy lines are active faults. Gray-tint area containing mainshock epicenter (star) encloses principal zone of aftershocks. L, sites of liquefaction-induced ground failure.



Seismic gaps are regions where the fault sticks and thus strain accumulates; it is here where large earthquakes are likely to occur. Cross section A *shows the location of earthquakes that occurred along the San Andreas fault from January 1969 to July 1989. Cross section* B *shows how the Loma Prieta gap was filled by the October 17 earthquake and its aftershocks.*

discussed before the event, but, in the days immediately prior to October 17, there were no foreshocks.

Just as the occurrence of this earthquake was anticipated, so were its principal effects. The extent of damage in San Francisco and Oakland, which lie approximately 60 miles from the epicenter, has many parallels with the 1985 tragedy in Mexico City caused by the magnitude 8.1 Michoacan earthquake that occurred more than 200 miles away from the capital. In both cases, the principal cause of damage was young, poorly consolidated, water-saturated, fine-grained sediments that amplified the ground shaking and were susceptible to ground failure.

The San Francisco Marina District tragedy is one of special irony; this community consists mostly of wood-frame buildings; such structures are flexible and ordinarily fare well even in strong earthquake shaking if there is solid ground beneath them. However, the Marina District is built on poorly consolidated artificial fill that was originally emplaced for the Panama-Pacific International Exposition, which celebrated San Francisco's recovery from the 1906 earthquake. This artificial fill amplified the shaking and failed massively and pervasively during the Loma Prieta earthquake. The Marina District fire resulted from a broken gas main, and the efforts to control the fire were hampered by broken water mains. The gas and water main breaks were a result of ground failures. Similar problems also had occurred in artificial fills in the 1906 earthquake.

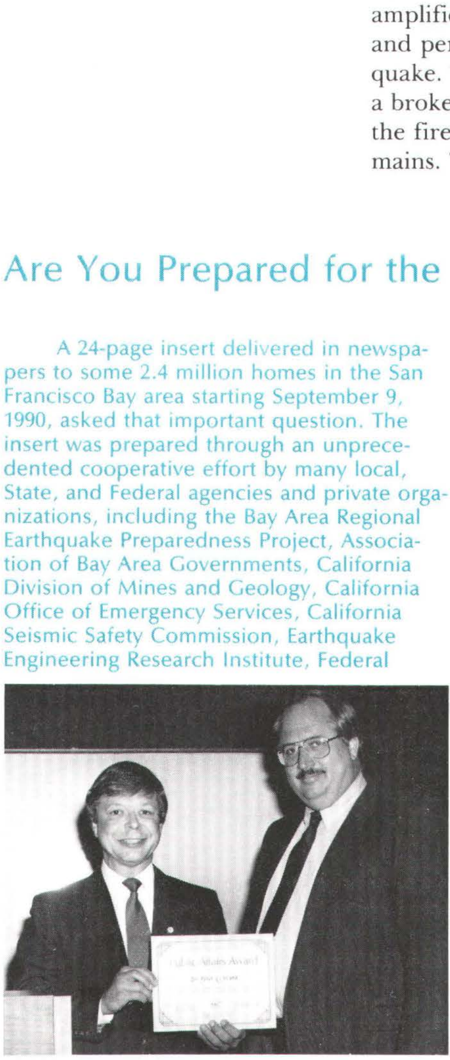
The collapsed portion of the Cypress Street section of I–880 in Oakland was built on San Francisco Bay mud that amplified the shaking; the undamaged portions were built on firmer ground. These soft soil areas, as well as other areas that sustained significant but less severe damage, had been identified on USGS maps as having a high potential for damage.

In the epicentral region, damage in the communities of Watsonville, Santa Cruz, and Los Gatos was most severe in unreinforced masonry buildings constructed before the modernization of California building codes. Here, as well as in the Marina District, major shaking damage occurred in structures having a poorly supported first floor that was unable to resist horizontal shear deformation; most structures built in the past few decades did not sustain major structural damage from the earthquake.

Liquefaction, the transformation of loosely packed and fully saturated sediment into a fluid mass, was responsible for some of the most devastating damage caused by the earthquake. Liquefaction occurred in man-made fill around the margins of San Francisco Bay and in flood-plain deposits in the Salinas-Santa Cruz area. In the San Francisco Bay area, liquefaction-induced ground failure

Are You Prepared for the Next Big Earthquake?

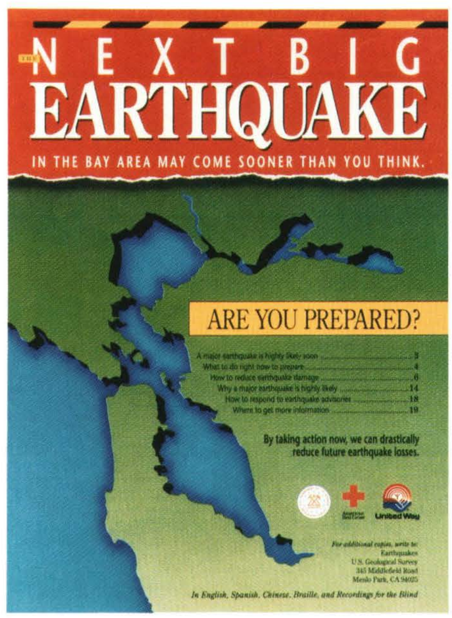
A 24-page insert delivered in newspapers to some 2.4 million homes in the San Francisco Bay area starting September 9, 1990, asked that important question. The insert was prepared through an unprecedented cooperative effort by many local, State, and Federal agencies and private organizations, including the Bay Area Regional Earthquake Preparedness Project, Association of Bay Area Governments, California Division of Mines and Geology, California Office of Emergency Services, California Seismic Safety Commission, Earthquake Engineering Research Institute, Federal Emergency Management Agency, Applied Technology Council, American Red Cross, United Way of Santa Clara County, and United Way of the Bay Area. Most of the cost of printing the newspaper insert was paid by the Northern California Earthquake Special Relief and Preparedness Project of the American Red Cross and the Northern California Disaster Relief Fund through the United Way of Santa Clara County and the United Way of the Bay Area.



JAY PRENDERGAST

The earthquake awareness information in the full-color insert was organized and written by **Peter Ward** (on right in photograph), a USGS geophysicist in Menlo Park, Calif. Ward was recognized for his "imagination, leadership, hard work, and perseverance" with a public affairs award from the U.S. Department of the Interior. The award was presented to Dr. Ward by **Dr. Harlan Watson**, science advisor to the Secretary of the Interior. In presenting the award, Watson noted that, while scientists tend to communicate with a rather small group of fellow specialists, Ward, through this special publication, communicated useful scientific information to millions of people.

Of the total 3.1 million copies of the booklet *The Next Big Earthquake: Are You Prepared?*, 2.4 million were distributed in Bay Area newspapers, and another 600,000 copies were sent on request to individuals, schools, libraries, and other interested parties throughout the country. A limited number of copies are available; write to Earthquakes, 345 Middlefield Rd., Menlo Park, CA 94025.



was most extensive in water-saturated man-made sand fills that subsequently had been paved over. Many of these areas also underwent liquefaction during the 1906 earthquake. Significantly, no obvious ground failure occurred in numerous other extensive bay-shore land fills that apparently were better engineered.

The Loma Prieta earthquake generated hundreds of landslides throughout a region of approximately 5,400 square miles (see map, p. 3). The epicentral region of the earthquake in the steep Santa Cruz Mountains historically has produced abundant landslides, both during earthquakes and during the rainy winters of the region. The largest October 17 landslide damaged dozens of residences. Other landslides, including rock falls, rock slides, and debris slides, occurred on coastal cliffs, steep hillsides, and along roads as far as 80 miles from the epicenter.

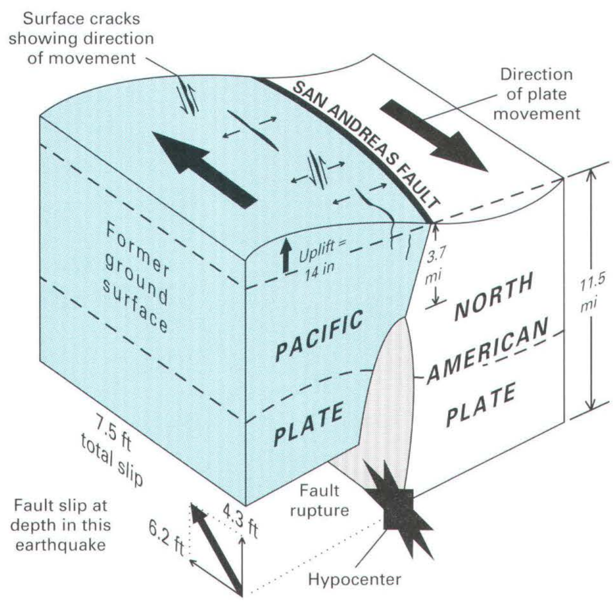
Although most of the above effects were anticipated, the Loma Prieta earthquake did hold some surprises. The forecasts had predicted horizontal motion on a vertical fault, but the 6 feet of horizontal motion occurred on an inclined fault plane and was combined with 4 feet of reverse vertical slip on the same plane. In hindsight, this vertical movement agrees well with models of earthquake motion; however, accurate prediction of the motion depended on identifying the dip of the fault plane.

Another surprising aspect was that the motion of the earthquake was not observed along a single fault break at the surface, which suggests that previous magnitude 7 earthquakes in this area may not have left direct evidence in the geologic record. This is an important issue because geological estimates of what has happened in the past form an important element of long-term forecasting and seismic hazard assessment. The motion on the fault was distributed across a broad zone of complex cracks and fractures. Individual cracks within this zone of unusual fractures generally follow, and may have controlled, the formation of the existing topography. These surface displacements have been explained as slope-related movements along the bedding plane faults that caused the strong shaking of the mainshock. Similar surface fissures were observed in this region after the 1906 earthquake.

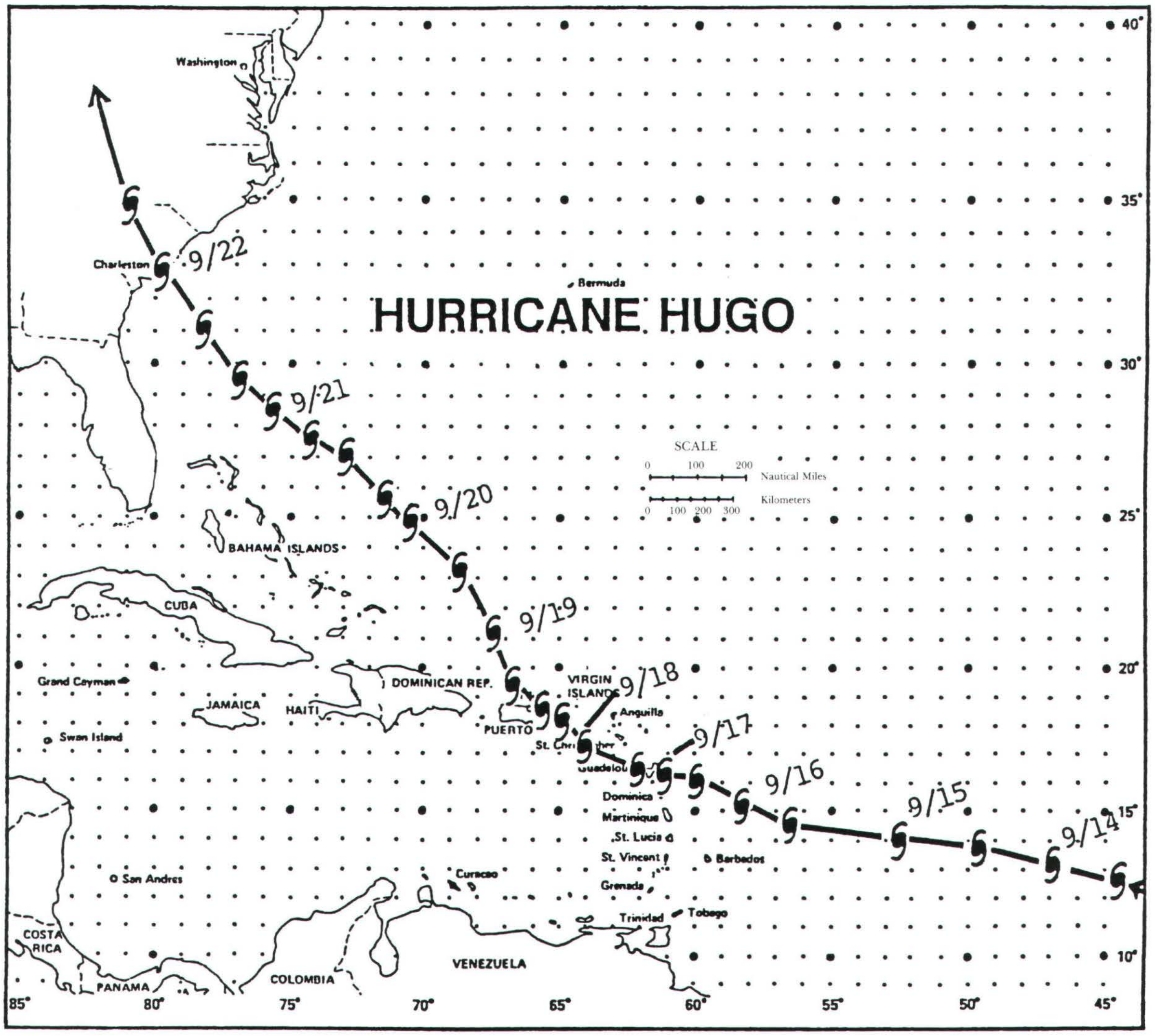
In the past, the occurrence and effects of a major earthquake generally were not predictable. The Loma Prieta earthquake is exceptional because the likelihood of its occurrence had been evaluated well in advance of the earthquake, and the worst damage and destruction occurred in areas known to be at greatest risk. The time duration of strong ground motion generated by the Loma Prieta earthquake was brief, scarcely one-third of the duration of the 1906 earthquake, and was not unusually violent. When similar or stronger earthquakes strike closer to major population centers, the hazard will be significantly greater. Reducing this future earthquake hazard across our Nation depends on how well we learn from our experience and how well we apply these lessons.

JOHN C. TINSLEY III

Sand boils in irrigated fields near Watsonville.



Changes in elevation and horizontal strain measured along the surface of the Earth after the Loma Prieta earthquake show that the Pacific plate moved 6.2 feet to the northwest and 4.3 feet upward over the North American plate. This motion was not observed along a single fault break at the surface but occurred in a complex series of cracks and fractures.



The path of Hugo, September 14–22, 1989.

Hurricane Hugo, September 1989

By R. Erik Schuck-Kolben and Lionel Kaufman

In September 1989, Hurricane Hugo, a very powerful and destructive hurricane having winds in excess of 130 miles per hour (see Saffir-Simpson scale, p. 8), hit the U.S. Virgin Islands, eastern Puerto Rico, and the coast of South Carolina. This hurricane was one of the most destructive storms to hit the Caribbean and the East Coast of the United States in the 20th century. Although rainfall totals associated with this storm were relatively low (4 to 10 inches in the most affected areas), high winds and storm-surge flooding along the coastal areas caused severe damage. The maximum storm surge measured in South Carolina was one of the highest ever recorded anywhere on the East Coast of the United States. At least 50 persons lost their lives as a result of the storm, and storm damage is estimated to be about $10.4 billion.

U.S. Virgin Islands.—Rainfall may have produced localized flooding in the islands, but total rainfall associated with Hurricane Hugo generally was less than 10 inches, which is relatively minor in comparison with rainfall totals commonly associated with hurricanes. Most of the flood damage in the U.S. Virgin Islands occurred in coastal areas as a result of tidal flooding. Storm-tide elevations ranged from about 3 to 11.5 feet on St. Croix and from 4.5 to 6.5 feet on St. Thomas and St. John. USGS personnel located and surveyed elevations of high-water marks throughout the U.S. Virgin Islands, Puerto Rico, and other nearby islands.

Damage from Hurricane Hugo was severe throughout the U.S. Virgin Islands, particularly in St. Croix. Approximately 65 percent of the buildings in St. Croix were destroyed, leaving about 20,000 people homeless. All public utility services were disrupted.

About 90 percent of all power lines on the island were downed by the storm, two of three desalination units were out of service, one 10-million-gallon water storage tank was destroyed and another severely damaged, and the sewage treatment system was out of service. A USGS employee, Bruce Green, living and working in St. Croix, played a key role in establishing emergency water supplies (see box, p. 8).

Damage in the U.S. Virgin Islands from Hurricane Hugo is estimated to total about $2 billion. The official death toll for this storm is 14.

Puerto Rico.—Rainfall associated with Hurricane Hugo exceeded 10 inches in 48 hours near the town of Naguabo in eastern Puerto Rico. Total rainfall, however, was between 4 and 8 inches over much of the east. The amount and intensity of rainfall were substantially less than those associated with other large hurricanes. Inland flooding, however, did occur along some small streams. Storm-tide elevations along the eastern and northern coasts of Puerto Rico ranged between 4 and 10 feet but exceeded 12 feet near San Juan. Coastal flooding occurred in some beach and low-lying areas.

The Luquillo Experimental Forest, also known as the Caribbean National Forest, was severely damaged. The area in and around the forest, where rainfall amounts and intensities were high, was also the site of more than 200 mostly shallow landslides on the steep and highly dissected mountain slopes. Half of the landslides were associated with highway construction and road cuts.

Other damage from the hurricane included the loss of fish and shellfish from lagoons along the coast as a result of drastic changes in water quality associated with the storm. Within several weeks after the hurricane, USGS teams sampled and tested the water quality of Laguna de Piñones, Laguna La Torrecellia, and Laguna San Jose. The most significant changes in water quality were noted in Laguna de Piñones where dissolved solids concentrations, which normally range from 14,000 to 32,000 milligrams per liter, had been reduced to 2,600 milligrams per liter by the freshwater flowing into the lagoon as a result of the heavy rains. Dissolved-oxygen concentrations, which normally exceed 6 milligrams per liter, were less than 3 milligrams per liter, and concentrations of sulfide, normally less than 0.5 milligram per liter, had increased to more than 10 milligrams per liter.

Property damage in Puerto Rico is estimated to be about $2.5 billion. Only two deaths were directly attributed to the hurricane, but six employees of the power authority were killed while repairing downed power lines.

South Carolina.—Rainfall produced by Hugo over the State of South Carolina ranged from a maximum of 10 inches south of Charleston to 2 inches in the upland part of the State; more than 4 inches occurred only in the southern coastal area. Rainfall from Hugo was much less than expected, and no serious flooding of inland rivers occurred. Severe coastal flooding occurred along much of the South Carolina coast. The high-water elevation at the Charleston tide gage peaked at about 10 feet above sea level shortly before 1:00 a.m. on September 22 when the hurricane came ashore. This peak was about 8 feet higher than the normal (predicted) tide stage.

Many mountain roads in eastern Puerto Rico were blocked by the more than 200 landslides that were a result of Hurricane Hugo, which hit the island on September 18, 1989.

MATT LARSEN

SAFFIR-SIMPSON HURRICANE SCALE

Category	Wind speed (in miles per hour)	Storm surge (feet above normal tides)	Evacuation
No. 1	74–94	4.5	No.
No. 2	96–110	6–8	Some shoreline residences and low-lying areas, evacuation required.
No. 3	111–130	9–12	Low-lying residences within several blocks of shoreline, evacuation possibly required.
No. 4	131–155	13–18	Massive evacuation of all residences on low ground within 2 miles of shore.
No. 5	155	18	Massive evacuation of residential areas on low ground within 5–10 miles of shore possibly required.

NATIONAL WEATHER SERVICE, NOAA

Water-surface elevations related to the storm surge were even higher in other areas along the South Carolina coast. Water-surface elevations of 12 to 16 feet above sea level were common in much of the area from Myrtle Beach southward to Sullivans Island east-northeast of Charleston. High-water elevations, based on more than 300 flood marks, were located and surveyed by USGS personnel within a few weeks after the storm.

The maximum water-surface elevations associated with the storm occurred in Bull Bay. The absence of barrier islands and the trapping effect of the bay on waves driven by extremely high onshore winds resulted in peak water-surface elevations of about 20 feet above sea level. Very few storms have ever produced storm surges of this magnitude along the East Coast of the United States (see "Hurricane Hugo and the South Carolina Coast," p. 11).

Damage to property along the South Carolina coast was severe and is estimated to be about $5.9 billion; 29 deaths have been attributed directly or indirectly to the storm.

Hurricane Hugo was one of the most destructive storms to hit the Caribbean and East Coast of the United States during this century. The devastating effects from Hugo underscore the need to continue efforts to study and understand the mechanisms and potential effects of hurricanes and other coastal storms. By being prepared as best as possible for nature's capricious action, we can help to reduce a disaster's toll.

Hurricane Hugo and Puerto Rico

By Rafael W. Rodriguez and Richard M.T. Webb

Coastal resources as diverse as offshore sand deposits, recreational beaches, and coral reefs were affected severely when Hurricane Hugo struck Puerto Rico. The Puerto Rico Marine Geology Program, a cooperative study between the Puerto Rico Department of Natural Resources and the USGS, assessed the impact of the storm and monitored the recovery of these resources in the months following the storm.

Offshore sand deposits are of major importance to Puerto Rico because onshore sources suitable for use in the construction industry and in beach replenishment projects have been depleted. Escollo de Arenas, the largest offshore sand deposit (more than 3 billion cubic feet), was severely degraded by Hugo. The Escollo de Arenas is a trailing edge sand deposit, which lies off the northwest coast of Vieques Island. Soil cores and aerial photography show a loss of between 3.5 and 7 million cubic feet of sand from this deposit. The sand from the Escollo de Arenas

USGS Employee Restores Water Supply to St. Croix Disaster Relief Center

By Sandra L. Holmes

During the late evening and early morning hours of September 17–18, 1989, Hurricane Hugo, a category 4 storm, hit St. Croix in the U.S. Virgin Islands with sustained winds of 140 miles per hour and gusts of 200 miles per hour. Hugo battered St. Croix for 8 hours, damaged 90 percent of all homes and other buildings, destroyed the main power station, and cut off all sources of freshwater supplies to the island.

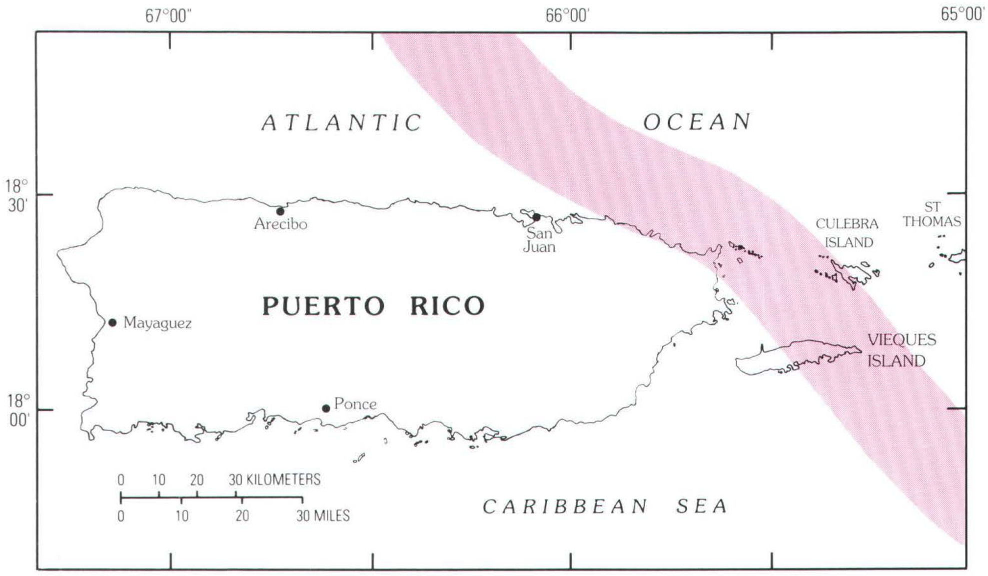
The USGS established a field office in December 1988 on St. Croix to support water-resources activities with the principal local cooperating agency, the Virgin Islands Water and Power Authority (VIWPA). **Bruce K. Green**, a USGS hydrologic technician stationed on St. Croix, had recently completed a project with the VIWPA in support of the siting and development of new public water-supply wells.

Green and his family rode out Hurricane Hugo along with fellow residents. In the aftermath, Green recognized the need for immediate disaster relief, especially the need for potable water for basic sustenance and disease control. Cutting his way with a chain saw to a passable road, he arrived via four-wheel-drive vehicle at the center for emergency relief operations. At the center, Green was asked by personnel of the U.S. Army Corps of Engineers, the lead agency for recovery operations, to serve on the formal Emergency Response Team.

Aided by his knowledge of the quantity and quality of the ground water in the newly developed well fields, Green directed his attention to the problem of water supply. Working through Army supply channels, he obtained miles of PVC pipe and many gasoline-powered generators and pumps.

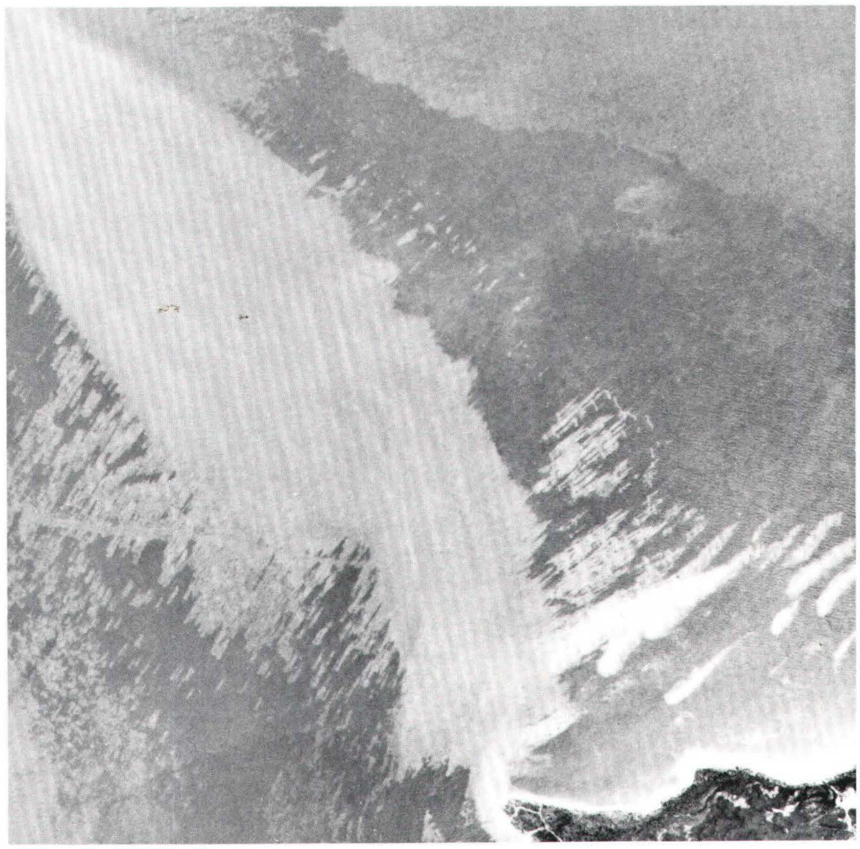
After cutting and clearing the way to the remote well fields, Green directed the construction of a temporary water-supply line to the disaster relief center. These efforts restored at least limited public water supply to island residents long before any other utility was available after the devastating storm. It took 5 months to repair the structure of and reinstall telephone and electrical lines to the U.S. Department of Agriculture building that had housed the USGS field office before the hurricane. During this time, Green operated the USGS field office out of the carport of his home.

For his dauntless courage and unquestioned leadership in an uncertain and potentially life-threatening situation, Green received the Valor Award of the U.S. Department of the Interior.



NOAA

Track of the eye (15.5 miles in diameter) of Hurricane Hugo as it passed over the Island of Puerto Rico.



PUERTO RICO DEPARTMENT OF TRANSPORTATION AND PUBLIC WORKS

A, *Escollo de Arenas before Hugo. Note the well-developed bedforms on the surface of the sand deposit. The area of the sand deposit is approximately 3 square miles.*

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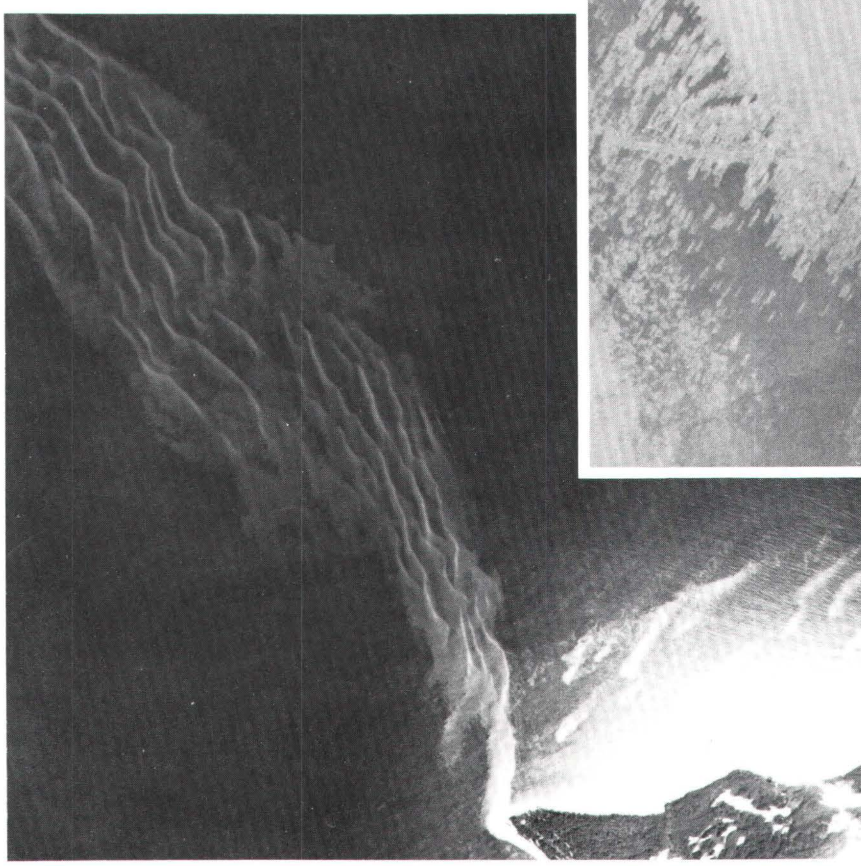

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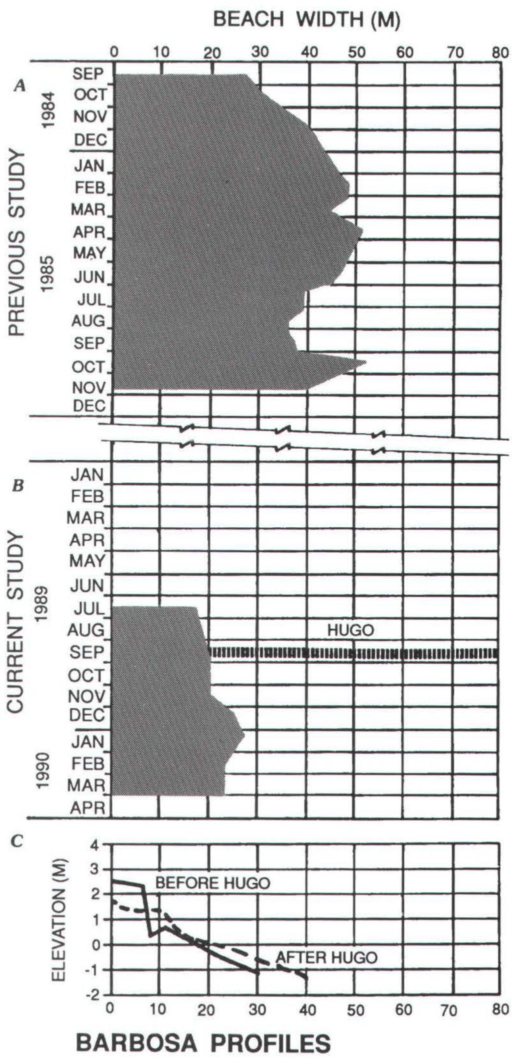
B, *Escollo de Arenas after Hugo. The hurricane leveled the characteristic bedforms on the surface of the deposit and dispersed sand over the adjacent sea floor. Seagrass meadows to the east of the Escollo were buried. The resulting sand apron and large blowout structures increased the area of exposed sand by 60 percent.*

was deposited as a thin 2- to 4-inch-thick blanket on top of a muddy substrate typical of seagrass bed communities and is therefore unlikely to be recovered. In addition, many square miles of this highly productive seagrass meadow were destroyed by the formation of large sediment blowouts. The loss of resources will cost government and industry about $2 million.

The long-term impact of Hurricane Hugo on recreational beaches and their subsequent recovery are critical to the Puerto Rican tourism industry. Although shoreline position remained fairly constant, the margins of the beaches along the eastern and northern coasts of the island were eroded by 10- to 13-foot-high waves. Storm wave damage was magnified by a high tide and a storm surge in San Juan. Beach overwash fans, containing about 17.5 million cubic feet of sand, were deposited behind the dune line in Piñones (east of San Juan). Approximately 90 percent of this



Beach profiles at Barbosa Park in the San Juan metropolitan area, A, before and, B, after Hugo. While the beach width actually increased after the storm, the storm waves flattened the profile and, C, eroded the backshore scarp.

RICHARD M.T. WEBB

Empress Hotel boardwalk located on Punta Piedrita, a headland in the tourist section of San Juan. An extensive boardwalk and bar and pool were built out over the ocean only 4 years ago.

RICHARD M.T. WEBB

Villa Pesquera, Vieques Island. This community fish market was impacted by both high swells and winds of more than 150 miles per hour.

material is unrecoverable. At other sites, material lost from the beach margins was deposited in the nearshore zone.

Preliminary reconnaissance surveys show that about 10 percent of the stands of the shallow-water elkhorn coral in Vieques Passage were degraded considerably by Hugo. However, many deeper water coral colonies showed no visible impact. Hurricane Hugo left many Puerto Rican beaches, their valuable resources of sand, and their economic value as recreation sites more vulnerable to damage from future tropical storms.

Hurricane Hugo and the South Carolina Coast

By John W. Haines

Sullivans Island and Isle of Palms, two of the most heavily developed islands in the South Carolina coastal area, were positioned to receive the major impact of Hurricane Hugo. The storm made landfall in South Carolina early on the morning of September 22, 1989. Historically, Sullivans Island and Isle of Palms have been remarkably stable coastal areas. By comparing the positions of past shorelines, coastal researchers can show that Sullivans Island and the southern two-thirds of Isle of Palms have grown slowly seaward during the last 50 years. The effort of USGS coastal studies in the wake of Hurricane Hugo is focused on how the coastal effects of the storm relate to these long-term trends.

One of the special challenges of coastal research is that estimates of coastal erosion typically bracket periods of tens of years. Present shoreline positions are compared with past positions to determine the rate of coastal retreat or growth. These erosion estimates may or may not include the effects of a number of major storms, depending on how frequently an area has been affected by hurricanes or other coastal storms. Thus, best estimates of coastal land loss may mask the importance of these extreme, yet short-lived events. Coastal erosion in a particular area, therefore, may be due primarily to a few major storms, or it may reflect less extreme but more persistent processes. In addition, coastal response to hurricanes may depend on the presence of dunes and the width of the beach.

To gain a visual perspective on the coastal effects of Hurricane Hugo, the USGS and the National Ocean Survey made overflights of the South Carolina coast during the week of October 2, 1989. While aerial photography provides a means of rapidly accumulating data covering a wide area, the information is limited to a few well-defined subaerial features, such as water, land, and vegetation boundaries. The poststorm shoreline was mapped from the new aerial photography for comparison with available prestorm shoreline data.

Beach and nearshore profiles were surveyed by the USGS from October 5–10, 1989, on Sullivans Island and Isle of Palms to provide a second source of needed data. This

JOHN W. HAINES

Severe dune scarping on Folly Island, S.C., after Hurricane Hugo.

JEFF LIST

Bull Island, an undeveloped area north of the Isle of Palms, S.C., after the hurricane.

effort resurveyed profiles previously obtained during a shoreline monitoring program initiated by the South Carolina Coastal Council. While such nearshore profiling provides only a local picture of coastal effects and is a slow data-collection process, it does show what has happened to the shore beneath the waterline and is critical in evaluating the redistribution of sediment.

Study of the profile data for Sullivans Island confirmed that sediment was removed from dunes and the subaerial beach and that there was an associated accumulation of material in the nearshore area. The profiles, which show only minor changes in the position of the shoreline, are consistent with the shorelines derived from the aerial photography. Because of this relatively small change in the shoreline position, USGS researchers suggest that shoreline position alone may not be a representative measure of the impact of a major storm. While aerial photography shows only shoreline position and indicates a negligible response to the storm, the profile data clearly show substantial movement of sediment and modification of the beach-dune system.

The coastal effects of Hurricane Hugo pose some interesting questions. Clearly large amounts of sand have been shifted offshore, but only when the ultimate fate of this sand is known will the long-term impact of Hugo be understood. If this sand is returned to the beach, the coastal system will have undergone little permanent change. Should the sand be transported further offshore, then, retrospectively, Hugo will be considered a major erosive event.

The role of dunes in the coastal response to storms also remains unclear. While protecting inland structures, dunes may concentrate wave energy and enhance the offshore movement of sand. Here again, the ultimate fate of this sand is critical to understand long-term effects. Also, because many of the dune fields were removed during Hurricane Hugo, the response of the beach to subsequent storms may be greatly modified.

Continued research is needed to determine the impact of hurricanes and other major storms on various coastal systems and the long-term impacts on coastal erosion and wetland environments. The infrequent and unpredictable nature of hurricanes pose special problems for the coastal geologist. A critical component in coastal studies will continue to be the availability of reliable prestorm data that provide a critical baseline for further research. The results from the studies of Hurricane Hugo will further efforts to understand and define the response of coastal systems to such devastating and unpredictable events of nature.

Redoubt Volcano, Alaska

By Thomas P. Miller

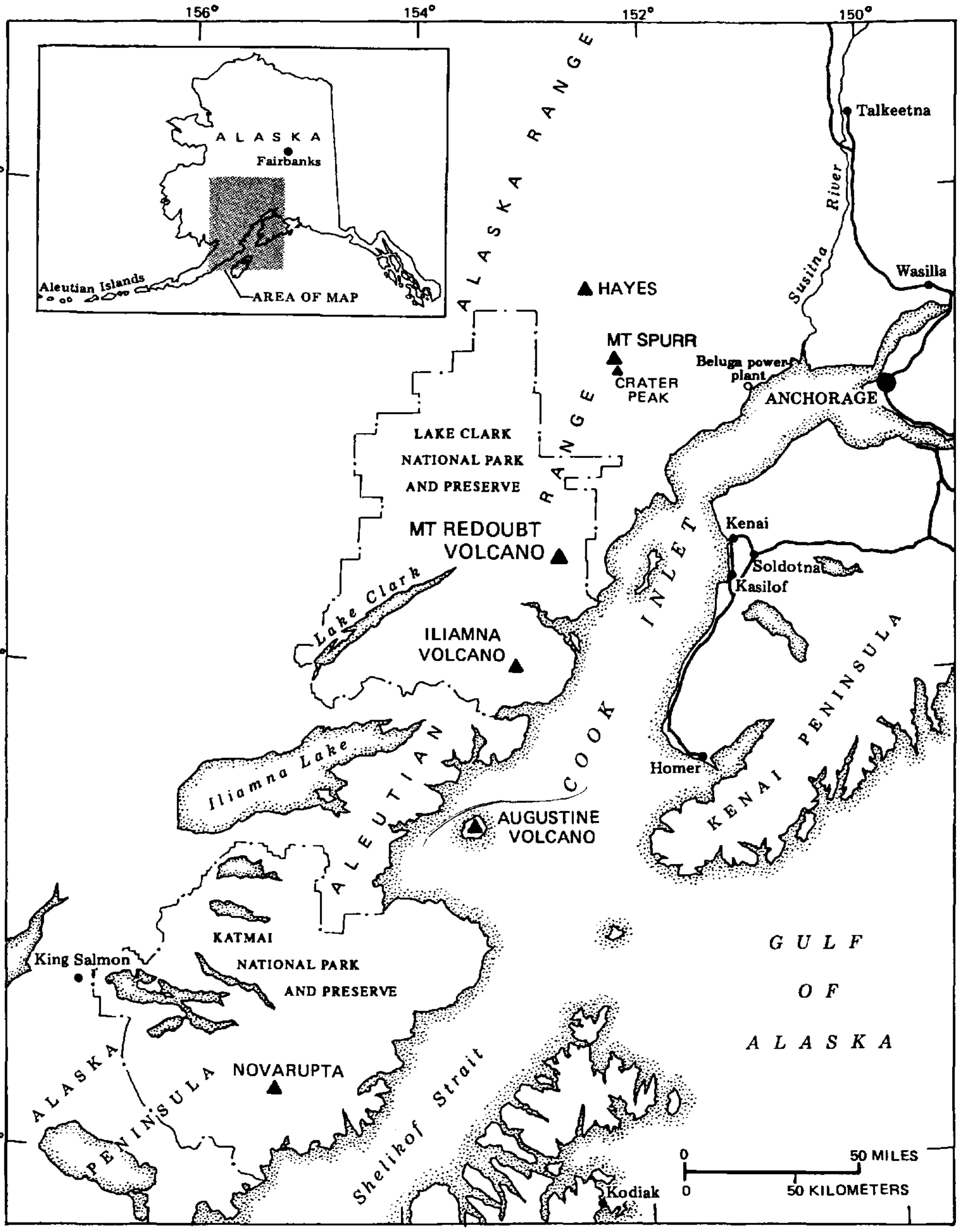
Mount Redoubt, an ice-mantled, 10,197-foot-high stratovolcano located on the west side of Cook Inlet in Alaska, began its third major eruption this century with an explosive summit event at 10:14 a.m. AST, December 14, 1989, and recorded its last major explosive event on April 21, 1990. Although the volcano is located in remote Lake Clark National Park, 115 miles southwest of Anchorage, the eruption caused $50 to $100 million in damages—the second most costly eruption in North American history.

The Alaska Volcano Observatory (AVO) monitored the eruption throughout its duration. The AVO is a cooperative effort that includes scientists from the USGS, the Geophysical Institute of the University of Alaska, and the Alaska Division of Geological and Geophysical Surveys. The AVO was established in 1988 to study and monitor Alaskan volcanoes and to provide volcanic hazard information to the public and private sectors. The principal AVO offices consist of a crisis center at the USGS office in Anchorage and a seismic interpretation center at the Geophysical Institute in Fairbanks.

Personnel at both centers continuously monitored the volcano during the eruption and reported eruption information through a series of daily, and sometimes hourly, eruption updates. Tape-recorded messages available to the media and airlines were updated on a daily and situation basis. More than 30 scientists from other USGS centers, principally the Cascades Volcano Observatory, aided the Alaska-based personnel. A call-down procedure, part of a preexisting crisis response plan, was used extensively to alert airports, civil authorities, and the public through the news media.

The existing seismic network around the volcano allowed AVO scientists to predict several major eruptive events, to inform appropriate agencies, the public, and the media when all major eruptions occurred, and to give estimates of relative eruption intensity. Overflights and helicopter-supported field studies provided critical information on the status and effects of the eruption. In spite of the bad weather and remoteness of the volcano, scientists successfully observed the volcano on more than 50 percent of the short winter days.

Experimental seismic instruments recorded the occurrence and advance of mudflows and floods. A lightning detection



Location of Mount Redoubt in Lake Clark National Park, Cook Inlet, Alaska.

system, emplaced around the volcano, confirmed the existence of ash versus steam in the eruption plumes—a matter of great significance to the airline industry. Data on hypothetical ash plume trajectories, plotted on the basis of wind data supplied by the National Weather Service, were released on a daily basis. Gas from the eruption plume was sampled to detect increases of sulfur dioxide that could be a precursor of an impending eruption. Sampling was conducted by using fixed-wing aircraft beginning in March.

The AVO developed a color coded classification system to more concisely describe the level of concern about possible eruptive activity at Redoubt volcano. The readiness and activity associated with each of the four color codes are

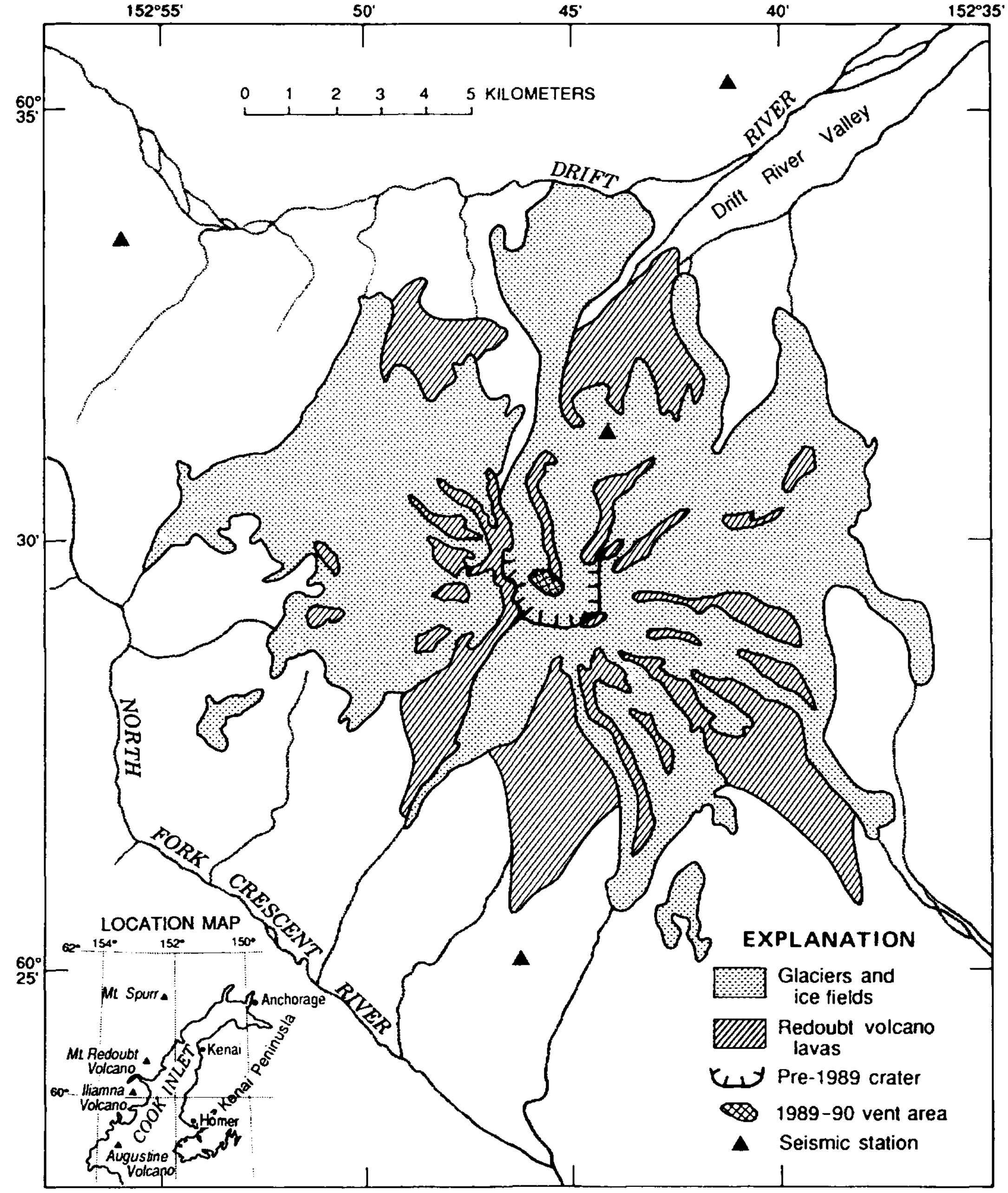
Green: Volcano is in its normal dormant state.

Yellow: Volcano is restless. Earthquake activity is elevated, and a plume of gas and steam may be rising several thousand feet above the crater. Activity may include extrusion of lava and emplacement of a lava dome.

Orange: Small ash eruptions expected or confirmed. Plume(s) not likely to rise to more than 25,000 feet above sea level. Minor flooding on the Drift River possible. Seismic disturbance recorded at Redoubt seismic stations but not recorded at more distant stations.

Red: Large ash eruptions expected or confirmed. Plume likely to rise to more than 25,000 feet above sea level. Significant flooding in Drift River possible; flooding in the Crescent River is also possible but less likely. Strong seismic signal recorded at all Redoubt stations and, commonly, at more distant stations.

Generalized map of Mount Redoubt volcano showing location of seismic stations monitored by the Alaska Volcano Observatory.



Mid-December 1989.—Warnings of a potential eruption were issued by the AVO about 20 hours before the initial explosive event of December 14, 1989. The eruptive activity of December 14 to 19 consisted of numerous vent-clearing and explosive events from the ice-filled summit crater. The largest events occurred on December 15 and sent eruption columns (initial ejection of hot gases) to heights greater than 39,000 feet. Flooding in the Drift River, which drains the north side of the volcano, threatened but only slightly damaged the Drift River Oil Terminal (DROT), a large oil-storage facility (10 million barrels capacity), located 25 miles downstream from the volcano at the mouth of the river.

Airborne ash generated by the numerous explosive events, particularly those of December 15, was carried east and north toward the parts of the Cook Inlet region where approximately 300,000 people reside. Air traffic was severely disrupted by the cancellation of hundreds of flights. A 747 jet airliner, carrying 248 passengers and crew, lost all four engines after encountering an ash cloud 198 miles northeast of Anchorage. Fortunately, the engines were restarted and a crash was averted. Incidents such as this illustrate the extreme importance of volcanic eruption prediction and monitoring.

December 1989 to January 1990.—Growth of a lava dome began on December 22, 1989, in the Redoubt summit area. The large (approximately 1 billion cubic feet), unstable, and oversteepened dome that eventually formed was destroyed by two explosive events on the evening of January 2, 1990. Voluminous flows of fragmented rocks and hot mud caused extensive melting of glacier ice, and mudflows and floodwaters from melted glaciers filled the 1-mile-wide Drift River valley and carried hot dome rocks 16 feet or more in diameter to the ocean. DROT buildings (which had been evacuated 2 hours earlier following an eruption prediction by the AVO) were flooded, but protective dikes around oil-storage tanks were not broken. On January 12, 1990, USGS Director Dallas Peck informed Alaska Governor Steve Cowper of USGS findings on the current and future eruptive hazards of Redoubt volcano.

February to April 1990.—A new, smaller lava dome began to form in the summit area in late January and was subsequently destroyed in an eruption on February 15. Deposits of an ensuing debris flow—rocks, hot ash, and ice—were less extensive than those of the January 2 eruption. Floodwaters overtopped the protective dike around one DROT tank, but no damage occurred. Following the February 15 eruption, 11 domes were emplaced and destroyed during events in February, March, and April. Although these events had little direct effect on DROT, ongoing concern as to the risks of storing oil at the facility resulted in a shutdown in late March and the suspension of oil production in Cook Inlet. Airborne ash continued to impact air traffic and commerce throughout the region, but AVO plume-tracking procedures and close communication with the airline industry kept disruption to a minimum.

As of this writing, Redoubt volcano has not had a major explosive event since April 1990, but further activity is possible. The most recent prior eruptive period, which began in 1966, continued for 3 years. Continued monitoring and close observation will be needed in the coming years until Redoubt volcano has clearly returned to dormancy. AVO scientists have substantially increased monitoring capabilities by enhancing the seismic network and the lightning detection system, by increasing knowledge of the eruptions and products of Redoubt volcano, and by deploying a satellite-based Global Positioning System that may detect the volcanic edifice inflating as molten material rises in the volcano. Changes in Drift River hydrology and drainage were closely monitored, and considerable research was conducted on the large debris flows of January 2 and February 15. Many of the lessons we have learned at Redoubt about debris flows, windborne ash, and other hazards will have wide application at similar volcanoes in Alaska and around the world.

Kilauea Volcano, Hawaii

By Thomas L. Wright

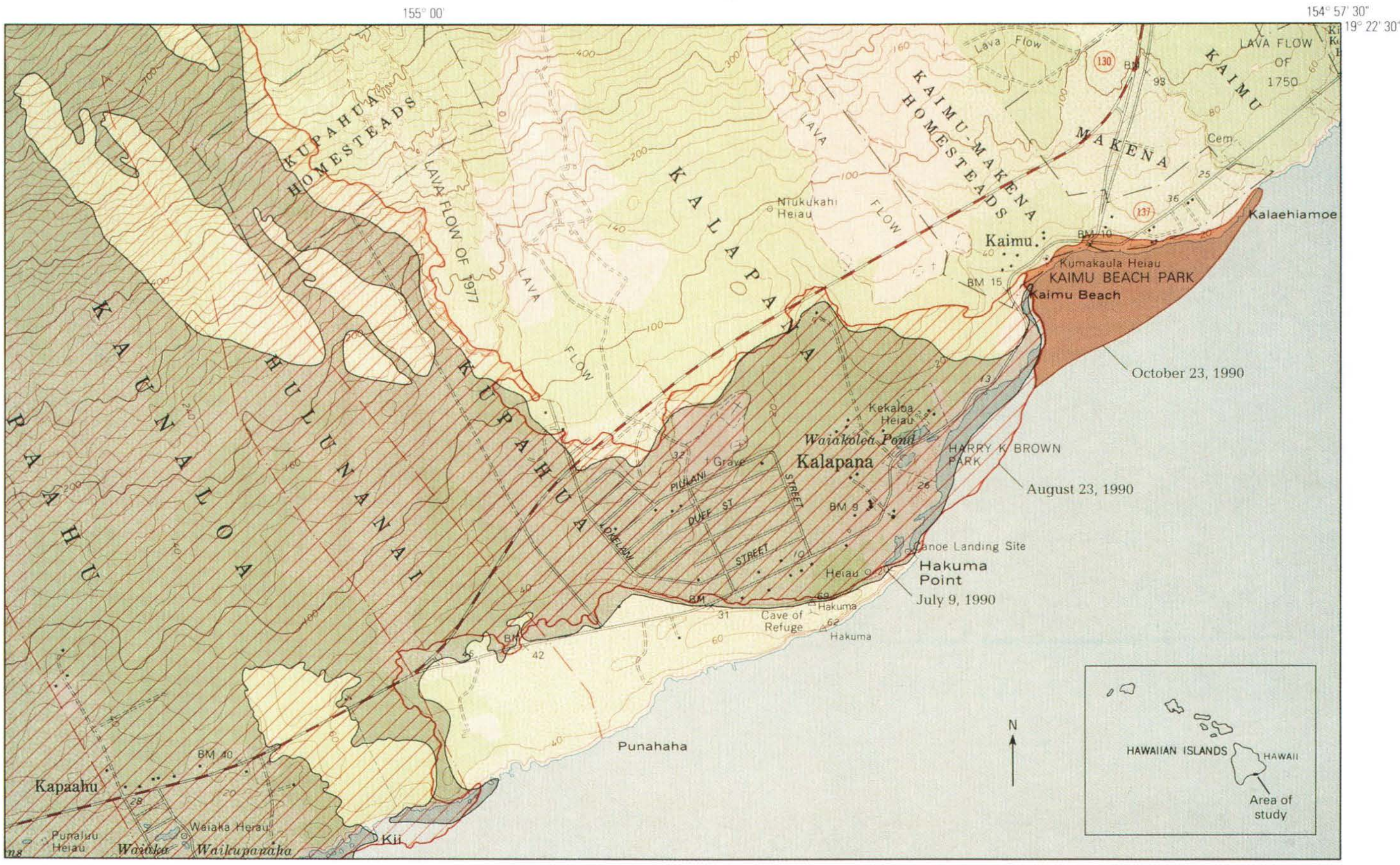
The longest-lived eruption of the east rift zone of Kilauea volcano in this century began in January 1983 and has continued through 1990. In February 1990, lava flows threatened developed property on the east side of the eruption field for the first time since December 1986. By April, lava had entered the Kalapana Gardens Subdivision. By the end of July, all of Kalapana was covered by lava, and flows were moving toward the well-known black sand beach of Kaimu. Between February and June 1990, 168 homes and 7 commercial and recreational structures were destroyed.

April 1990.—Personnel from the USGS Hawaiian Volcano Observatory (HVO) worked around the clock to advise the Hawaii County Civil Defense Agency (HCCDA) on the advance of the lava. This information became the basis for HCCDA decisions to close roads and evacuate residents. The USGS gave the HCCDA daily worst-case prognoses of where lava flows might move overnight, in 24 hours, and in 48 hours. The close USGS–HCCDA coordination continued, and by August more than 100 homes had been evacuated safely.

The success of this crisis management is due to the action taken by the HCCDA, which coordinated all of the numerous State and County agencies, such as the police department, fire department, Department of State Highways, and Department of Land and Natural Resources, in providing for orderly evacuation. Thus the USGS information was delivered to a single source and disseminated consistently to all persons needing the information.

The activity of Kilauea during February to April 1990 has led to a greater appreciation of hazard evaluation on the active volcanoes of Hawaii. The timely publication of the USGS general interest booklet *Volcanic and Seismic Hazards on the Island of Hawaii* put the current eruptive activity in a broader context.

May 1990.—The State of Hawaii requested Federal disaster assistance, and the Federal Emergency Management Agency (FEMA) came to Hawaii to evaluate the request. HVO personnel briefed FEMA on the nature of the eruption and associated seismic activity. On the basis of the FEMA investigation, President Bush signed a precedent-setting disaster declaration on May 22. This declaration was unusual because it was retroactive to the beginning of the eruption in 1983 and it was open ended to include areas that the HVO predicted could be affected over the next few months. FEMA, after



Topographic map showing the extent of Kilauea lava flows as of July 9 (light shaded area), August 23 (lined pattern), and October 23, 1990 (dark shaded area).

consultation with the HVO, also included damage claims related to a magnitude 6.1 earthquake that occurred on the south flank of Kilauea in June 1989. They agreed in principle to cover claims for lava damage extending beyond the area anticipated in May and to cover damage from future Kilauea south flank earthquakes associated with the ongoing eruption.

Easy access to the flows in Kalapana allowed the study of lava tube development and the varied processes of lava emplacement. Monitoring the inflation and the activity of different lava tubes within the developed area led to more accurate hazard evaluation than could be done without detailed knowledge of the mechanics of the lava emplacement. The eruptive activity at the vent was interrupted repeatedly by 2- to 3-day pauses during which lava tubes drained and partially collapsed. Because the collapsed tubes could not convey renewed flow, breakouts of lava occurred and adjacent land was enveloped. This activity formed the eastward-moving glacier of lava that overwhelmed Kalapana, and, by the end of 1990, lava had filled Kaimu Bay.

Where lava entered the ocean, a new threat was produced; a hydrochloric acid mist (dubbed "laze," for lava haze, by the HCCDA), formed where the lava boiled seawater. Fortunately, expansion of the lava field at the ocean was consistently into the prevailing northeast trade winds so that laze was carried away from residences, and evacuation due to laze itself was infrequent. Because laze is a greater hazard when wind conditions are reversed, the USGS helped HCCDA prepare a pamphlet informing residents of the hazards inherent in being exposed to laze.

The experience gained during the Kalapana disaster is being used to plan for future eruptions in which risk will be greater because of greater population density in closer proximity to a rift zone, such as the lower east rift zone of Kilauea or in one subdivision adjacent to the southwest rift zone of Mauna Loa, or because of larger eruptions and faster flows that travel rapidly down steep slopes, such as on Mauna Loa's southwest rift zone. The USGS is currently seeking to broaden its cooperative efforts to address these far greater potential hazards.

Aerial photograph showing the extent of Kilauea lava flows as of August 20, 1990.

Alaska Disasters—Natural and Manmade

By Mark B. Shasby

The latest scientific data and computer-aided mapping technology helped to mitigate the effects of two large-scale environmental events in Alaska: the Exxon Valdez oil spill and the eruption of Mount Redoubt volcano. The Exxon Valdez oil spill, a manmade environmental disaster, occurred March 24, 1989, in Prince William Sound and is the largest offshore oil spill in North American history; cleanup efforts will continue into 1991. The December 14, 1989, eruption of Redoubt volcano produced ash clouds that disrupted air traffic and darkened the skies intermittently for 5 months. Flooding on the Drift River caused by snow and ice melt from the volcanic activity resulted in the closing of the Drift River Oil Terminal, which is the storage and shipping center for oil wells in Cook Inlet.

December 1989 eruption of Mount Redoubt volcano, Cook Inlet, Alaska.

ALASKA VOLCANO OBSERVATORY

In response to the Exxon Valdez oil spill in Prince William Sound, a joint Federal-State Board of Trustees, formed from land management agencies, was established under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980. The Board established an Exxon Valdez Oil Spill Damage Assessment Team, which was assigned responsibility for all operations related to the disaster assessment effort. One of the first acts of the team was to establish a Geographic Information and Mapping Technical Group, comprising Federal and State land and resource management agencies as well as the USGS Alaska Field Office in Anchorage.

Initially, the group prepared a series of maps that depicted four types of information relevant to the oil spill: (1) shoreline sensitivity information from the NOAA Environmental Sensitivity Index Map Series, (2) oil-impact data from the Alaska Department of Conservation, (3) land ownership information, and (4) coastline information derived from 1:63,360-scale USGS maps.

The USGS served as the host site for data base compilation, integration, analysis, and design and production of maps for the damage assessment team. Through the efforts of the USGS and its cooperators, a single integrated map was produced for each of the 180 1:63,360-scale quadrangles covering the 1,500 miles of shoreline affected by the oil spill. Long-term data-base management was assumed by the Alaska Department of Natural Resources. The USGS has retained the original data as backup and for use by other agencies that continue to assess and monitor cleanup activities.

During the eruption of Redoubt volcano, digital data from a NOAA weather satellite were used to monitor the distribution of ash in the atmosphere. This information was combined with coastline and elevation information to help scientists monitor the activities of the volcano (see "Redoubt Volcano, Alaska," p. 12).

Both the Exxon Valdez oil spill and the Redoubt volcano eruption underscore the value of sound earth science information and scientific cooperation in coping with natural and manmade disasters.

Water Quality—Addressing a National Need

A Perspective for the 1990's

By David A. Rickert

The protection and enhancement of the quality of the Nation's surface and ground water are high-priority concerns of the public and government. Since 1970, Congress has passed several acts that created regulatory programs aimed at curtailing the entry of point-source pollution into our waters. These programs have the interrelated, basic goals of maintaining or enhancing the quality of surface and ground water and protecting aquatic resources and human health.

Twenty years ago the major water-quality concerns were low dissolved oxygen content and accelerated eutrophication of specific rivers, lakes, and estuaries. Accordingly, considerable time and money were spent to reduce oxygen-demanding wastes and plant nutrients from municipal and industrial point sources. These expenditures have abated the worst of gross point-source pollution, but more subtle, complex problems have become evident. During the 1980's, the effects of acid precipitation, a nonpoint source, were observed, investigated, and politically debated.

The Nation faces a new water-quality challenge in the 1990's—how to reduce contamination from potentially toxic trace elements and manmade trace organic substances that enter surface and ground water largely from nonpoint sources, such as urban storm drainage and agricultural and forestry practices.

Water-Quality Information

The Water Quality Act of 1987 reauthorized and amended the Clean Water Act of 1977 and switched the focus of new water-quality regulations in the United States from point to nonpoint sources. The U.S. Environmental Protection Agency administers the Water Quality Act. Section 316 of the Act requires each State to develop and implement a plan to identify and limit pollution from nonpoint sources. In addition, in 1989, President Bush announced a major multiagency water-quality initiative, administered by the U.S. Department of Agriculture, to prevent and ameliorate contamination from agricultural sources.

To successfully respond to the Water Quality Act and the President's Water-Quality Initiative, government agencies and the private sector must address complex, technical questions. Questions of policy also must be addressed. Are national water-quality goals being met? How should funds be allocated to solve important water-quality problems? How should monitoring networks differ in different areas and hydrologic settings of the country? Can regulations and best management practices be targeted to particular geographic regions of hydrologic settings? Information on the relations among land use practices, relative sources of pollution, and water-quality effects is the key to answering first the technical and then the policy questions. And, to be most useful, this information must be made available at various scales—local, regional, and national.

The USGS and Water Quality

As a nonregulatory agency, the U.S. Geological Survey (USGS) of the U.S. Department of the Interior provides objective, interpretive information on the quantity, movement, and quality of surface and ground water. The new (1990) National Water-Quality Assessment (NAWQA) program will provide nationally consistent information on the Nation's water quality that can be used by Congress and resource-management agencies to address the water-quality issues of the 1990's. The NAWQA program is a capstone to the total USGS water-quality effort.

The NAWQA program builds on and expands the output from all existing water-quality programs. The overall USGS water-quality effort, including NAWQA, is

- National in scope,
- Inclusive of detailed, in-depth studies of local areas,
- Highly interpretive,
- Based on a continually updated understanding of fundamental chemical and biological processes,
- Perennial, and
- Closely linked to present and changing information needs of Congress and regulatory agencies.

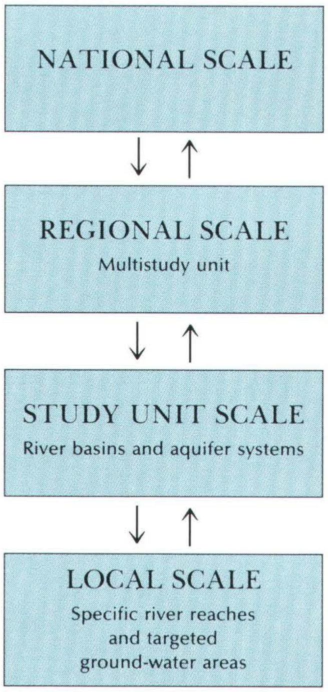
IMPORTANT WATER-QUALITY QUESTIONS

Status of Water Quality

- On the basis of occurrence in surface and ground water, what substances need further studies on toxicity and risk assessment and, therefore, consideration for regulation?
- What are the relative magnitudes of point- and nonpoint-source contributions to different types of surface- and ground-water contamination?
- What is the relation between pesticide application rates, soils, and hydrogeologic factors and the occurrence of pesticides in surface and ground water nationwide?
- What are the effects of nonpoint-source contamination on the biological condition of streams and rivers nationwide?

Trends in Water Quality

- How have nitrogen and phosphorus levels in surface and ground water changed with time in response to changes in various sources?
- How have best management practices affected surface-water and ground-water quality in agricultural areas?
- How have best management practices affected surface-water and ground-water quality in forestry areas?



Areal scales of water-quality studies.

The total water-quality effort of the USGS includes research, monitoring, and assessment, which together provide an understanding of water-quality problems and are the basis for evaluating resource-management decisions.

- Research.—To provide an understanding of fundamental physical, chemical, and biological processes and rates.
- Monitoring.—To continually measure water-quality conditions over space and time by using networks that are fixed station and fixed in time.
- Assessment.—To define the status and trends of water quality and the causes of observed conditions and trends by building on research and monitoring.

Research

Water-quality research in the USGS is primarily conducted under the water resources National Research Program and the Toxic Substances Hydrology program.

National Research Program (NRP).—Improves the understanding of the nature and rates of physical, chemical, and biological processes that affect the movement of water and chemical constituents through hydrologic systems so that appropriate methods can be developed to predict the effects of natural and man-induced stresses. The NRP is functionally divided into six research disciplines: surface-water hydrology, ground-water hydrology, surface-water chemistry, ground-water chemistry, geomorphology and sediment transport, and ecology.

Toxic Substances Hydrology Program.—Provides increased understanding of the occurrence, movement, and fate of hazardous substances in the Nation's surface and ground water. Program efforts consist of small-scale field studies of point-source contamination that has resulted in waste plumes in ground water and degraded stream reaches and regional-scale field studies of the occurrence and movement of toxic substances and the controlling of natural and human factors.

Monitoring

The USGS operates the only two national monitoring networks that measure surface-water quality, the Hydrologic Benchmark Network and the National Stream Quality Accounting Network.

Hydrologic Benchmark Network (HBN).—Consists of 58 sites for water quantity and quality data collection in relatively small, pristine watersheds. The HBN identifies long-term water-quality trends over time in areas unaffected by in-basin activities and provides a baseline with which to compare basins directly impacted by man. The HBN consists of fixed stations having fixed sampling schedules, consistent methods for collecting samples, and a consistent schedule for analysis of field parameters, major ions, nutrients, trace elements, and coliform bacteria (no trace organics are measured). The HBN provides a commitment to long-term data collection, analysis, and interpretation.

National Stream Quality Accounting Network (NASQAN).—Consists of 411 active stations where outflows from most of the major rivers of the country, both to other rivers and to the oceans, are measured. NASQAN identifies long-term water-quality trends in the major rivers of the country, relates the trends to upstream land and water use, and accounts for transport (fluxes) of measured constituents off the continent and to critical estuaries and the Great Lakes.

In addition to HBN and NASQAN, the USGS coordinates and operates part of the Federal National Trends Network for acid precipitation, from which weekly samples of wet deposition are collected and analyzed from 150 network sites nationwide.

Assessment

While research and monitoring are well-established approaches that provide an understanding of environmental processes and conditions, these approaches do not provide the depth and breadth of information necessary to address important technical and policy questions at a national scale. Research is exhaustively detailed, usually areally limited, and open ended over time. In contrast, monitoring can provide broad areal coverage and continuing observations over time, but it does not provide insight into explanations or causes. Assessment fills the critical void between research and monitoring, building on knowledge of processes to explain observations by identifying factors and defining cause and effect.

To date, most water-quality assessment has been conducted through the USGS Federal-State Cooperative Program. This program, established in 1895, manages agreements wherein State and local agencies provide at least one-half of the funding for USGS investigations on statewide and local resource issues. As such, the program provides a commitment for funding and allows flexibility in monitoring and assessing those issues of greatest local and national concern.

In 1990, the USGS has agreements with nearly 1,000 agencies. Many of the current investigations include assessing water-quality conditions in a particular river reach or part of an aquifer. These studies include extensive data acquisition that form the core of State monitoring programs, interpretation of new and existing data, and computer modeling of hydrologic systems to understand the probable consequences of various management actions. In many States, the cooperative program has provided extensive long-term data bases that are extremely valuable for regional and national assessments.

Water-quality assessments have been conducted by many agencies, academia, and the private sector in the United States for about 100 years. Most previous water-quality assessments, however, have addressed local problems, and all have been limited in scope and scale. A national, perennial water-quality assessment has never been attempted and, in this absence, important national-in-scope technical and policy questions are left unanswered.

Challenges of a National Water-Quality Assessment

Assessing the Nation's water quality is formidable. The land area to be assessed is vast, water quality varies over space and time, water-quality problems are numerous, and field work and laboratory analyses, especially those for trace organic chemicals, are expensive.

The dual challenge of managing a large area and water-quality variability can be lessened because many national issues are actually repetitive problems from different climatic or geohydrologic environments that represent specific regions of the country. For example, most questions relevant to national policy on the occurrence of pesticides can be answered by studying a few types of crops, each treated with a typical array of applied pesticides, in a few climatic or geohydrologic regions. Those questions left unanswered by these small-scale studies can then be addressed by combining information to cross regional boundaries to the national scale.

Most field research occurs at the local (river reach or ground-water contaminant plume) scale. In contrast, most water-quality monitoring occurs at the statewide (study unit to regional) or national scales. To date, water-quality assessments generally have been conducted at the local scale. The water-quality program of the USGS is unique because it fully integrates research, monitoring, and assessment and is conducted at all scales.

Information derived from the other scales can be integrated at the national level only if certain factors are consistent within a national framework. These factors are (1) common study approaches, (2) common protocols for field and laboratory analysis, including descriptions of sampling sites, (3) consistent records of ancillary information, (4) data storage in national files, and (5) a nationally consistent set of water-quality constituents. Certain water-quality constituents and issues are of concern only in certain areas of the country; therefore, the USGS has stipulated a national set of constituents that can be added to or reduced, as appropriate, at the other scales. At each areal scale, the NAWQA program will result in different information products: statistical descriptions, geographic descriptions, and explanations of observed conditions.

Why the USGS?

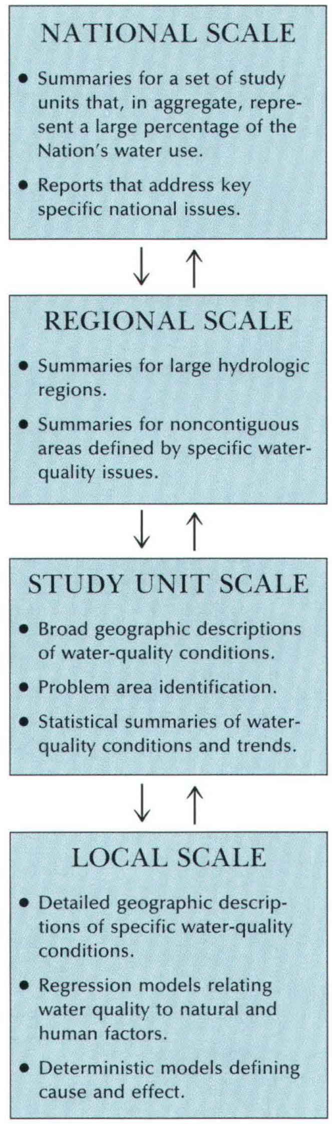
The USGS is ideally suited to conduct a national, perennial water-quality assessment because it has

- Experience in managing national water-quality networks,
- A national water-resources research program, a large portion of which is focused on the chemical, biological, and morphological fundamentals of water quality,
- An existing national water-quality program that measures the quantity and flow of surface and ground water and provides the hydrologic basis needed to conduct chemical and biological studies,
- A nationally distributed field staff trained to collect and interpret chemical and biological data (see map, p. 22),
- In-depth experience in surface-water, ground-water, and linked surface- and ground-water studies,
- Experience in water-quality assessments at the local and statewide scales,
- No regulatory jurisdiction, and
- Experience working across political boundaries on multi-State river basins and aquifers.

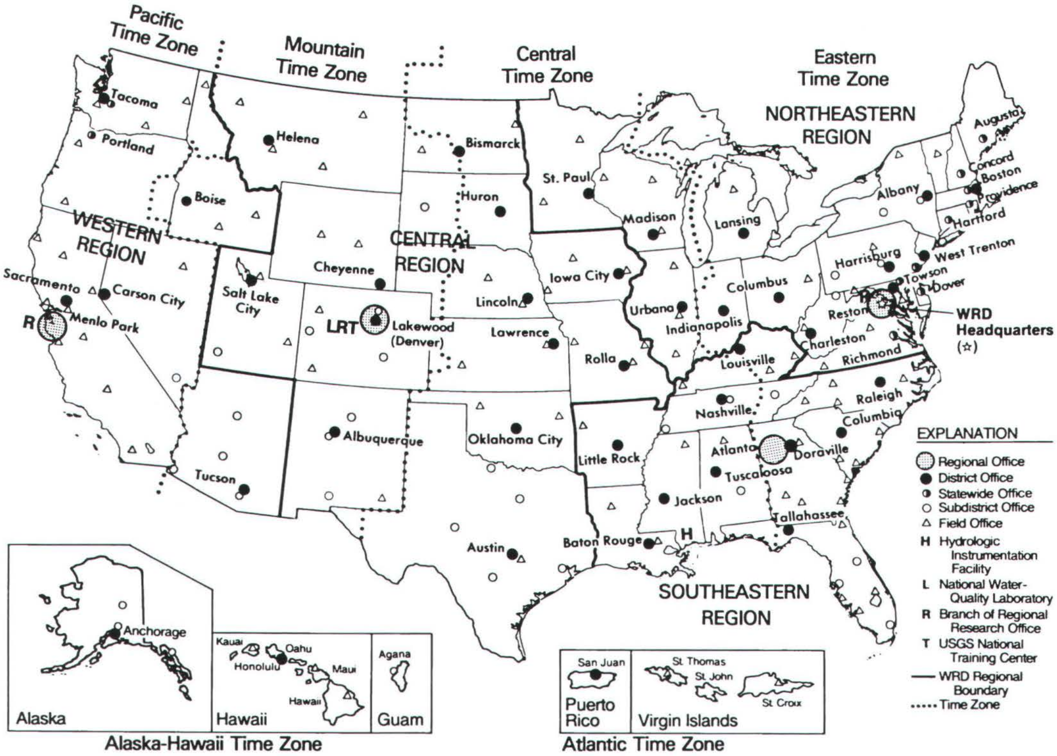
NAWQA Program Design

The NAWQA program will provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources, define long-term trends (or lack of trends) in water quality, and identify, describe, and explain the major factors that affect observed water-quality conditions and trends. In some cases, the program also will enable hydrologists to define specific cause and effect relations.

NAWQA combines the surface-water and ground-water investigations of 60 areas around the country that incorporate about 60 percent of the Nation's population and water use (see map, p. 23). Study units range in size from a few thousand to several tens of thousands of square miles. By conducting the national program as an aggregation of individual studies, NAWQA results will be useful in understanding and managing important river basins and aquifers, as well as in



Primary products for each areal scale of the National Water-Quality Assessment program.



Offices of the USGS Water Resources Division.

answering national-scale questions. This approach also readily permits detailed investigations of specific river reaches and small parts of aquifers.

Because of the emphasis in NAWQA on defining trends in water quality, the program is designed to be perennial. Assessments in each of the study units, however, are conducted on a rotational rather than a continuous basis. A subset of only 20 study units is studied in detail at a given time. For each study unit, 3- to 4-year periods of intensive data collection and analysis are alternated with 6-year periods during which the assessment activities are less intensive.

NAWQA focuses on water-quality conditions that affect large areas and are persistent in time, that is, on water-quality problems that result from nonpoint sources or from an aggregation of point sources. All major types of water-quality problems, ranging from classical sanitary issues, such as dissolved oxygen and bacteria through sediment and nutrients, to a major emphasis on toxic substances, including trace elements, pesticides, and industrial organics, are being investigated.

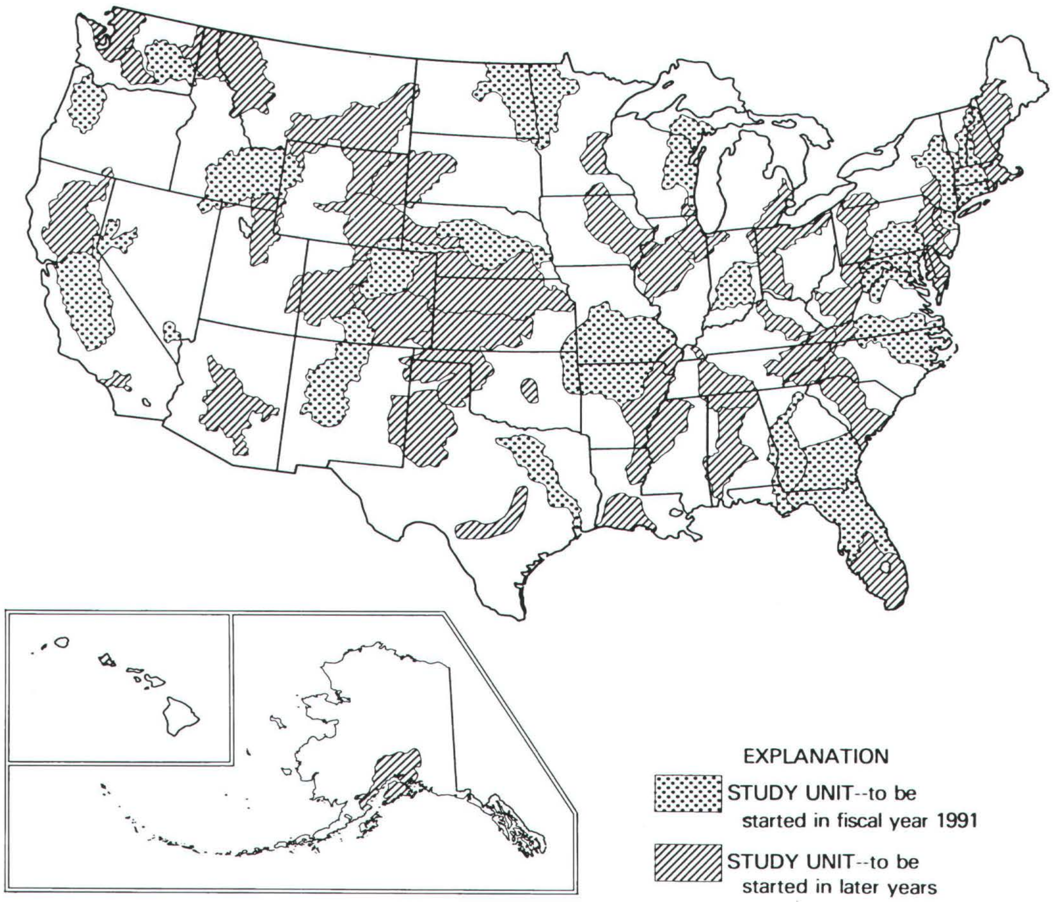
Chemical measurements form a national target list of variables, including some in situ measurements of inorganic constituents and organic compounds. Biological measurements in NAWQA are used to determine the occurrence and distribution of waters contaminated by fecal material, help determine the occurrence and distribution of potentially toxic substances, and define the relations between the physical and the chemical characteristics of streams and the functional and structural aspects of the biological community.

Within each study unit, surface-water quality is investigated through a combination of fixed-station sampling (frequent monitoring), supplemental sampling, and studies of selected stream reaches. In contrast, ground-water quality is studied by regional sampling, targeted sampling, and long-term sampling (less frequent monitoring).

Coordination With Other Agencies

Historically, the coordinated nature of the Federal-State Cooperative Program, plus considerable work with other Federal agencies, has kept the USGS abreast of emerging water issues and the information needs of water management officials. Such close involvement has helped to identify needs that in turn have guided many USGS research and monitoring studies.

External coordination at all levels will be an integral component of NAWQA. Effective interagency coordination is needed to continually, quickly, and fully understand the water-quality information needs of regulatory and resource management agencies, to locate existing water-quality and ancillary data to help interpret NAWQA data, and to permit rapid communication of important findings.



Study units for the National Water-Quality Assessment program.

Primary time and areal scales of all major USGS water-quality programs

Time scale	Areal scale: Local	Areal scale: Regional	Areal scale: National
Short term ...	Federal-State Cooperative Program. Urban hydrology Some research on rivers		
Multiyear.....	Federal-State Cooperative Program. Toxic substances hydrology program. Acid-precipitation studies....... Research on rivers, lakes, estuaries, and ground-water contamination.	Federal-State Cooperative Program. Toxic substances hydrology program (regional studies). Acid-precipitation studies Regional aquifer-systems analysis (geochemical studies). Irrigation drainage program NAWQA	NAWQA.
Decade.......	Acid-precipitation studies....... Nuclear hydrology.............	Federal-State Cooperative Program (water-quality networks). NAWQA	NASQAN. Hydrologic benchmark network. National trends network (wetfall). NAWQA.

To achieve these goals, the USGS has formed two committee structures. Each NAWQA study unit has a local liaison committee, which provides for information exchange at the field level. This liaison committee includes representatives from agencies that manage or regulate surface and ground water in the project area. A National Coordinating Work Group, which is composed of representatives from Federal agencies that regulate and manage water resources, meets annually to define the information needs, from the national perspective, of those Federal agencies responsible for water quality.

Conclusion

In its review of the NAWQA program, the members of the National Research Council said, "Human health and environmental health are inextricably linked to our Nation's water quality. As our population grows and our water resources become intensively developed and stressed, water quality becomes a more important component of our political, economic, social, and environmental decisionmaking. Such decisionmaking cannot proceed without adequate information and understanding."

The USGS total water-quality effort, capped by NAWQA, is designed to provide the kind of information needed about the quality of the Nation's waters to Congress and the citizens of this country. The information will be obtained on a continuing basis and be made available to water managers, policymakers, and the public to provide an improved scientific basis for evaluating water quality and trends in water quality in the United States. In fiscal year 1991, the first 20 NAWQA study-unit investigations will begin, ushering in a new era in the longstanding and ongoing water-quality efforts of the USGS.

Water Quality—What We Have Learned

By William G. Wilber

In 1986, the USGS began a 4-year pilot study, under the National Water-Quality Assessment (NAWQA) program, of the quality of surface- and ground-water resources in seven areas across the country. These seven areas represent diverse hydrologic environments and water-quality conditions. Each pilot study has contributed to a growing understanding of the quality of the Nation's water resources and to how that quality may be changing.

Nitrate and Herbicides in Ground Water—Delmarva Peninsula

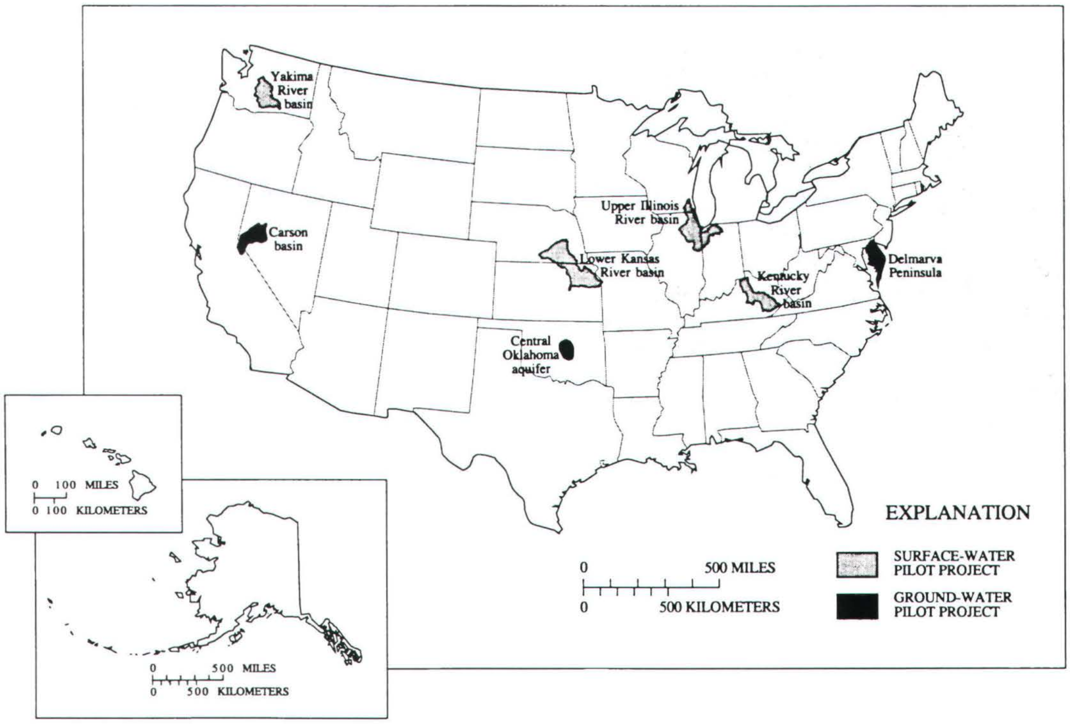
Elevated nitrate concentrations are prevalent in the shallow aquifer of the Delmarva Peninsula, located in Delaware, Maryland, and Virginia. Sources of nitrate include septic systems, animal wastes, and fertilizers. About 18 percent of the samples of shallow ground water from the peninsula exceed the U.S. Environmental Protection Agency (EPA) drinking-water standard of 10 milligrams per liter of nitrate as nitrogen. The standard is based on concerns that excessive nitrate can cause methemoglobinemia (blue baby syndrome) in infants. The elevated nitrate concentrations exist both in urbanized areas (from septic systems) and in agricultural areas (from fertilizers and animal wastes).

Agriculture, the primary source of herbicides, is the most prevalent land use on the peninsula (about half the land area). The shallow depths to the water table, the high permeability of the soils, and the high rates of recharge all favor the migration of herbicides to ground water. Low concentrations of herbicides are common in the top part of the shallow ground-water system throughout the peninsula, but concentrations are lower than those of the EPA Health Advisories.

Bromide in Surface Water—Kentucky River Basin

High concentrations of bromide in streams in the Kentucky River basin occur during low flows in summer and fall and are linked to the discharge of brines produced by the oil and gas industry. Bromide is a concern because of its role in the formation of potentially carcinogenic trihalomethane (THM) compounds, such as bromoform, in the Lexington, Ky., drinking-water supply, downstream from major brine discharges. THM compounds form during the disinfection of water supplies; chlorine and similar ions such as bromine react with natural organic substances to form THM's.

The Maximum Contaminant Level (MCL) established by the EPA for total THM's in drinking water is 0.10 milligram per liter, calculated as a 12-month average. The 12-month average concentration of THM's in the Lexington water supply has not yet exceeded the MCL during low-flow conditions, but THM concentrations in individual finished water samples have exceeded 0.10 milligram per liter.



National Water-Quality Assessment program pilot study sites.

Toxic Compounds in Surface Water—Upper Illinois River Basin

Potentially toxic pesticides and other synthetic organic compounds are detected in the water, sediment, and fish from streams in the upper Illinois River basin. High concentrations of atrazine (an herbicide) are detected in those parts of the basin used for agriculture (see "Atrazine in Streams of the Midwestern United States," p. 55). High concentrations of lawn and garden insecticides, such as diazinon, and herbicides, such as 2,4-D (2,4-dichlorophenoxyacetic acid), also are detected in storm runoff from urban and suburban catchments.

High concentrations of PCB (polychlorinated biphenyl) are detected in the sediments and fish tissues from streams in the Illinois Waterway. Concentrations of PCB in a significant number of fish samples exceed the Food and Drug Administration action level of 2 parts per million. At this level, the State Environmental Protection Agency warns that the fish should not be eaten.

Low concentrations of volatile organic compounds are detected in streams in the urban part of the basin. Chlorine in the structure of the compounds indicates that the compounds may be associated with the disinfection of sewage effluent.

Atrazine in Surface Water—Lower Kansas River Basin

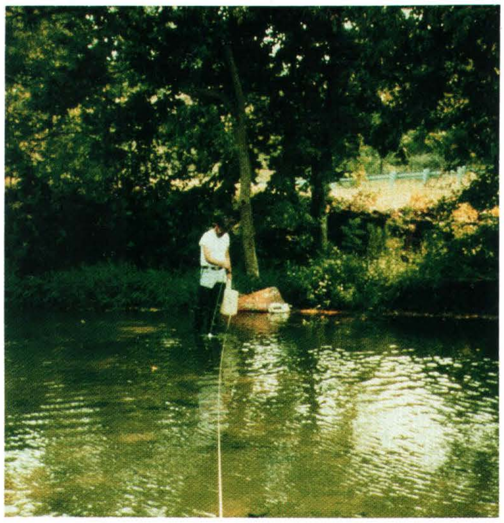
Significant concentrations of atrazine are detected at many locations in streams of the lower Kansas River basin. For example, during spring runoff in 1987, atrazine concentrations in intensively cultivated cropland in the West Fork Big Blue River ranged from 1.7 to 18 micrograms per liter. The median concentration was 9 micrograms per liter. During a low-flow survey of about 50 sites in 1988, atrazine was detected in samples collected at all of the locations and in higher concentrations than other widely used herbicides. One-third of the locations had concentrations of atrazine exceeding 3 micrograms per liter, EPA's proposed lifetime Health Advisory level. Monthly concentrations of atrazine at the outflow of Perry Lake, a major Federal reservoir used for public water supply, recreation, and flood control, ranged from 1.7 to 7.0 micrograms per liter during the study period.

Inorganic Constituents and Pesticides—Central Oklahoma Aquifer

The Central Oklahoma aquifer has elevated levels of trace elements and natural radioactivity. Arsenic exceeds EPA drinking-water standards in about 4 percent of the samples studied, and selenium and natural alpha radioactivity each exceed the standards in 12 percent of the samples. Many of the higher concentrations are detected in deeper ground water.

Pesticides are detected in about 16 percent of the wells sampled throughout the Central Oklahoma aquifer, most frequently in the urban area of Oklahoma City (29 percent

USGS hydrologist collects a water sample from Otter Creek near Redhouse, Ky., as part of the investigation in the field for the pilot National Water-Quality Assessment program study of surface waters of the Kentucky River basin.



KEVIN D. WHITE

of the wells sampled). Most of the detected pesticides are those commonly used by homeowners and include dieldrin and chlordane for termite control and 2,4-D and prometone for weed control.

Inorganic Constituents in Ground Water—Carson Basin, Nevada

Several naturally occurring inorganic constituents exist in ground water throughout the Carson basin. These constituents include trace elements (particularly arsenic) and natural radioactivity. Trace-element concentrations in drinking water are greater in the downgradient portions of the basin; this increase is concurrent with a downgradient transition from granitic source rocks to lacustrine deposits. For example, more than 50 percent of the sampled wells in the Carson Desert, the farthest downgradient valley, exceed the State of Nevada drinking-water standard for arsenic.

The natural radioactivity of the area causes radon concentrations to exceed 500 picocuries per liter in most of the ground water in the basin. The highest concentrations that locally exceed 14,000 picocuries per liter are in granitic rock and its sedimentary derivatives. In the Carson Desert, uranium concentrations locally exceed 1,000 picocuries per liter in shallow ground water. Drinking-water standards do not currently exist for these constituents, but the levels are unusually high and may exceed standards that are under review.

Insecticides in Surface Water—Yakima River Basin, Washington

Use of the insecticides DDT (dichlorodiphenyltrichloroethane) and dieldrin was banned in the early 1970's. During the irrigation season and during periods of high sediment erosion, however, concentrations of these compounds and their metabolites are found frequently to exceed EPA chronic toxicity criteria (CTC) and State of Washington standards in the water and sediment of the lower part of the Yakima River basin.

The CTC is 0.001 microgram per liter for DDT and its metabolites and 0.0019 microgram per liter for dieldrin. The amount of DDT and its metabolites remaining in the soil, particularly in agriculture soil, is large. Preliminary estimates indicate that, of the pesticides in the soil, less than 1 percent is transported from the basin each year. Thus, even though the use of these compounds was banned almost 20 years ago, water-quality standards will be exceeded for many years to come.

Summary

The intensive data collection and analyses for the seven pilot studies will be completed in 1991, followed by a 6-year period of less intensive assessment activities. During this 6-year period, other USGS programs, such as the Federal-State Cooperative Program, will support the studies of local and regional interest that were developed as a result of the NAWQA pilot studies.

In 1988, members of the National Research Council (NRC) Water Science and Technology Board began a 2-year evaluation of the NAWQA pilot program. The evaluation, completed in 1990, strongly supported the program. The NRC board members recommended that a national water-quality assessment be conducted because it is in the best interests of the Nation, and stated that the USGS was the appropriate agency to conduct the assessment because of the success of the pilot studies. In 1990 the President's fiscal year 1991 budget proposed implementation of the full-scale program, a proposal endorsed by Congress. Accordingly, the USGS fiscal year 1991 budget, appropriated by the Congress, includes $18 million to begin the first 20 studies of the full-scale, 60-study national water-quality assessment program.

People and Programs

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.

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.; and at field offices in Flagstaff, Ariz.; Anchorage, Alaska; Woods Hole, Mass.; Tucson, Ariz.; Reno, Nev.; and Spokane, Wash.; and 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.

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 and the Cascades Volcano Observatory in Vancouver, Wash., are the principal field research centers for this program. The Alaska Volcano Observatory, a cooperative effort with State and academic organizations, is located in Anchorage.

The Landslide Hazards Program emphasizes field and laboratory research on the active earth processes that result in ground failures such as landslides, mudflows, and debris flows.

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 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 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.

The Geomagnetism Program measures and interprets changes in the strength and direction of the Earth's magnetic field. Eleven geomagnetic observatories provide data for continually updating global navigational charts and maps produced by Federal agencies.

The Climate Change Program conducts research on the natural variability of past climate, on the extent of human influence on natural patterns of change, and on the magnitude of climate change demonstrated in the geologic record in support of Federal global change research efforts.

The Coastal Erosion Program provides geologic information on the nature, extent, and cause of coastal erosion. This information is used by Federal and State agencies to mitigate coastal retreat and land loss.

Offshore Surveys.—The Offshore Geologic Framework Program conducts scientific investigations to acquire an understanding of basic geologic and geophysical characteristics of the continental margins, adjacent slope and deep-ocean areas, and the U.S. Exclusive

Mission

The U.S. Geological Survey, a bureau of the U.S. Department of the Interior, was established by an Act of Congress on March 3, 1879, to provide a permanent Federal agency to conduct the systematic and scientific "classification of the public lands and examination of the 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, or 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.

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."

Economic Zone. Results of these studies and analysis of new information are essential for energy and mineral resource evaluation and assessment.

Mineral Resource Surveys.—The National Mineral Resource Assessment Program provides comprehensive multidisciplinary surveys to identify undiscovered mineral resources in the conterminous United States and Alaska and provides mineral-resource information for planning the use of public lands.

The Strategic and Critical Minerals Program provides comprehensive information on domestic and world resources of nonfuel minerals that are essential to a strong national economy and defense.

The Development of Assessment Techniques Program conducts basic and applied research on the origin and the geologic, geochemical, and geophysical characteristics of mineral deposit systems to develop concepts and techniques to improve the capability to identify and evaluate mineral resources.

Energy Surveys.—The Evolution of Sedimentary Basins Program conducts multidisciplinary research to define the evolution of and the energy and mineral commodities in sedimentary basins in the United States.

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.

The Oil and Gas Investigations Program conducts basic and applied research on the generation, migration, and entrapment of petroleum and natural gas 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.

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.

The Uranium/Thorium Investigations Program conducts basic research to determine the nature and distribution of uranium and thorium resources, including newly forming uranium deposits and daughter products, such as radon, that may be health hazards.

The Geothermal Investigations Program conducts basic research to determine the nature, distribution, and magnitude of the Nation's geothermal resources. These studies define the geologic and hydrothermal regimes of the various classes of geothermal resources and identify the crustal, geochemical, and hydrothermal processes that produce geothermal systems.

The World Energy Resources Assessment Program provides information on worldwide energy resources for use by other agencies in the development of national-energy, international-trade, and foreign policies.

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.; Atlanta, Ga.; Denver, Colo.; and Menlo Park, Calif. Forty-two 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 program seeks to provide nationally consistent descriptions of the quality of the Nation's water resources over a large, diverse, and geographically distributed portion of the country; provide a baseline for evaluating future trends in water quality and, where possible, define trends in water quality over recent decades; and provide an understanding of the factors influencing water quality. This information provides the basis to forecast change and evaluate the likely effect on water quality of various proposed remedial actions. Initial efforts include four surface-water and three ground-water pilot studies; 20 study units are planned for operation beginning in fiscal year 1991.

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.

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 in 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 Systems Analysis.—The Regional Aquifer Systems Analysis 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.

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, and aquifers; operation of the National Trends Network; and research into more precise methods of measurement. The program is coordinated through the Interagency Task Force on Acid Precipitation.

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.

Federal-State Cooperatives.—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 performs most of the work on behalf of the cooperators. Hydrologic data collection activities and water-resources investigations are included in the program.

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, geochemistry, ground-water hydrology, sediment transport and geomorphology, water chemistry, 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 carried out 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 1964. 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 leadership to coordinate the water-data acquisition and information sharing activities of all agencies of the Federal Government. The office was created as part of the U.S. Department of the Interior's implementation of Office of Management and Budget Circular A–67. The scope of the activities includes the quality, quantity, and use of streams, lakes, reservoirs, estuaries, and ground water.

Much of the program is accomplished through two committees that advise the Secretary of the Interior on programs and plans related to the implementation of Circular A–67. Thirty Federal organizations are represented on the Interagency Advisory Committee on Water Data, and more than 100 representatives of those organizations conduct the activities of the committee. The second group is the Advisory Committee on Water Data for Public Use, which is composed of 16 national organizations involved in water-related issues. This committee operates under the Federal Advisory Committee Act.

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 Management; Research; and Information and Data 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 Circular A–16. The bureau 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 Digital Cartography Coordinating Committee (a departmental committee) and the Federal Interagency Coordinating Committee on Digital Cartography (Federal Geographic Data Committee per revised OMB Circular A–16, October 1990) and provides leadership in the use of digital 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 data, and selected thematic maps of the Nation that are used extensively for land planning, land and resource management, and recreation purposes. These maps and data are available in printed and digital form. 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 almost 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 scales of 1:250,000 and 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 (known as Mark II) to move from manual to digital production and revision of map products. The goals of Mark II 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), 61 ESIC-State affiliated offices, and the Earth Resources Observation Systems Data Center. The information is provided in many forms, from maps and books to computer-readable magnetic tapes and compact discs. About 125,000 different maps, books, and reports and about 9.5 million aerial and space images are available for purchase. USGS maps are also available from more than 3,500 authorized commercial map dealers nationwide.

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.

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. He chairs the USGS Information Systems Council, which is composed of the top automated data processing manager in each Division and in the Central and Western Regions. The council recommends technology-related policies to the Director, coordinates computer science research and technology, and provides guidelines for the sharing, acquisition, and use of major computer systems and information management programs for the USGS.

Administrative Division

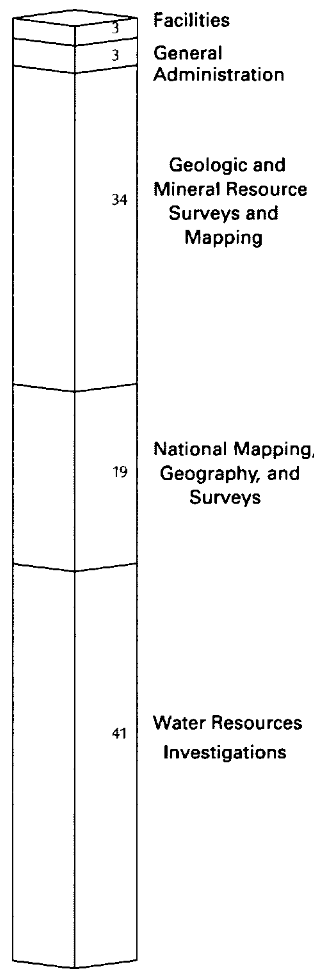
The headquarters office of the Administrative Division is located in Reston, Va. The Division is composed of five headquarters offices. Financial Management and Systems Management are centralized headquarters functions; Facilities and Management Services, Personnel, and Procurement and Contracts provide 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.

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.

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 1990, the USGS had obligational authority for $723.1 million, $501.5 million of which came from direct appropriations, $7.8 million from estimated receipts from map sales, and $213.8 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. 96).

Percentage of Total Funds by Activity



People

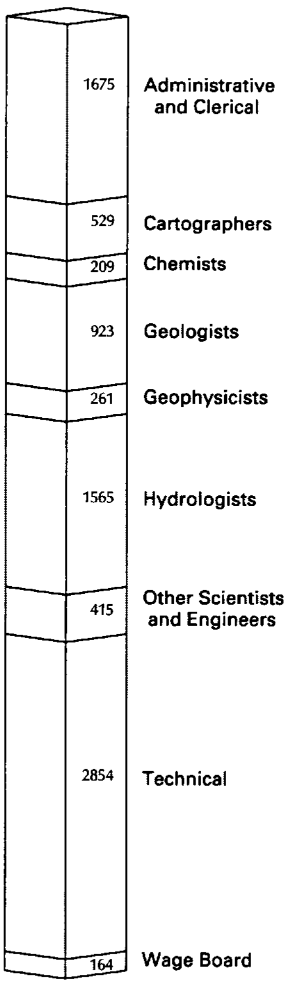
At the end of fiscal year 1990, the USGS had 8,595 permanent full-time employees. The diversified earth science research programs and services of the bureau are reflected in the workforce, about half of which possess a bachelor's or higher level degree.

Permanent employees are supported by the 1,899 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 and at Hispanic-serving institutions. (See "Women, Minorities, and Persons with Disabilities," p. 39.)

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

Personnel, by Occupation



information. The results of USGS investigations are published in scientific reports and in topographic, geologic, and hydrologic maps. About 125,000 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, real-time 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 1990, the USGS produced 2,259 new or revised topographic, geologic, and hydrologic maps, bringing the total number of maps available to 84,000. Of these, more than 9.5 million copies were distributed. The number of reports approved for publication in fiscal year 1990 was 4,544, 71 percent of which were designated for publication in outside professional journals and monographs and the remainder for publication by the USGS.

More than 122,756 copies of technical reports were distributed. Also, 889 new reports were released as open files, making the total more than 28,000 open-file reports available. More than 914,000 copies of general-interest publications were distributed in response to inquiries from the public. Of the approximately 9.5 million aerial and space images available for sale, about 185,000 copies are sold annually.

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. Abbreviations used throughout are GD, Geologic Division; WRD, Water Resources Division; and NMD, National Mapping Division.

Presidential Rank Awards

Presidential Rank Awards are presented annually by the Office of Personnel Management 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 ($20,000 award) and Meritorious ($10,000 award).

John N. Fischer, Jr., Associate Chief Hydrologist, WRD, received the Meritorious Rank award for his managerial and executive leadership during the past 10 years. He has directly and significantly influenced the philosophy, policies, and accomplishments of USGS programs through his leadership abilities and his effective communication skills, particularly with other Federal agency managers and science practitioners and with congressional leaders and their staffs.

Distinguished Service Awards

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 nine USGS employees:

James F. Blakey, Regional Hydrologist, Central Region, WRD, for exceptional contributions to the management of water-resources programs that have significantly increased the impact of hydrologic research on national environmental issues.

Robert D. Brown, Jr., GD, for outstanding contributions to the integration of earth science data with planning and decisionmaking processes related to facilities siting and seismic hazards.

Bruce B. Hanshaw, GD, for outstanding contributions to radioactive waste management, shale membrane theory, and paleoclimatology and for his leadership as Secretary General for the 1989 28th International Geological Congress.

L. J. Patrick Muffler, GD, for outstanding contributions including establishing a method for classifying and assessing geothermal resources.

Gary W. North, Assistant Division Chief for Information and Data Services, NMD, for outstanding efforts in promoting earth science information technology, developing a national network of information centers, and for cooperative education efforts with the Historically Black College and University program.

Stanley P. Sauer, Regional Hydrologist, Northeastern Region, WRD, for exceptional achievements in addressing water-resources problems, including ground-water contamination research, and for management of water-resources programs.

Kiyoshi J. Takasaki, Assistant Chief, Hawaii District Office, WRD, for notable accomplishments in geohydrology and the island hydrology of Hawaii and other Pacific islands.

Donald E. Vaupel, Chief, New Jersey District Office, WRD, for exceptional contributions to the development and management of water-resources programs, particularly in advanced computer technology, and for cooperation with State organizations and associations.

Richard E. Witmer, Assistant Division Chief for Program, Budget, and Administration, NMD, for outstanding contributions to the advancement of resource mapping, development of geographic information systems technology, and management of programs to accommodate changing technologies in cartography.

Meritorious Service Awards

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 are

Office of the Director

Linda D. Stanley

Geologic Division

Robert C. Bucknam
M. Devereux Carter
Thomas P. Miller
Gary R. Olhoeft
Jack Rachlin
John W. Salisbury
Stanley P. Schweinfurth
Kenneth Watson

Water Resources Division

James F. Wilson, Jr.

National Mapping Division

Franklin S. Baxter
Ernest B. Brunson
Gary L. Fairgrieve
Richard L. Kleckner
Joel L. Morrison

Administrative Division

Aiko C. Hayashi

Superior Service Awards:

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 are

Office of the Director

Nancy S. Hawkins
Patricia Jorgenson

Geologic Division

John L. Boatwright
Carol S. Breed
Jerry L. Clayton
Patricia Cuneo
James H. Dietrich
William L. Ellsworth
John P. Galloway
Thomas C. Hanks
Donald B. Hoover
Frederick W. Lester
Carl L. Long
Charles S. Mueller
Robert A. Page
Daniel J. Ponti
Cynthia C. Ramseyer
Laurie F. Rinker
Christopher J. Schenk
Katheryn M. Sloan
Paul A. Spudich
Margo I. Toth
John R. VanSchaack
Peter L. Ward

Water Resources Division

Claire B. Davidson
Paul V. Dresler
Sandra L. Holmes
Robert W. James, Jr.
Harry F. Lins
Daisie M. Oden
Thomas G. Ross
Leanna E. Sweet

National Mapping Division

James N. Brooks
Teresa A. Dean
George F. Delinski, Jr.
Burley C. Edwards
Janet C. Flanagan
Robert L. Gwynn
Bradish F. Johnson
Mike Karich
Michael A. Kelley
Rodney L. Krone
Carol A. Lee
Benjamin S. Ramey
Charlene R. Hall Raphael
Margaret A. Rawson
Ocie V. Sigley
Judy J. Stella

Administrative Division

Connie R. Sanders

Information Systems Division

Pedro Cadenas-Planas
Sharon L. Crown
Linda E. Deiter
Patrick C. Doherty

Awards and Honors Received by USGS Employees During 1990

Charles E. Barker, GD, elected President of the Society for Luminescent Microscopy and Spectroscopy.

Christopher C. Barton, GD, selected as Distinguished Lecturer by the American Association of Petroleum Geologists and elected Secretary of the Rocky Mountain Section of the American Geophysical Union.

Franklin S. Baxter, NMD, received presidential citations from the American Congress on Surveying and Mapping for serving on and as secretary of the Board of Directors.

Charles W. Bennett, Manager, Federal Map Depository Library Program, NMD, received a special award from the American Library Association for his guidance to map librarians through the depository program.

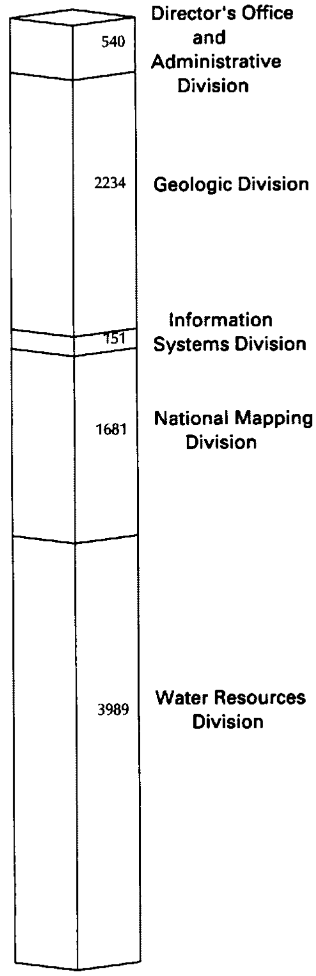
M. Clarke Blake, Jr., GD, received the McKay Hammer Award from the Geological Society of New Zealand for his outstanding contributions to the geology of New Zealand.

Arthur F. Buddington (deceased), GD, a mountain range in the Coast Mountains of Alaska has been named the "Buddington Range" in his honor by the Alaska State Geographic Names Board in recognition of his outstanding research on the geology and mineral deposits of southeastern Alaska.

William A. Cobban, GD, awarded the Raymond C. Moore Paleontology Medal of the Society of Economic Paleontologists and Mineralogists.

J. Thomas Dutro, Jr., GD, is Trustee and VP of the Paleontological Research Institution; Geological Society of America Representative to the AAAS Section on Geology & Geography; Association of Earth Science Editors Representative to the AAAS Section on

Personnel, by Division



Information, Computing, and Communication; Research Associate of the Smithsonian Institution; Titular Member for the U.S. Carboniferous Subcommission of the International Union of the Geological Sciences Stratigraphic Commission; and U.S. Member of Permanent Committee for the Congress of Carboniferous and Permian Stratigraphy and Geology.

George E. Ericksen, GD, received the Distinguished Alumni Award from the University of Montana for his outstanding contributions to the understanding of the geology and mineral resources of South America.

Norman O. Fredericksen, GD, received the Fulbright Senior Partial Award to conduct palynological research at the University of Göttingen, West Germany.

Bruce B. Hanshaw, GD, elected VP of the International Division of the Geological Society of America.

James L. Hott, ISD, received a special award from the Department of the Interior and Government Computer News Agency for his work in the development of the GEONET telecommunications network now used by all Interior bureaus.

Information Systems Division, Branch of Telecommunications, received one of seven governmentwide awards from the Government Computer News Agency for sustained excellence in telecommunications planning, management, and operations. At the same ceremony, the Interagency Working Group on Data Management for Global Change was honored by the same group for facilitating the study of global change. The USGS participates in this working group with other Federal agencies involved in global change research.

Marshall E. Jennings, WRD, named Engineer of the Year for the USGS by the National Society of Professional Engineers.

Lucille M. Jones, GD, elected to the Board of Directors of the Seismological Society of America.

Debra S. Knopman, WRD, named Chairman of the American Geophysical Union's Public Information Committee.

Robert M. Kosanke, GD, received the Gilbert H. Cady award of the Coal Division of the Geological Society of America for his work in coal geology including palynology, paleobotany, stratigraphy, coal petrology, coal chemistry, and coal reserves.

Arthur H. Lachenbruch, GD, received the Walter H. Bucher Medal from the American Geophysical Union for his outstanding research that combined observations of geological phenomena with mathematical representations to provide insight into fundamental problems of the lithosphere of the Earth.

Ricardo Lopez, GD, received the GD Safety Achievement Award in recognition of his outstanding performance as collateral duty safety officer and member of the National Center Hazardous Chemical Spill Team.

Bernard A. Malo, WRD, received the 1990 American Society for Testing and Materials (ASTM) Award of Merit and was made a Fellow of the Society for his outstanding leadership in promoting ASTM standards development in the analysis of water.

Alan M. Mikuni, Assistant Chief of the Western Mapping Center, NMD, serving as chairman on the Engineering Cartography Committee of the Surveying and Engineering Division, American Society of Civil Engineers.

Bruce F. Molnia, GD, selected as editor of a new Geological Society of America publication, "Geology Today."

Joel L. Morrison, Assistant Division Chief for Research, NMD, elected Chairman of the Board of Directors of the National Center for Geographic Information and Analysis.

Douglas J. Nichols, GD, served as Sigma Xi National Lecturer.

Gordon L. Nord, Jr., GD, awarded a 1-year Guest Research Fellowship by the Royal Society of Great Britain to participate in cooperative studies at the University of Cambridge.

John Pojeta, Jr., GD, elected President, Paleontological Society; Secretary, Council of Systematic Malacologists; Secretary, Association of North American Paleontological Societies.

John K. Powell, Mid-Continent Mapping Center, NMD, served as Director for the American Society for Photogrammetry and Remote Sensing, Rolla Region.

Stephen E. Prensky, GD, elected VP of publications and editor for the Society of Professional Well Log Analysts.

Dudley D. Rice and **Romeo M. Flores**, GD, received the award for the best paper presented at the Energy Minerals Division of the Rocky Mountain Section of the American Association of Petroleum Geologists. Rice was elected to the office of Treasurer by the Rocky Mountain Association of Geologists.

Paul Segall, GD, received the American Geophysical Union's James B. Macelwane Medal in recognition of significant contributions to the geophysical sciences by a young scientist.

Robert L. Smith, GD, received an Honorary Doctor of Science degree from the United Kingdom's Lancaster University for his outstanding research in the field of volcanology.

John P. Snyder (retired), NMD, elected President of the American Cartographic Association, of the American Congress on Surveying and Mapping.

Jerry W. Wagner, Mid-Continent Mapping Center, NMD, elected President, American

Society for Photogrammetry and Remote Sensing, Rolla Region.

Allen H. Watkins, Chief of the EROS Data Center, NMD, elected member of the International Academy of Astronautics.

Outstanding Federal Employees with Disabilities

Each year the USGS nominates one or more employees for recognition as Outstanding Federal Employees with Disabilities. Nominations are forwarded through the Interior Department for consideration and recognition at the Annual Presidential Awards Ceremony for Outstanding Federal Employees with Disabilities. USGS employees nominated in 1990 are

William D. Zitrin, WRD, who is hearing impaired, was nominated for his outstanding accomplishments in the area of computerized administrative systems. He has programmed an entire financial system for the USGS eight-state Western Region and has written manuals, trained users, and maintained the system. He also assists other hearing impaired people.

Marcella Bernhard, ISD, who is hearing impaired, was nominated for her outstanding accomplishments in monitoring regional communications systems, installing local area networks, and troubleshooting and repairing computer communication problems. She, too, works with other hearing impaired employees to help them communicate more effectively.

Public Service Recognition Awards

Special awards were presented by the USGS to 11 employees in 1990 for their outstanding contributions as public servants. These presentations were part of the governmentwide Public Service Recognition Week (May 7–11, 1990), which celebrates the indispensable and diverse contributions of the millions of women and men who make up the public work force and is a "time set aside to recognize the 'unsung heroines and heroes' who give so much to America."

Two of these USGS employees, **Mrs. Maxine Millard** and **Dr. Cornelia Cameron**, were further honored by the U.S. Department of the Interior at a special ceremony. Together these two outstanding women represent a combined Federal service of nearly 90 years. Mrs. Millard, who is the Chief of the Office of Personnel, Administrative Division, was cited for her significant accomplishments in personnel administration and for her many "firsts" as a woman in the personnel field. This year, she received special recognition for 50 years in public service. Dr. Cameron, GD, has been an active field geologist for more than 50 years and is recognized as the world's foremost authority on peat and peat resources. Both women are featured in the Interior Department publication *Profile of Women at Work.*

Other USGS employees honored for their outstanding contributions to public service are **Willie McDuffie, Jr.**, Office of the Director; **Clara C. Wilson**, Administrative Division; **Flora A. Heggem**, GD; **Florence R. Weber**, GD; **Mary Ellen Lazarus**, ISD; **Evelyn F. Christian**, NMD; **Dan A. McCord**, NMD; **Paul R. Beauchemin**, WRD; and **Bruce K. Green**, WRD (see box p. 8).

At a special ceremony in Denver, Colo., several USGS employees were honored as "Unsung Heroes" for their special achievements both in the workplace and in the community: **William C. Butler**, GD; **Tom Ging**, GD; **Robert O'Donnell**, GD; **Waverly Person**, GD; **Walter Rast**, WRD; and **Richard Scott**, GD.

USGS employees who are involved in other public and community service activities are recognized by outside organizations for their activities. Employees so honored include

Waverly J. Person, GD, presented with the Boulder County, Colo., special award for minorities who make outstanding scientific contributions to community action programs.

David C. Prowell, GD, the first individual to receive the Hughes Award for Outstanding Contributions to Education in Georgia, from Atlantic Telephone and Telegraph, for his commitment to the advancement of earth science knowledge through public education.

Stewardship Award For Volunteerism

In support of his initiative on volunteerism, Secretary of the Interior Lujan presented the following award:

Maxine C. Jefferson, Supervisory Employee Development Specialist, Administrative Division, in recognition of her outstanding program leadership and contributions to volunteerism at the USGS, in development and administration of the Volunteer for Science Program. The District of Columbia Public Schools named Mrs. Jefferson an Outstanding Partner in Education for the years 1988 and 1989.

John Wesley Powell Awards

Each year the USGS presents the John Wesley Powell Award 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."

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 1990 are **Genevieve Atwood**, former Utah State Geologist, received the Powell Award for **achievement in State Government**, in recognition of her role in the formation of the Utah Seismic Safety Advisory Council, which led to the adoption of improved seismic safety policies in Utah. She was further cited for her cooperative efforts with the USGS that benefited the National Earthquake Hazards Reduction Program and for her overall efforts to deepen understanding of the scientific and social aspects of natural disaster reduction.

Walter Sullivan, retired science editor of the New York Times, received the Powell Award for **citizen's achievement**, in recognition of his significant accomplishments as a science writer and communicator. In his writings for the New York Times and in his books, Sullivan has covered earth science subjects and activities of the USGS for more than 40 years, beginning with some of the the Survey's early scientific work in Antarctica. Sullivan was cited for fostering improved public understanding of the earth sciences and for making the work of the USGS "come alive on the written page."

Glass Instruments, Inc., a Pasadena, Calif., firm that makes technical glass products and specialized light sources for science and industry, received the Powell Award for **industry achievement**. For more than 25 years the firm, through competitive bidding, has supplied the USGS with argon-38 traces for potassium-argon age determination and other glass specialty products used in age dating of rock and mineral samples. The award was presented to Thurston LeVay, president of Glass Instruments, citing the substantial investment in research and equipment by the company as a major benefit to the radioisotope geochronology programs of the USGS.

Special Programs and Initiatives

During fiscal year 1990, the USGS increased its participation in programs supporting U.S. Department of the Interior special initiatives, such as volunteerism, education, and women, minorities, and persons with disabilities. The activities of 1990 reflect intensified efforts in on-going programs that have long been a part of the bureau's overall mission. The following are highlights of the special programs and efforts underway.

Volunteer is Honored

Carolyn Shoemaker, a volunteer with the Geologic Division in Flagstaff, Ariz., received an Honorary Doctor of Science Degree from Northern Arizona University for her outstanding achievements in research on asteroids and comets.

Volunteerism

The USGS has an active in-house volunteer program called Volunteer for Science. Since 1986 this successful and rapidly growing program has proven to be of mutual benefit to the USGS and the volunteers. The spirit of volunteerism also is a commitment in the lives of many USGS employees, who are active in their communities and in various service groups. During the past year, the USGS has made special efforts to recognize and applaud these extra efforts made by its employees.

Volunteers . . . in a Scientific Agency?—Most people are surprised to learn that the USGS has a volunteer program. Traditionally, volunteerism is thought of in relation to hospitals, schools, parks, social service, or other activities. The most frequently asked question about the USGS Volunteer for Science program is, "What could volunteers do in a scientific agency?" The answers are many, varied, and amazingly interesting.

Volunteers perform assignments as geologists, geophysicists, cartographers, hydrologists, field assistants, laboratory assistants, library aids, and rainfall observers. They come from such sources as high schools, colleges and universities, scientific agencies, professional associations, retiree associations, private industry, and the community at large. High school students, for example, can investigate career possibilities and develop a broader interest in science. College students pursuing degrees in the earth sciences and other professional fields broaden their knowledge and experience as they work with USGS personnel. Teachers welcome access to state-of-the-art equipment and technology. Retirees can remain involved in their scientific career—or can finally pursue a long-deferred interest in science. Community members have an opportunity to be involved in public service. Clearly, both the volunteer and the USGS benefit from this program.

The Volunteer for Science program is a national effort, and volunteers help in USGS offices from Maine to Hawaii. More than 1,700 volunteers, who help with a variety of earth science and administrative efforts, have provided more than 419,000 hours, at a savings of $4.5 million to the Federal Government. In fiscal year 1990, 489 new agreements were signed, a remarkable addition to the Volunteer for Science program.

Volunteers assist with bedrock mapping in Vermont, measure radon in the soils in New Jersey, prepare rainfall reports in North Carolina, review manuscripts in Colorado, study geology and mineral resources of an Apache Reservation in Arizona, conduct tours and special programs for visitors to the USGS

National Center in Reston, Va., and work on projects at the Cascades Volcano Observatory in Washington.

A natural link between volunteerism and education has been strengthened by efforts to promote interest in the earth sciences, especially in the elementary schools. The USGS contribution to earth science education includes teacher workshops, the Visitors Center program at the National Center, scientist visits to schools around the country, and local-school cooperative programs. Increased formal educational partnerships are being encouraged to develop programs for teachers and mentorships for students. Anyone interested in the Volunteer for Science program may write to the Administrative Division, Office of Personnel, USGS, 215 National Center, Reston, VA 22092, or call (703) 648–7439.

Dinosaurs, Tree Rings, Printing Presses.—Those are some of the features of a visit to the USGS National Center. Beginning with a brief orientation in the new Visitors Center, students and the public are led on a tour of exhibits, displays, and laboratories. Guides for the tours are retired USGS employees who have returned on a volunteer basis. About two dozen retirees are now on board as docents, leading visiting groups that range in age from preschoolers to senior citizens.

During fiscal year 1990, more than 5,400 people had an opportunity to learn about the work of the USGS. Visitors are treated to many sights and activities. Elementary students are taken on orienteering exercises around the National Center grounds to learn about map scale and how objects in real life are portrayed on a map. A visit to the tree-ring laboratory shows them how scientists use the information in tree rings to tell a story of floods and droughts that occurred hundreds of years ago. Surrounded by the roar of fast-moving presses and a bustle of activity, as sheet after sheet of colorful maps roll off the presses, visitors see first hand how the thousands of maps the Survey produces each year are printed.

A favorite stop is at the dinosaur footprints—a gift from a local Virginia quarry where the tracks and trails of a three-toed carnosaur were recently uncovered. This dinosaur walked the Earth about 210 million years ago. Visitors also have a chance to browse in the Earth Science Information Center and peruse the thousands of maps and book reports available from the USGS. Visits are arranged by appointment on selected days of the week. Call the Visitors Center at 703–64VISIT ((703) 648–4748).

"What's Under Your Feet?"—That was the question USGS geologist Eleanora Robbins asked young students from a Washington, D.C., inner city elementary school during a summer field course she designed. Raised with the understanding that one person can make a difference, Norrie started a geology field course 3 years ago for inner city children in the Anacostia region of the Nation's capital. For the program during the 1990 summer season, she contacted the principal of Draper Elementary School and asked to speak with the 4th and 5th grade classes. She invited all 150 students to join her on a field trip.

ADELE CONOVER

The "What's Under Your Feet" field class begins.

Her budding young geologists—about 10 to 15 each time—met on five Saturdays in July and August. The "What's Under Your Feet" class included walking with the children around their neighborhood to learn about watershed divides, looking for fossils, examining how water shapes and rounds rocks, and panning in a creek for gold and magnetite. A special highlight of the field trip was a visit out of the neighborhood to a nature center. For her efforts, Norrie Robbins was recognized as one of the U.S. Department of the Interior Points of Light.

Points of Light Honored.—In support of President Bush's Thousand Points of Light, Interior Secretary Lujan hosted monthly lunches during 1990 to recognize Department employees for community volunteer activities. In addition to Eleanora Robbins, the following USGS employees were recognized for their many hours of service to their fellow citizens and their communities:
C. Michael Hacke, WRD, Doraville, Ga., for his nearly 20 years of active service as a volunteer and contributor to numerous nonprofit and charitable organizations; **Alan R. Stevens**, NMD, Reston, Va., for his extensive work with drug and alcohol treatment programs for young people; **Judy A. George**, Administrative Division, Reston, Va., for her extensive work as an instructor in cardiopulmonary resuscitation; **Robert E. Wakefield**, NMD, Reston, Va., for his more than 20 years of active volunteer service to many organizations and to church activities; **John E. Cotton**, WRD, Bow, N.H., for his extensive voluntary contributions as an ambulance attendant and in emergency response; **Barbara Herring**, Office of the Director, Reston, Va., for her active involvement in providing services and activities for mentally retarded and developmentally disabled adults; **Peggy Mervine**, Administrative Division, Reston, Va., for her

countless contributions to local community activities; and **Olga Sandoval**, WRD, Albuquerque, N. Mex., for her active advocacy and sponsorship of programs to encourage minority students to pursue careers in mathematics and science.

Education

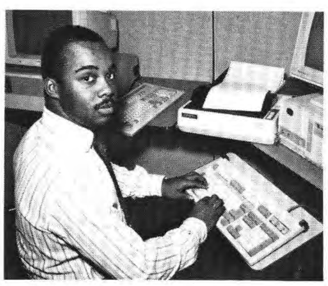
The need for public awareness of science issues of national importance and the smaller number of students who are preparing for careers in science and engineering has prompted the USGS to increase its efforts in providing its earth science information to the educational community and in encouraging more students to pursue careers in the earth sciences. During the coming years, the USGS will be focusing increased attention on assisting teachers at precollege and college levels to have access to and involvement in USGS research and program activities and to develop materials that will be useful to the teacher in the classroom.

Science Teacher Internship.—In May 1990, two science teacher students from Elizabeth City State University, a historically Black university in North Carolina, spent a 1-month geological sciences internship with the USGS. This internship program gives minority students, whose major is precollege science teaching, an opportunity to work in the discipline they intend to teach.

The students, who spent 4 weeks of in-depth work on designated projects, performed field, laboratory, and office work. They spent 1 day each week in the field or in discussions with USGS scientists to gain a broad view of the different types of research underway at the Survey.

At the end of the internship program, and throughout their first teaching year, the participants are expected to design classroom activities for use in their local school districts and to share those ideas with the USGS for use in other educational outreach efforts.

Elizabeth City State University provided each student with credit hours for their internship participation, and financial support for living expenses was provided by the USGS and the Department of the Interior's Historically Black College and University program. The success of this first-time internship effort has prompted the USGS to expand the program to 12 internships next year.


DAVE USHER

A graduate of Hampton University working in the Information Systems Division as a mathematical statistician.

Cooperative Education in Computer Applications.—A cooperative education program with Hampton University, a historically Black university in eastern Virginia, allows students to study computer applications in the earth sciences. The program offers students cooperative education assignments at the USGS on a full-time basis for one to two semesters or during the summer. Students work with computer scientists at the USGS in conducting technology assessment studies and participating in scientific visualization projects.

A series of lectures are part of the cooperative education program in which USGS computer and information scientists work with university faculty to prepare lectures and course materials on computer security, artificial intelligence, and on-line information retrieval.

The program provides a special win-win combination in that the students gain a broader understanding of computer applications in the earth sciences and the USGS can gain new employees. Two permanent employees in the Information Systems Division were recruited from Hampton University. Future plans include identifying additional positions that may be filled by students from the cooperative program.

Bringing Science to the Classroom.—The exciting world of real and current scientific data is being explored on the desktops of over 50 schools around the country this year as part of the Joint Education Initiative (JEdI) project. Three JEdI CD–ROM (compact disc-read only memory) discs containing earth science data contributed by the USGS, the National Oceanic and Atmospheric Administration, and the National Aeronautics and Space Administration are now available.

The computer industry also has contributed time and equipment to the project. In a 3-week science education workshop held during the summer of 1990 at the USGS National Center, 20 precollege teachers worked closely with computer experts and scientists to develop classroom activities for use with the CD–ROM discs. The workshop activities, covering data on geophysics, ozone, seismicity, ocean temperature and salinity, the sea floor, and Antarctica, are included in a published USGS report available with the JEdI discs.

During fiscal year 1990, the USGS western region office in Menlo Park, Calif., played a major role in designing a National Science Foundation-funded program for teacher enhancement. The first part of this program was a 4-week summer institute presented at San Jose State University. USGS personnel provided speakers and tours for the institute. The long-term goals of this effort include a book of resources for science teachers and establishment of a scientific mentor-teacher program.

Many other workshops and teacher-involvement activities were conducted by the USGS around the country during the year. At a workshop for Nevada teachers, members of the USGS Minerals Information Office provided lectures, hands-on sessions, and field trips to local mines and the Nevada Nuclear Test Site.

In an unusual event, the USGS helped to set up a life-sized board game as part of a nationwide earthquake and national weather preparedness program. The game, which toured St. Louis, Mo.; Chicago, Ill.; Miami, Fla.; and Houston, Tex.; included three-dimensional representations of the forces of nature. Students walked the board and answered questions on safety precautions to take during natural disasters.

An earth science and mapping workshop in mid-August gave 200 educators and science curriculum administrators in the Denver area a chance for experience in cartography, geology, and hydrology. The workshop was designed to foster better communication between scientists and earth science educators, to acquaint the educators with the latest advances in the earth sciences, and to discuss how to make science more relevant to students. USGS scientists led discussions on recent advances in their fields of study. Field trips were conducted to dinosaur fossil sites and gold mines.

Partners in Education.—The USGS and Dogwood Elementary School in Reston, Va., have signed a Partnership in Education Agreement. The agreement, which marks the beginning of a program for an exchange of resources and personnel for both Dogwood and the USGS, has benefits for teachers, students, and employees.

Under the agreement, the USGS will assist the school with special events, such as judging science and invention fairs and literature and essay contests. Employees will provide computer assistance and will develop a mentorship program that pairs students with employees. The bureau will also provide maps and audiovisual materials to the school. Dogwood School was chosen for the partnership agreement because of its proximity to the USGS—students can walk between the school and the National Center—and its designation as a special needs school by the Fairfax County Public Schools.

Other USGS offices around the country, many of which have had long-term informal relationships with schools in their local areas, are being encouraged to establish formal partnership programs like that with Dogwood School.

"Helping Your Child Learn Geography."—This new publication, available in 1990 and prepared cooperatively by the U.S. Department of Education and the USGS, is designed to help parents stir their children's curiosity about geographic knowledge. Suggested games and activities in the booklet assist parents in showing their children that learning geography is fun.

Earth Science for the Global Community.—A 1-day workshop for science teachers, part of Federal efforts to gear up for the 20th anniversary of Earth Day, focused on such timely earth science and environmental issues as global change, water quality, and natural hazards. Lectures at the USGS National Center focused on global environmental change, earthquakes and volcanoes, water quality, and ancient climates. Also, the teachers had an opportunity to talk with USGS scientists about exhibits and demonstrations on acid rain, coastal erosion, Arctic and Antarctic research, and the local geology of Virginia, Maryland, and the District of Columbia.

In April, USGS scientists in the San Francisco, Calif., area planted trees, including a living-fossil garden of redwoods, cycads, and ginkgos. They also presented lectures on topics such as climate change, water resources issues, and problems of arid environments.

As part of Earth Day events in Denver, Colo., USGS and other Federal employees at the Denver Federal Center worked on a wildlife enhancement area that will include an environmental education center featuring interpretive trails.

Women, Minorities, and Persons with Disabilities

This broad human resources initiative has long played an important role in addressing the needs of USGS employees. The strong program of liaison, training, and recruitment that the Survey has through the Department's Historically Black College and University program has been an important means of encouraging minority involvement in the earth sciences and in identifying career opportunities for minorities. Another project, the USGS Minority Participation in the Earth Sciences program, encourages women and minorities to develop an interest in the earth sciences and supports career opportunities.

The USGS has an admirable record in the employment of persons with disabilities, particularly those who are hearing impaired. In any given year, more than 1 percent of the appointees to the USGS work force have disabilities. Also, more than 1 percent of the disabled persons have disabilities that were targeted for special recruitment efforts. The current total USGS work force, of which more than 6 percent are persons having disabilities, continues to be among the highest in the Department of the Interior in the employment of persons having disabilities.

Because women and minorities have traditionally been underrepresented in the engineering and science fields, the USGS sees a special challenge in encouraging them to pursue an interest in the earth sciences. In the coming fiscal year, with the increase in funding to support Secretarial initiatives, the USGS is working to increase internal training for women and minorities, to target more positions in the upward mobility program, to seek more management development opportunities for women and minorities, and to promote career counseling that includes all series and grades.

Women's Forum.—A Women's Forum, in recognition of Women's History Month and cosponsored by the USGS, the Minerals Management Service, and the U.S. Department of the Interior, was held in Reston, Va. The forum provided an avenue for employees to discuss issues and concerns that affect the employment and advancement of women within the Department and to identify possible mechanisms for resolving those issues and improving the workplace.

Women's Program Established.—A concerted effort is being made within the USGS Geologic Division to establish women's programs and to diversify the work force at all levels. A Women's Advisory Committee was formed to represent the interests of all women employees in the division. Advice from the committee helps the division to improve the quality of the work environment and to take action to enhance the professional development of all women employees. Short-term rotational management assignments will expand opportunities for leadership experience. Other initiatives for all employees include formal mentorship and leadership development programs that emphasize the participation of women and minorities.

"Profile of Women at Work."—This publication of the U.S. Department of the Interior commemorates the significant contributions and achievements made by women in the Department. It is anticipated that the publication will attract more women to the broad spectrum of exciting job opportunities in the Department. The career successes of 24 women of the USGS, employed in positions from secretary to research geologist to information specialist, are recognized in this publication.

Computer Technology for the Handicapped.—The USGS participated in a national convention of the Association for Educational Communications and Technology (AECT) at which Amy Berger gave a presentation on the accessibility of computer technology for visually impaired persons and her own successful use of a speech synthesizer with her personal computer. Amy will serve on a new AECT committee that will address educational and computer technologies and their role in providing opportunities for specially challenged individuals.

Science Workshop at a Native American College.—A workshop at Haskell Indian Junior College in Lawrence, Kans., one of two Indian colleges nationwide, helped teachers extend their skills in science and mathematics teaching. The workshop was sponsored by the Bureau of Indian Affairs (BIA) and the USGS, along with support from other Interior bureaus and private industry. The USGS is also working with BIA in a program that will provide volunteer opportunities for BIA teachers to train with USGS scientists. In another effort, plans are underway to establish an electronic mail system through which teachers at BIA schools can ask questions of USGS scientists.

HBCU Workshop.—This year, the annual USGS Historically Black College and University (HBCU) workshop focused on applications of geographic information systems (GIS) and included presentations by faculty members who have used the technologies presented in previous workshops to enhance their course offerings and research. Experience in using GIS software was included in the workshop, which included representatives from 10 HBCU's located in the Eastern and Central States.

Unit Award for Excellence of Service and Minority Business Enterprise Award

Each year the U.S. Department of the Interior presents the Unit Award for Excellence of Service to those bureaus and (or) offices that have either met or exceeded all of their business and economic development program goals. In addition, the Department selects one bureau or office to receive the Annual Minority Business Enterprise Award for outstanding achievement in assuring minority business enterprise participation in Interior's acquisition programs.

At an awards ceremony in May 1990, the Deputy Secretary of the Interior, **Frank A. Bracken** (right, at left), presented both awards for fiscal year 1989 to the USGS Director, **Dallas L. Peck**, and to **Betty B. Brodes**, Business Utilization and Development Specialist, Office of Procurement and Contracts, Administrative Division. The USGS was recognized for its outstanding contributions and continuing support of the Department's Business and Economic Development Program.

TAMI HEILEMANN, DOI

Geologic Investigations

Transportation Planning and Geologic Maps

By Richard L. Bernknopf and John F. Sutter

Detailed, publicly accessible information about the character and origin of the geology of an area is an essential requirement for informed public policymaking and for profitable commerce. Many public-policy decisions and commercial enterprises require a specific kind of earth science information—that is, spatially based information that is linked to geologic materials and geologic structures. The geoscience product that captures and displays this kind of information is the general-purpose geologic map, the primary product of the National Geologic Mapping Program (NGMP).

The NGMP provides basic geologic information for use by Federal and State agencies, academia, and the private sector. The need for this information, in a user-oriented format and on a national scale, became evident in the 1980's as the Nation addressed national environmental and resource issues such as geologic hazards (earthquakes, volcanic eruptions, landslides, and coastal erosion), land use planning, critical facilities siting and management, waste disposal, and the use of mineral, energy, and water resources. How geologic map information can reduce the cost of highway construction and maintenance serves as an example of the practical benefits of geologic mapping.

Benefit-cost studies to identify the most cost-effective approach to the design and construction of road improvement projects are an important part of the public decisionmaking process. Route selection and capacity, for example, are based on many independent factors, each having its own associated costs. Because the geologic attributes of land parcels affect political, environmental, and engineering variables, geology has an impact on the costs of road construction and maintenance. All too often, however, costs associated with local geology normally are considered only after the route has been selected or the extent of improvement has been determined. Unforeseen problems, such as the ease with which a road cut can be excavated, slope setback, or swelling soils (soils that expand when saturated and cause pavement failure), therefore, generally are not considered fully in predevelopment cost estimates. Depending on the terrain, these geologic factors can contribute significantly to costs.

The case of the proposed Washington, D.C., Bypass illustrates how digital NGMP geologic map information can be helpful in reducing potential losses and costs to the public. As part of an ongoing study to estimate the economic value of general-purpose geologic map information, the Washington, D.C., Bypass was selected as a pilot study to demonstrate the value of geologic data to highway construction.

The Proposed Bypass

A draft environmental impact statement (DEIS) of the Washington Bypass has been prepared by the U.S. Department of Transportation, Federal Highway Administration (FHWA), Maryland State Highway Administration, and Virginia Department of Transportation. According to the FHWA, the Washington Bypass is a proposed interstate-type highway that would bypass the Washington, D.C., region and provide additional roadway capacity to the area.

The proposed action consists of an eastern bypass, a western bypass (the USGS study only applies to the western bypass), or both. The jurisdictions affected by the planned bypass are the States of Maryland and Virginia and the cities of Washington and Baltimore. Twenty-three counties, or portions of counties, are included. Figure 1 shows the location of Loudoun County, Va., and the alternative western bypass routes being considered (see table 1 for detailed costs for each of the routes).

The Geologic Framework

The Loudoun County population, commercial base, and road network mirrors the underlying geologic framework. The western portion of the county (west of US 15) is a complex group of igneous and metasedimentary rock of the Blue Ridge province (fig. 2). The soils, slopes, and water resources of this area are natural limitations to economic development unless there is significant alteration of the subsurface (including the import and

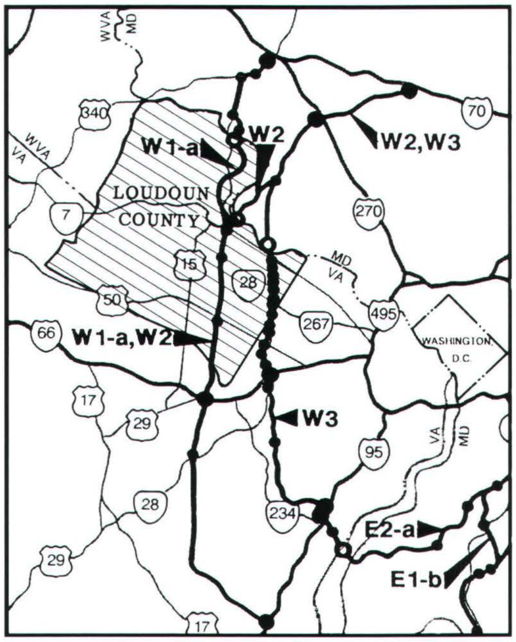
Mission

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.*
- *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, with particular emphasis on strategic and critical minerals.*
- *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.*

Figure 1. Composite of alternative routes and the location of Loudoun County, Va. (from DEIS, FHWA).

ALTERNATIVES	W1–a	W2	W3
LENGTH IN MILES	77	82	65
NUMBER OF INTERCHANGES	11	9	20



export of waste materials). East of the US 15 corridor, the county plan delineates large tracts of land for intensive regional growth. These parcels are underlain by a sedimentary sequence of conglomerate, red siltstone, claystone, and sandstone (fig. 2) that are faulted and interlayered with massive basalt or intruded by diabase dikes and sills.

All proposed western bypass corridors cross through the eastern part of Loudoun County. The road lengths of the alternative routes in Loudoun County (fig. 1), range from 5.6 miles to 25 miles, and the terrain is flat to rolling. The engineering workability (that is, ease of excavating the surficial geologic materials) of the routes varies considerably (fig. 2) from easy (siltstone) to difficult (diabase and metamorphosed conglomerate).

Economic Factors

All three alternatives would result in an increase in population, number of households, and the level of employment in Loudoun County. Including geologic information in the consideration of alternatives, however, changes the benefits of the western bypass. The total benefits of the western bypass, as estimated in the DEIS, are based on

Table 1. Costs of building the western Washington, D.C., bypass
[From Washington Bypass DEIS, FHWA, 1990]

Alternative	Length (in miles)	Costs (in millions of dollars)[1]			
		Construction	Right-of-way	Engineering, planning, and overhead	Total
W1-a	76.5	$ 980.0	$170.0	$260.0	$1,410
W2	82.0	1,060.0	160.0	280.0	1,500
W3	66.0	1,210.0	180.0	320.0	1,710

[1] Dollar values are at 1990 levels.

Table 2. Projected employment and property tax revenues by 2010 in Loudoun County, Va.
[From Washington Bypass DEIS, FHWA, 1990]

Alternative	Employment[1]	Property tax revenue (in thousands of dollars)
W1-a	106,436	$119,519
W2	116,951	130,012
W3	116,818	126,281
No bypass	98,329	109,030

[1] Figures are the number of jobs above the 1985 base of 23,297 jobs.

an increase in the population, number of households, level of employment, and property taxes (see table 2).

Costs without geologic map information.—The cost estimates for the various Washington Bypass alternatives were developed in the DEIS for items that determine average construction and right-of-way costs (table 3). Unit cost values, such as cost per mile or cost per acre, were determined for each of the cost elements. Preliminary engineering, planning, and overhead costs were estimated by using percentages of the construction and right-of-way costs. Maintenance costs, which were not included in the DEIS, may be considerable in Loudoun County where swelling soils will have a substantial impact.

The DEIS is based on a simplifying assumption that all subsurface geologic conditions are the same and that costs related to changes in geology do not vary among corridor options. This is simply not true, as shown in figure 3. Instead, costs will vary considerably by route, and the cost variations due to geology increase the total cost because the DEIS is based on the least troublesome geology. Therefore, the benefits of the highway are reduced because unexpected costs or losses due to uncertain physical conditions along the route can be encountered during the construction phase of the highway. For example, the presence of diabase materials is a strong indication of the presence of unweathered bedrock near the ground surface. This type of rock unit requires extensive blasting, which significantly increases construction costs. Diabase is found throughout the eastern portion of Loudoun County (fig. 2). On the other hand, swelling soils, also found in the eastern part of the county, do not significantly increase construction costs but do cause substantial maintenance costs. As illustrated in figure 3, both diabase and swelling soils occur along each route and are separated by very short distances.

Costs including geologic map information.—The Washington Bypass DEIS contains estimates of the total cost of alternative highway routes that are based mainly on topographic and hydrologic data. However, it is geologic map information that improves cost effectiveness when used in public-policy decisions that include prior planning for mitigation of natural hazards and when making route selections.

The relations among the geology, engineering characteristics of the soils, and weathered rocks of Loudoun County can be combined with demographic and economic data to present a more complete picture. This approach demonstrates how geologic map information is useful in two ways. First, geologic information can be influential in the planning and preliminary engineering steps. Since DEIS preliminary engineering and overhead costs were estimated as a percentage of roadway, structure, and interchange costs and on the basis of discussions with the FHWA, we assume a 1 percent reduction in the percent allocated to these costs with the addition of geologic information. Second, the geologic information is useful in improving the selection of alternative routes on the basis of construction and right-of-way costs (fig. 3).

The benefit of the geologic map information is that it can improve the accuracy of

Table 3. *Expected costs of building the Loudoun County portion of the western Washington, D.C., bypass with and without geologic information*

[From Washington Bypass DEIS, FHWA, 1990]

Alternative	Length (in miles)	Costs (in millions of dollars)[1]					
		Construction[2]	Right-of-way[3]	Engineering, planning, and overhead		Total	
				With	Without	With	Without
W1-a.....	25.1	$165.8	$55.5	$78.2	$88.7	$299.5	$310.0
W2.......	15.2	99.7	29.6	46.5	52.4	175.8	181.7
W3.......	5.6	36.9	15.5	17.8	20.1	70.2	72.5

[1] Dollar values are at 1990 levels.

[2] Unit construction costs: $2.48 million per mile for the no-geology case for all alternatives; $2.54 million per mile for geology case W1-a due to the terrain; $2.52 million per mile for geology case W2 due to the terrain; $2.54 million per mile for geology case W3 due to the terrain.

[3] Unit right-of-way costs: $0.85 million per mile for W1-a; $0.75 million per mile for W2; $1.07 million per mile for W3.

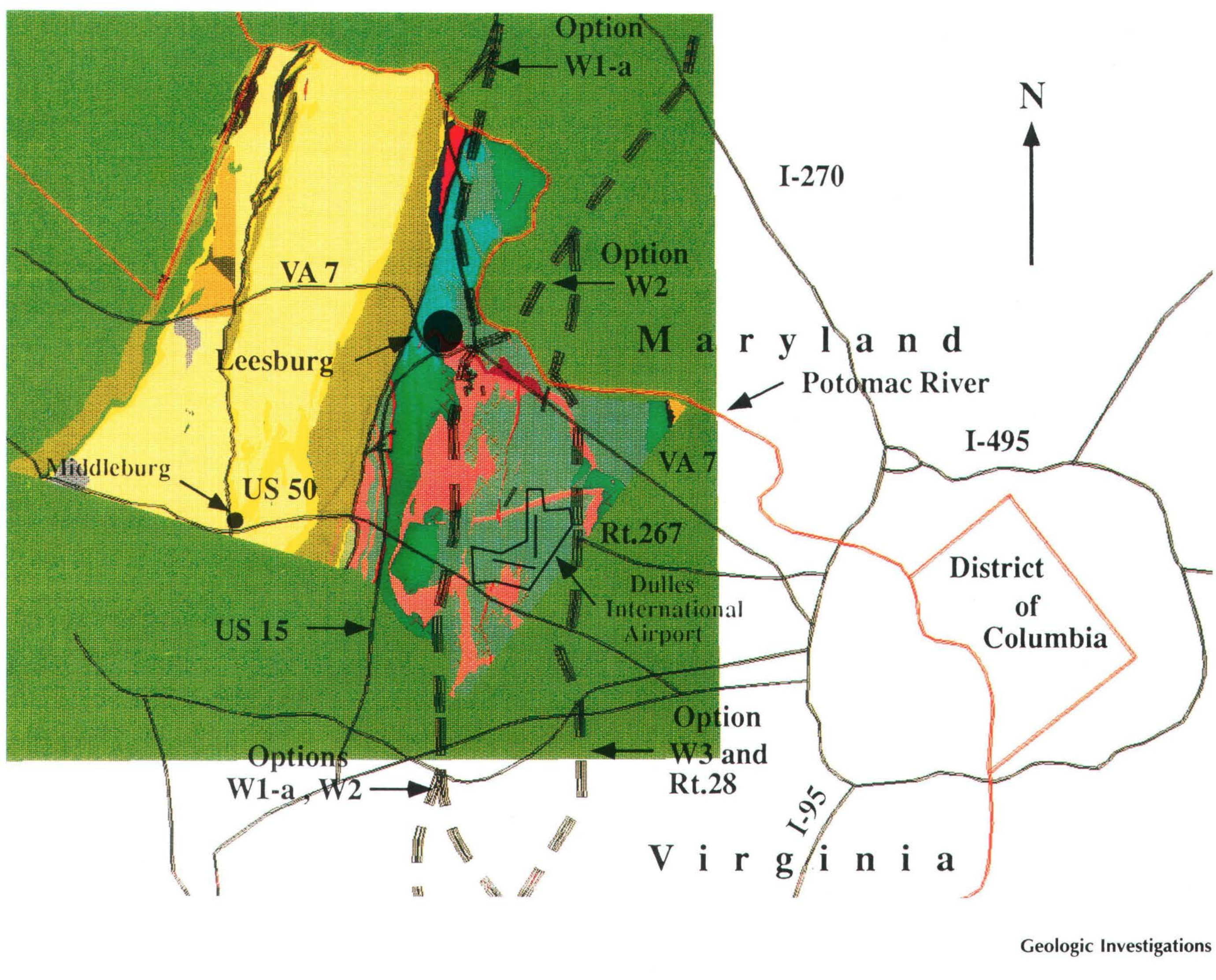


Figure 2. *Proposed western bypass corridors and selected existing transportation corridors superimposed on a digital geologic map of Loudoun County, Va. In the western part of the county, yellows, browns, and greens represent the igneous, metaigneous, and metasedimentary complex of the Blue Ridge province. In the eastern part of the county, pink represents diabase and basalt, greens represent sandstone, siltstone, and claystone (swelling soils), and blue represents conglomerate.*

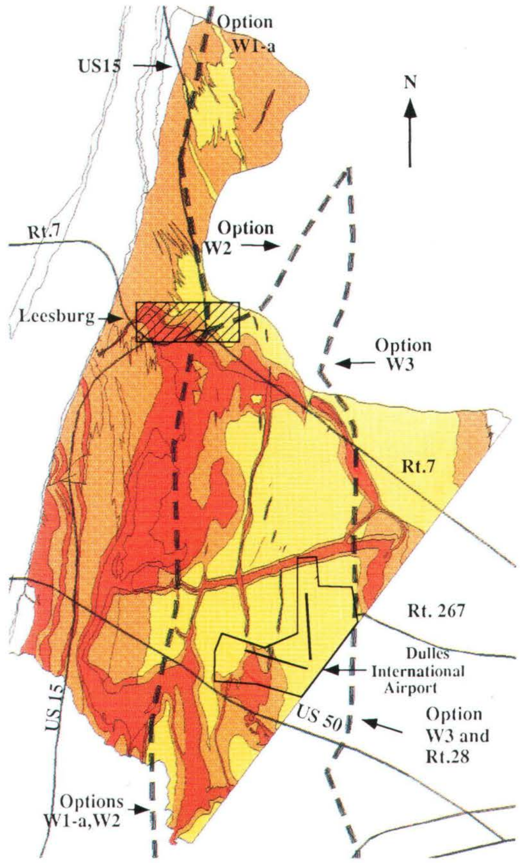


Figure 3. *Digitally produced, derivative map of eastern Loudoun County showing the percent difference in construction costs as geologic units change (yellow, 0 percent difference; orange, 5 percent increase; and red, 10 percent increase). Superimposed are the proposed western bypass corridors and existing major transportation routes.*

cost estimates of road development. The geologic map information used for this case study was acquired and digitized for $1.2 million. With the geologic information as a fact in the cost estimates, the change in total costs for the Loudoun County segment of the Washington Bypass is a savings of $10.5 million for W1-a, $5.9 million for W2, and $2.3 million for W3.

The difference between the total costs of each route with and without geologic map information illustrates the benefit of using geology in planning and development. Geologic maps provide decisionmakers with a tool, in this instance, for determining which route is the best for the county and, in general, for solving many land use, natural hazard-management, and mineral and energy resources issues.

World Energy Resources Assessment

By Donald L. Gautier and Charles D. Masters

During the summer of 1990, political developments in the Middle East and rapidly rising gasoline prices bluntly reminded the people of the United States of their precarious petroleum-supply situation. While domestic production continues to decline, increasing imports, added to by growth in demand for crude oil, now amount to about 50 percent of supply. The United States, having one-twentieth of the world population, consumes more than one-fourth of total world crude oil production. Oil-producing countries of the Middle East increasingly will dominate world petroleum supply.

The Organization of Petroleum Exporting Countries (OPEC) produced about one-third of the world's oil supply in 1990, but their share is increasing and is expected to exceed 50 percent by the year 2010. Within OPEC, oil production from proven reserves and supporting undiscovered resources will be dominated by countries of the Persian Gulf well into the 21st Century.

Crucial decisions will have to be made in the United States concerning energy conservation, new technologies, use of strategic supplies, exploratory drilling, and the use of coal, nuclear, and nonconventional energy sources. Despite the indisputable dominance of Middle East oil reserves, additional sources of oil exist, and it is in the interest of the world's consumers that oil supplies remain geographically dispersed to as great a degree as possible. Countries such as Venezuela, the U.S.S.R., China, Indonesia, and Nigeria are large oil producers, and other countries may also become contributors to world oil supply. Energy strategies require a clear understanding of the potential for additional sources of petroleum to the U.S. energy supply. This understanding depends upon reasoned and credible estimates of the undiscovered oil and gas resources of the United States and the world.

The World Energy Resources Program (WERP) of the USGS was established to provide an unbiased assessment of the occurrence of world oil and gas resources. The WERP is the only Federal program that makes such assessments, and the assessments are made available to all government agencies and to the public. The program was developed to coordinate with the Federal Energy Supply Assessment Program of the Energy Information Administration, an Energy Department program that focuses on determining world reserves of oil and gas. In recent years the WERP has conducted several assessments of the world's undiscovered oil and gas resources, and the results have been presented to the World Petroleum Congress.

The World Petroleum Congress, a quadrennial technical meeting, was established in 1933 to give the international exploration and production industry a perspective on world petroleum activities, capabilities, and resource potential. Congress membership is held by countries, petroleum companies, and interested professional groups. The 13th Congress will be held in Buenos Aires, Argentina, October 1991, under the theme of New Horizons for the Petroleum Industry—Technical and Economic Challenges and Opportunities.

The WERP continuously conducts assessments of oil and gas resources on a region-by-region basis. Regions are selected according to their significance to world petroleum supply. The assessments are supported by background information from various types of topical and regional studies. Recent accomplishments include a study of the petroleum geology and resources of Antarctica, a report on the petroleum resources of West Siberia, a petroleum basin map of China, and a USGS bulletin on the distribution of major petroleum source rock and its relation to discovered occurrences of oil and gas and to plate tectonics.

The world petroleum source rock study concluded that the bulk of the world's discovered petroleum has come from several comparatively thin sequences of source rock deposited during a relatively small fraction of geologic time. For example, two intervals during the Cretaceous Period (138 to 63 million years ago) are responsible for more than 54 percent of all the world's petroleum. Future work may identify additional oil source rock that has generated significant amounts of petroleum.

During 1990, the WERP has become increasingly integrated with the USGS Domestic Resource Appraisal Program. This integration is necessary to meaningfully place domestic resources in the context of world petroleum supply. The WERP initiated cooperative projects in several areas of the world to investigate oil and gas resources of critical regions where resources are large and geologic uncertainties exist. In particular, cooperative projects with scientists of the U.S.S.R. Ministry of Geology will redefine categories and methods of resource assessment and improve our estimates of the resources and reserves of the Soviet Union. Similarly, cooperative projects with Saudi Aramco will develop a program of mutually beneficial topical research that will update assessments of the undiscovered resources of the Arabian Peninsula and Persian Gulf. Discussions of program cooperation with other countries, including Norway and Venezuela, will further enhance our global petroleum resource understanding.

Tapping the Potential Mineral Resources of Alaska

By Donald J. Grybeck

For more than a century, the favorable potential of Alaska's mineral resources has been cited in the popular and professional press, by politicians, by geologists and mining engineers, by industry, and by many in the public and private sectors. Since systematic work began in Alaska in 1895, the USGS has devoted a major share of its work to defining those mineral resources.

The several large mines that have come into production in Alaska within recent years may signal a promising future for the Alaskan mining industry. Future mining activity depends on identifying undiscovered deposits and delineating other deposits that, while known, have not yet been measured with any assurance. Undiscovered deposits are those that cannot now be identified and are thus by definition individually unpredictable in their size and location. While many mineral deposits are already known in Alaska, only one in several hundred will ultimately prove to be mineable.

How can one predict the number of undiscovered deposits in Alaska? One technique is by geologic analogy; that is, study the geology of a given area and predict the number of undiscovered deposits by considering the type of deposits that are likely to occur based on known deposits, worldwide, that have comparable geology.

Other predictions can be based on the number and type of mineral deposits found during exploration. Some examples are the discovery of the Red Dog zinc-lead-silver deposit in the western Brooks Range in 1968 (now the largest zinc mine in the world), the Greens Creek lead mine on Admiralty Island in 1973, and the U.S. Borax molybdenum deposit in southeastern Alaska in 1974—all in areas not previously known to be mineralized.

OSWALD W. GIRARD, JR.

COMINCO's "Red Dog" watches over zinc-lead-silver production at the company's mine and processing facility in the Brooks Range, Alaska.

OSWALD W. GIRARD, JR.

Red Dog mining waste disposal area. Close scrutiny shows a lone caribou at center.

These discoveries indicate that more large mineral deposits are yet to be found in Alaska.

Another predictive method is to compare the mineral production of Alaska with that of other producing regions. For instance, most Western States have produced many times more metals per square mile than Alaska has produced or even contains in known deposits. The unavoidable conclusions are that Alaska almost certainly contains numerous undiscovered metal deposits and that some of them probably will be of world-class dimensions.

The process of assessing Alaska's mineral resources and the subsequent mineral exploration and development of those resources follows a series of steps:

1. Regional geologic analysis of the State or large areas,
2. Definition of areas of mineral potential,
3. Systematic studies, usually for specific types of deposits, in selected areas,
4. Detailed studies of deposits or mineralized areas, usually by drilling,
5. Detailed economic, logistical, and metallurgical studies of selected deposits that have the potential of becoming a mine, and
6. The actual development of the property into an operating mine.

The USGS is primarily concerned with the first four steps of the process, and, in Alaska, has an active role in the first two steps, in particular, geologic mapping and mineral-resource assessment at the regional scale. Detailed studies of selected areas and deposits establish the scientific framework for studying mineral deposits. Development of mineral deposits into actual mines is carried out by private industry aided by the U.S. Bureau of Mines.

At this time, about 30 to 40 percent of Alaska has potential for undiscovered mineral deposits; however, less than 1 percent of Alaska will contain mineable mineral deposits. A mineral deposit, even one that can be developed into a world-class mine, is usually difficult to locate. Many deposits are concealed by tundra and soil or are buried beneath glacial drift or other transported materials. Sophisticated exploration techniques and considerable work are necessary to locate them.

Currently, most USGS Alaskan regional mineral-resource work leading to the identification of deposits is being carried out under the Alaska Mineral Resource Assessment Project (AMRAP). AMRAP, a component of the National Mineral Resource Assessment Program, includes systematic multidisciplinary studies of 1:250,000-scale quadrangles. Geologic mapping, geochemical techniques using sophisticated analyses of stream sediments, soils, and heavy minerals concentrated in streams, and geophysical techniques that measure the magnetic and electrical properties of rocks and mineral deposits are the primary methods used to generate data for a mineral assessment.

In most quadrangles, 3 to 4 years are necessary to collect and synthesize field data into a regional mineral-resource assessment. The goal is to define those areas that have mineral potential, to assemble all the geologic and mineral deposit data for the quadrangle in a usable form, and to predict the number and size of undiscovered deposits. To date, AMRAP studies have been published or are now in press for 38 of the approximately 100 1:250,000-scale Alaska quadrangles that have mineral potential. An additional 16 quadrangles are under study.

In 1981 Congress passed the Alaska National Interest Lands Conservation Act (ANILCA). Among the many provisions of the act, Section 1010 charged the Secretary of the Interior with assessing the mineral potential of all Federal lands in Alaska. That responsibility has been delegated to the USGS and the U.S. Bureau of Mines. ANILCA placed land management responsibilities for most of Alaska's Federal lands with the National Park Service, the U.S. Fish and Wildlife Service, the Bureau of Land Management and, in the Department of Agriculture, the U.S. Forest Service.

These agencies are engaged in extensive land use planning, and the estimated value of mineral resources is usually factored into these plans. Thus, in addition to the traditional clients for minerals information (industry and the public), Alaskan land managing agencies increasingly need up-to-date, comprehensive mineral-resource data for their lands. For example, the USGS currently is working with the Bureau of Land Management to assess the geology and mineral potential of the southern part of the National Petroleum Reserve in northwestern Alaska and with the U.S. Forest Service in assessing the mineral potential of the Tongass National Forest in southeastern Alaska.

Common metallic minerals, such as gold, silver, copper, molybdenum, lead, and zinc, are known or are likely to be present in major quantities in Alaska. However, another class of minerals in Alaska is especially important to the Nation. This class, the strategic and critical minerals, includes mineral commodities that play a critical role in modern technology or are largely imported from foreign sources. Among these minerals are the platinum-group elements, tin, chromium, manganese, and certain rare-earth elements, commodities that are essential in the production of steel alloys, as chemical catalysts, and in the semiconductor industry.

Many of Alaska's known deposits have potential for these strategic and critical minerals. Strategic minerals in Alaska have been mined intermittently in the past, usually during periods of war or international unrest. The USGS and the U.S. Bureau of Mines currently have plans for an expanded program of research on Alaska's strategic and critical minerals, not only to better understand and inventory known deposits but also to search for new deposits. The improved information will serve the Nation during periods of national emergency and identify new sources of strategic and critical minerals to make the United States less dependent on foreign sources in the future.

Idaho National Forest Roadless Areas

By Ronald G. Worl

The USGS, U.S. Bureau of Mines (USBM), and Idaho Geological Survey (IGS) are conducting joint mineral resource studies of roadless public lands in Idaho. These public lands may be included in the National Wilderness System. The studies will provide geological, geophysical, geochemical, mining, and mineral deposit information on roadless public lands that will benefit the domestic mining industry and other users of earth-science data responsible for making informed land use decisions. The roadless areas under study are located mainly within central Idaho in areas underlain by the Idaho batholith, a large composite granitic intrusive body, which is 70 to 95 million years old, and by younger granitic rock, which is about 50 million years old.

Defining the geologic setting of the mineral deposits and determining the extent of the important mineral-bearing terranes are the focus of the geologic studies. This 3-year (fiscal years 1989–91) program of geologic mapping by the USGS and IGS will complete 1:100,000-scale geologic maps for most of the previously unmapped roadless areas. The IGS, with funding from the USGS, is mapping more than 3,000 square miles of ground in the Elk City and Hamilton 1° × 2° quadrangles. Studies in the Edwardsburg and Profile mining districts indicate that known mineral deposits are aligned along a major shear zone that extends through one of the proposed wilderness areas.

The proximity of many of the known gold deposits to 75-million-year-old two-mica granite has been shown in several areas. Gold in large placer deposits in the Warren and Florence mining districts, for example, was derived by weathering and erosion of networks of precious-metal-bearing quartz vein and veinlets emplaced near the upper boundary of two-mica granite bodies and overlying rock.

Field interpretation of these regional geophysical data indicates that magnetic highs correspond to the younger granitic intrusive rock, some of which is mineralized. Several regional magnetic and radiometric highs indicate the presence of granitic intrusions that are not exposed. The regional gravity data indicate that younger granitic rock underlies more of central Idaho than was previously recognized. Site-specific studies include geoelectrical surveys of possible deep-seated fracture systems and gravity surveys in areas that may contain unrecognized intrusive bodies.

Interpreting existing geochemical data from the Challis area led to the delineation of 10 areas that contain significant amounts of cobalt in stream sediment samples. Four of the areas are associated with exposures of the more than 1-billion-year-old Yellowjacket Formation, a known host for cobalt deposits elsewhere. Six are in the Bayhorse area and are underlain by 45-million-year-old volcanic rock not known to host cobalt deposits.

Site-specific geochemical surveys show that black shales and mafic dikes in the Borah

Peak area may host unrecognized mineral deposits. Samples of black shale contain anomalous amounts of molybdenum, silver, and zinc, and heavy-mineral concentrates of stream sediment collected throughout the area contain significant amounts of barite. Metals associated with the mafic dikes include chromium, nickel, cobalt, and copper. In the Smokey Mountains area, anomalous amounts of gold were found in heavy-mineral concentrates from a cluster of sample sites in an area of about 10 square miles. Studies of stream sediment and mechanically panned concentrate samples in the northern Lemhi Range led to the discovery of a large area containing anomalous amounts of gold.

Detailed mining area studies by the USBM have delineated several locations where known mineral resources occur within roadless areas that are being considered for inclusion in the National Wilderness System. The areas are within or next to the Profile, Edwardsburg, Warren, Relict, Big Smoky, and Skeleton Creek mining districts. Known resources in these areas include gold, silver, lead, and zinc.

Several mineral deposit models are being developed or revised for the assessment of undiscovered deposits in Idaho roadless areas. Two types of productive gold vein deposits have been recognized—massive quartz veins and complex quartz veins. The massive quartz veins are characterized by several generations of quartz deposition, simple mineralogy, and close proximity to two-mica granites. The structural setting of this deposit type is along major fracture systems formed by compression in the Earth's crust. These deposits formed 78 to 57 million years ago at depths of 5 to 10,000 feet. The complex quartz veins are characterized by open-space quartz filling, the presence of numerous complex minerals, and close proximity to felsic dikes. The structural setting of this deposit type is along major fracture systems formed by tension in the Earth's crust. These deposits formed 50 to 25 million years ago at depths of less than 4,000 feet.

Summary reports on the accomplishments of all studies under this plan will be prepared jointly by the three agencies at the end of the project in fiscal year 1991. The summary reports will include maps showing areas of known mineral resources, maps showing areas that have potential for undiscovered resources, descriptions of mineral deposit types, and an estimate of the number of undiscovered deposits in terranes delineated as having potential for selected mineral deposit types.

Voyage of the Century—Neptune and Triton

By Laurence A. Soderblom, Randolph L. Kirk, and Alfred S. McEwen

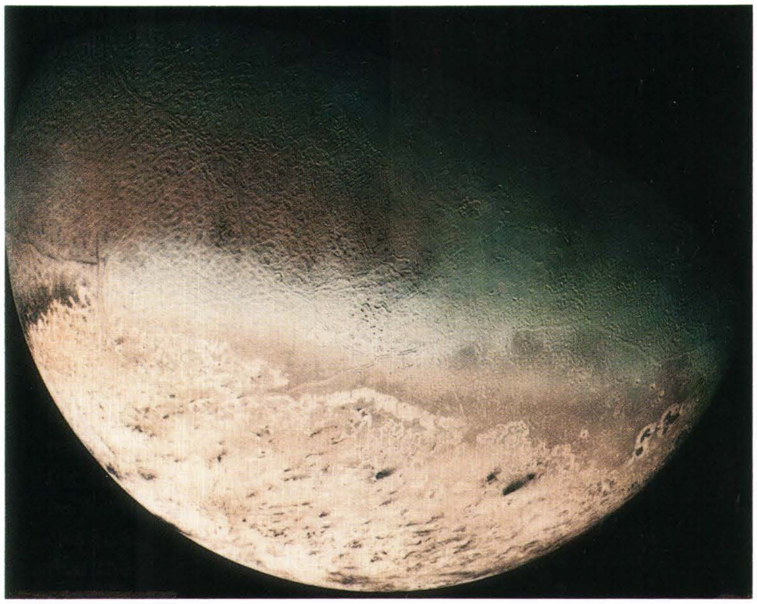
More than 12 years after its 1977 launch, the Voyager 2 spacecraft completed its fourth and final planetary encounter—the flyby of Neptune and its large companion satellite Triton—in August of 1989 (fig. 1). The Voyager spacecraft have provided the reconnaissance exploration of the major part of the Solar System and have revealed a diversity of planets, moons, and rings that is almost beyond comprehension. Voyager has been the premier extraterrestrial exploration of the twentieth century.

The Voyager project, conducted by the Jet Propulsion Laboratory (JPL) of the National Aeronautics and Space Administration, has been a coordinated effort of Federal agencies, industries, research institutions, and universities. USGS scientists participated with JPL scientists in planning and executing data gathering efforts and analyzing the resulting information from the Voyager encounters of Jupiter, Saturn, Uranus, and Neptune. USGS scientists also mapped and analyzed the surfaces of the 57 known outer-planet moons, 17 of which were discovered by Voyager. The largest of the outer-planet moons—the four Galilean satellites (at Jupiter), Titan (at Saturn), and Triton (at Neptune)—are about the size of Earth's moon. In addition, Voyager recorded the surfaces of 12 medium-sized moons orbiting Saturn and Uranus. Each of these moons were revealed to be unique and varied worlds, and they have increased the number of bodies available for comparative planetary geologic study from 5 (Mercury, Venus, Earth, Moon, and Mars) to 23.

Triton provides some of the major surprises of the Neptune flyby in that it has an unusual and geologically young surface and at least two active geyserlike plumes (fig. 2). A huge polar cap, probably composed of nitrogen and methane ice and frost, covers almost the entire southern hemisphere of Triton. The cap has a slight reddish tint, possibly due to the presence of organic compounds produced from methane and nitrogen by the actions of photochemistry and energetic particle bombardment. A very bright and slightly bluish fringe occurs around the margin of the cap and probably consists of fresh nitrogen frost or snow.

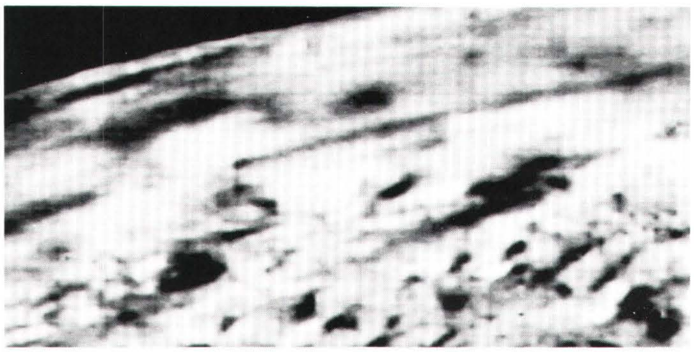
Northward of the polar cap, the surface has a variety of exotic terrains. The relatively low number of impact craters attests to the geologic youth of the surface. The western hemisphere is dominated by a dense concentration of pits crisscrossed by ridges, dubbed the cantaloupe terrain. The eastern hemisphere consists of a series of much smoother units, including calderalike structures. These structures appear to be frozen lakes and are surrounded by successive terraces indicative of multiple episodes of flooding and collapse.

The numerous, dark northeast-trending streaks seen on Triton's south polar cap are similar to wind streaks on Mars. However, some Voyager scientists doubt that Triton's tenuous atmosphere, exerting only 1/100,000 the atmospheric pressure at sea level as that on Earth, is sufficiently dense to entrain particles from the surface. These scientists propose that the streaks are the result of geyserlike venting of gas particles (fig. 2). Triton's nitrogen frost migrates from pole-to-pole every 80 years as the subsolar latitude varies ±50°; therefore, the dark streaks are probably less than 80 years old. The presence of more than



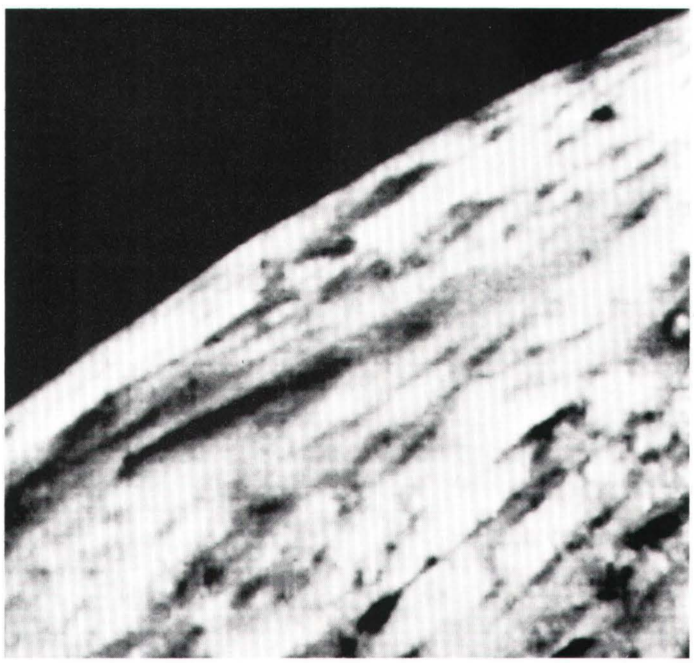
NASA/USGS

Figure 1. *Color mosaic of the portion of Triton imaged at high resolution (about 0.6 mile) in an orthographic projection. Part of Triton's huge south polar cap includes dark streaks thought to be due to recently active geyserlike eruptions. The cantaloupe terrain and smooth flooded areas are visible.*



NASA/USGS

Figure 2. *Profile views of Triton's active geyserlike plumes. These views are of regions in the southern portion of Triton (south is up, west is to the right). The plumes are about 5 miles high, and the east-west dimension of each view is about 93 miles.*



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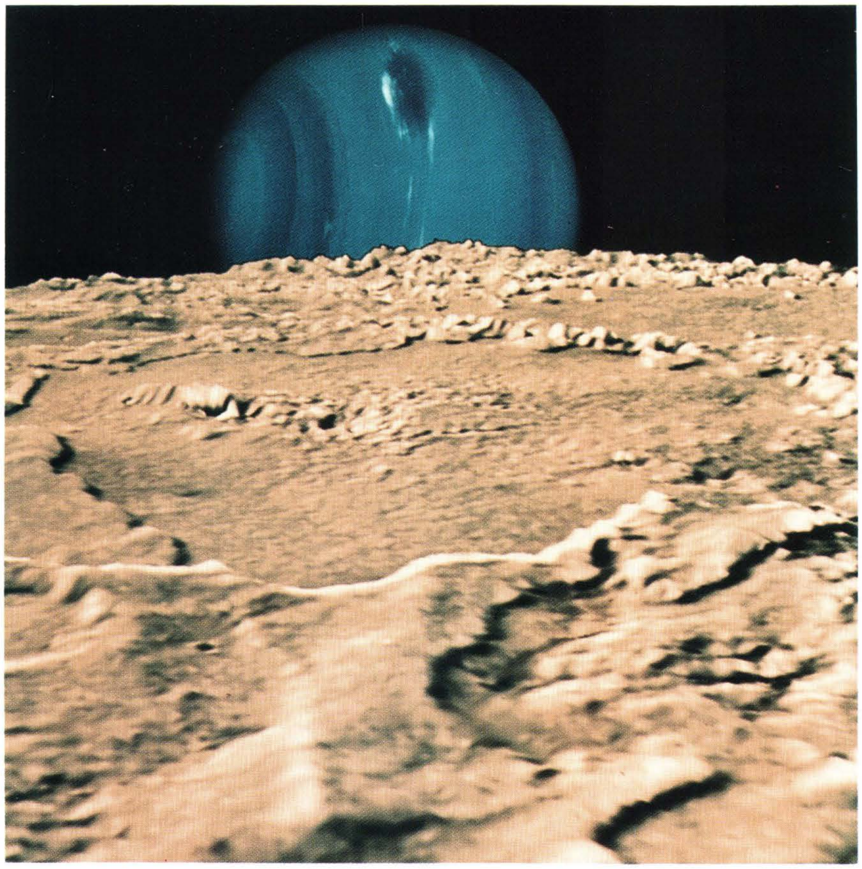
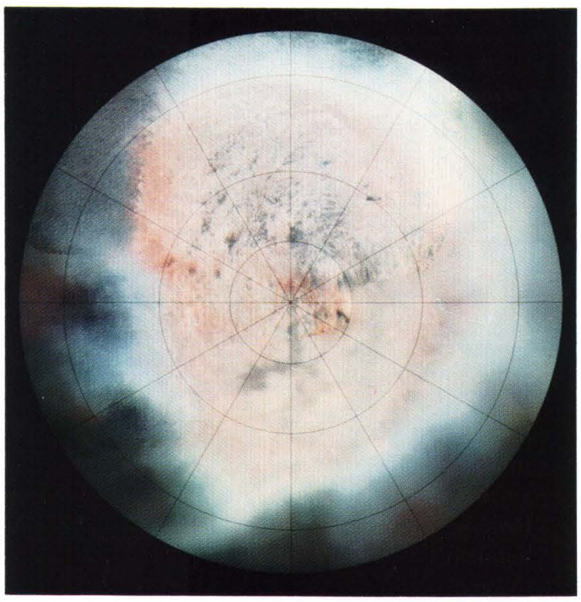


__Figure 3.__ Composite view showing Neptune on the horizon of Triton. The Neptune disk shows a great dark spot (the south pole is to the left). The foreground is a computer-generated view of Triton's icy volcanic plains as they would appear from a point about 28 miles above the surface. The terraces indicate multiple episodes of flooding, freezing, and collapse. This view was computed from a Voyager image and a photoclinometric topographic model. Topographic relief has been exaggerated about thirty fold; the actual difference in elevations is about 0.6 mile.

__Figure 4.__ Color mosaic of Triton in polar stereographic projection, centered on the south pole. Grid indicates 30° intervals of longitude and latitude. The entire south polar cap and bright fringe are visible. Diffuse bright rays extend north-northeast for hundreds of miles and emanate preferentially from the points of the scalloped cap margin. These rays probably consist of fine-grained frost or snow from the bright fringe that was redistributed by prevailing northerly winds.



100 such streaks suggests ongoing venting activity.

Other conclusive evidence exists for active venting. By reprojecting and coregistering images acquired at different viewing angles, a match was found for all of the features except two sets of long westward-trending dark streaks. The offsets between the paired images of the streaks indicate that these materials are located about 5 miles above the surface. Closer inspection of the images reveals vertical eruption columns extending from the surface to the eastern ends of the streaks. Apparently, these are active geyserlike eruptions in which plume material rises vertically for about 5 miles before being carried downwind above the transition zone between the troposphere and the stratosphere.

Images of Triton's complex surface became the highlight of the Voyager and Neptune flyby (figs. 3 and 4). About 50 high-resolution images of Triton were acquired during a complex sequence that commenced 8 hours prior to the close flyby of the moon on August 25, 1989. These images were taken through various color filters, at different resolutions, and from rapidly changing spacecraft positions.

The computerized processing of such a data set is complex, and, in the past, months or years have been required to produce high-quality digital cartographic mosaics. For the Neptune flyby, however, USGS personnel were able to assemble a suite of high-resolution, multispectral, geometrically controlled digital mosaics in less than 3 days, which gave the public their first glimpse at this new world. In addition, the USGS, working in collaboration with the JPL Digital Animation Lab, generated a three-dimensional time-lapse simulation of Triton's bizarre surface as it would be viewed by a spacecraft descending over the surface.

Final maps of Triton are being prepared, and the USGS is working with the International Astronomical Union to assign names to the many new features. The USGS also plans to publish a geologic map of Triton. Planetary geologic maps are used to gain an understanding of the processes now active on other planets that may have been active on Earth during its formation. Geologic maps also are essential for future planetary exploration that includes manned or unmanned spacecraft landings.

Water Resources Investigations

Flooding in the Arkansas, Red, and Trinity Rivers

By Kenneth L. Wahl

In spring 1990, unusual amounts of rain produced record or near-record flooding during April and May in northeastern Texas, southeastern Oklahoma, western Arkansas, and along the Red River in Louisiana. The flooding was the culmination of an extremely wet winter and early spring. In Oklahoma, the statewide average precipitation for the first 4 months of 1990 was the largest January to April total reported since record keeping began in 1892; the 4-month total exceeded the previous high for the period by about 15 percent. The Dallas-Fort Worth Airport reported total precipitation for January to March of 22.05 inches, 129 percent above normal.

These extremely wet conditions were conducive to extensive flooding: by mid-April, soils were saturated, flows in the principal river systems were already near flood stage, and reservoirs and lakes were at or near capacity. Because of these conditions, two major storm sequences in late April and early May produced widespread flooding and caused new record high levels in most major lakes and reservoirs in the area.

From April 16–26, a series of slow-moving storms developed along a storm front that was centered over southeastern Oklahoma and extended into northern Texas and western Arkansas. These storms produced more than 8 inches of rain over the area, and more than 15 inches were reported at several locations southwest of Dallas, Tex. The late-April rains, which fell on already saturated soils, produced widespread flooding; many rivers and streams crested on April 25 or 26. On the morning of April 30, as the floods were beginning to recede, an abnormally strong, cold air mass moved across the region. The leading edge of this cold air mass stalled on a line from northern Texas to southwestern Arkansas, and the system remained stationary until May 3.

During these 4 days, the warm moist air being lifted over the cool stationary front produced torrential rains that caused record flooding in northern Texas, southeastern Oklahoma, and western Arkansas. Rain continued sporadically through mid-May. Total precipitation from April 15 to May 19 averaged more than 16 inches over the affected

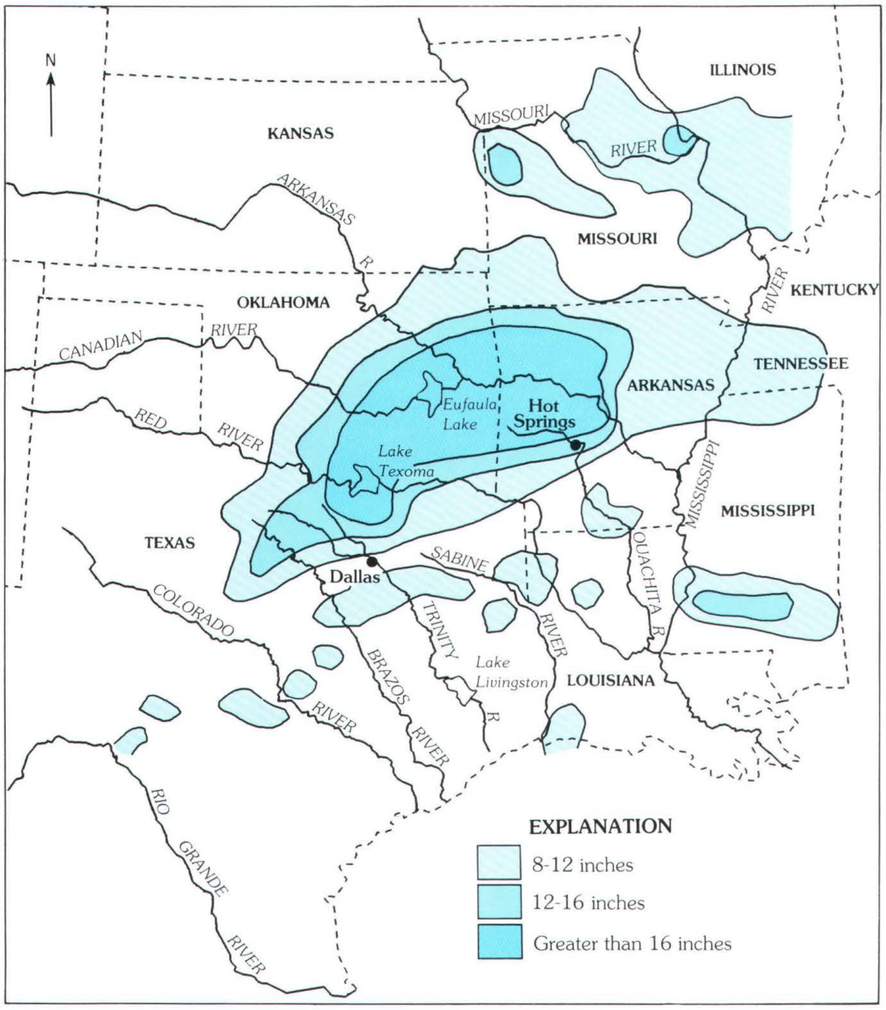
DALE BOYLE

Red River at Arthur City, Tex., on May 7, 1990, shortly after flood crest of 34 feet.

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.*



Total precipitation (in inches) for April 15 through May 19, 1990 (modified from Weekly Weather and Crop Bulletin, published by NOAA–USDA Joint Agricultural Facility).

area and more than 24 inches on the Arkansas-Oklahoma State line. Rainfall recorded at numerous individual precipitation stations, however, greatly exceeded the averaged amounts.

New record-high flows occurred at many streamflow gaging stations because of the early May storm. Flooding equal to or greater than the 50-year recurrence interval occurred in streams originating in the areas of greatest precipitation; floods of the magnitude of 100-year or greater recurrence-interval floods occurred on many streams. A recurrence interval is the probability of occurrence and the average number of years between occurrences; for example, a 100-year flood, on average, is the flood magnitude that occurs in a 100-year period. Regularity of occurrence, however, is not implied: a 100-year flood might be exceeded in consecutive years or might not be exceeded in a 50-year period.

Most major rivers in this area are controlled by dams, many of which have been in place for more than 25 years. The levels of most of the reservoirs upstream from these dams reached new record highs during this period. Because these reservoirs were full before the storm abated, the runoff from the floods could not be contained. As the runoff from the tributary streams reached the major rivers, the flooding that occurred exceeded all previous floods since the major storage reservoirs were completed.

The Arkansas, Red, and Trinity Rivers are the principal river systems that had the greatest flooding. Because of the size of the

CHRIS E. O'DELL

A large amount of debris appears to be waiting to be locked through the James W. Trimble Lock and Dam near Van Buren, Ark., on the Arkansas River, May 5, 1990.

area affected by the storms and the saturated condition of the soil, the flooding extended far downstream from the source areas. In addition, the relatively flat slopes of the rivers and the need to reduce the storage levels in the reservoirs increased the duration of downstream flooding. Downstream from Livingston Reservoir on the Trinity River, for example, flood stage usually corresponds to a discharge of about 52 billion gallons per day; the discharge from that reservoir exceeded that amount for 10 consecutive days (May 17–26).

Because the main-stream impoundments, such as Eufaula Lake on the Canadian River (tributary to the Arkansas River), Lake Texoma on the Red River, and Livingston Reservoir on the Trinity River, have large storage capacities, major reductions in flooding would be expected to occur as the flood peaks passed though the storage systems. All three impoundments were full, however, when the April 30 to May 3 storm occurred. In addition, the extremely large inflows to the reservoirs would have taxed the systems even if the pool levels had been normal for early May.

The total maximum daily inflow to Eufaula Reservoir is estimated to have exceeded 259 billion gallons per day. On 1 day alone, about 800,000 acre-feet (an acre-foot is the volume of water that covers an acre of land to a depth of 1 foot) of water entered the reservoir; this is about 20 percent of the total capacity of the reservoir. The inflow to Livingston Reservoir was greater than 200,000 acre-feet (about 10 percent of capacity) per day for 7 consecutive days (May 10–16). Maximum daily inflow to Lake Texoma was also about 10 percent of total reservoir capacity.

A separate and somewhat isolated thunderstorm during May 19–20 produced 13 inches of rain in about 8 hours and caused severe flooding in Hot Springs, Ark. The resulting flood peak on the Ouachita River (tributary to the Red River) about 20 miles downstream from Hot Springs was about 103 billion gallons per day. This peak was 14 percent greater than the previous record peak that occurred in 1923.

DALE BOYLE

Overflow of Lake Texoma on May 7, 1990. Spillway overflow channel cuts north from the lake (top of photograph).

Seventeen deaths and millions of dollars in damage to public and private property are attributed directly to the storms and related flooding in the four-State area. Agricultural losses were extensive. In Arkansas and Oklahoma alone, the homes of more than 2,000 families were either damaged or destroyed. Public facilities in the entire area that were damaged or destroyed include roads, bridges, and water and sewage treatment facilities. Before the flooding subsided, 104 counties in the area had been declared eligible for Federal disaster assistance.

DALE BOYLE

Flooding continued on May 7, 1990, in Lake Texoma spillway overflow channel. Lake Texoma forms the border of Oklahoma and Texas between Ardmore, Okla., and Denison, Tex.

Toxic Substances in Water Resources

By Gail E. Mallard and Paul D. Capel

The USGS examines the fate and transport of contaminants in the Nation's waters through the Toxic Substances Hydrology program. Research concentrates on determining the mechanisms and the chemical and biological processes that control the environmental fate of pollutants at selected contaminated field sites.

Physical, chemical, and biological reactions change the chemical structure of contaminants. Newly produced (daughter) chemicals can have either greater or lesser toxic effects and mobility in the environment. Discovering how these transformation reactions occur and what happens to the daughter chemicals produced is an important part of investigations sponsored by the Toxic Substances Hydrology program.

Changes induced by sunlight in the chemical form of iron, for example, were measured in a stream receiving acid mine drainage near the headwaters of the Arkansas River in Colorado. These photochemical reactions are responsible for daily changes in the chemical form of iron that have been overlooked in previous studies of acidic streams and lakes. These overlooked changes may account for the reports of wide variations in concentrations of iron, copper, and other metals in acidic streams and lakes.

In South Dakota, daily fluctuations in pH caused by photosynthetic reactions affect the concentrations of dissolved arsenic in Whitewood Creek. This reaction is significant because dissolved arsenic is much more readily taken up by organisms than is arsenic associated with particulate material.

Biologically induced transformations are studied extensively at many of the field sites. Investigations of a crude-oil spill site in Bemidji, Minn., show an anaerobic (oxygen-free) degradation of oil components, a process previously thought to be unimportant. At a Pensacola, Fla., creosote site, natural microbiological reactions appear to be removing contaminants. Study of biological degradation at this site will show the potential of using biological remediation of contaminated ground water at other sites.

Many important environmental processes occur at the interfaces between air and water or between solids and water. The transfer of chemicals across an interface can have a profound impact on the transformation and transport rates of these chemicals and on their availability to organisms.

For example, at the Whitewood Creek field site, arsenic accumulates in benthic invertebrates, and, in the Calcasieu River study in Louisiana, synthetic organic compounds accumulate in clams, fish, crabs, and aquatic plants. Careful analysis of contaminant concentrations in water, sediment, and tissue taken from the Calcasieu River tracks the mechanisms of contaminant uptake. This information is useful in predicting the effects of chemicals on organisms living in contaminated environments.

Interface reactions can also be important in removing contaminants from the environment. The loss of organic chemicals via volatilization (vapor) from unconfined ground-water contamination sites is demonstrated for chlorinated solvents at Picatinny Arsenal, N.J., and for crude oil components at the Bemidji site. In Minnesota, volatilization is the most important loss mechanism for the crude-oil components and their degradation products.

Knowing how quickly and in what concentrations chemicals move away from the site of contamination is important to environmental managers. In the case of ground water, contaminant movement may be only a few feet per year; whereas, in surface water, movement may be tens or hundreds of miles per year. In the Whitewood Creek and Arkansas River study areas, variable flow conditions affect the transport of trace metals and arsenic in streams. The transport and accumulation of trace metals in surface-water sediments over time can be determined by examining historical concentration profiles in reservoirs that receive contaminants from upstream sources.

At the Cape Cod, Mass., site, relating the movement of colloidal-sized bacteria to water movement has shown the importance of transport mechanisms of chemicals that are not diluted or broken down in ground water. This is important because many organic chemicals of environmental concern may travel as or with colloidal material.

The hydraulic connection between surface and ground water can be an important route for contaminant transport. Contaminated surface water, such as waste-disposal pits or evaporation ponds, can be a source of pollutants to ground water. The reverse is also true. At the Globe, Ariz., site, ground water contaminated by copper mining is discharging into a perennial stream. Scientists have successfully predicted the timing of the

Toxic Substances Hydrology program field sites

Type of site	Study area	Contaminant
Ground water	Bemidji, Minnesota	Crude oil.
	Cape Cod, Massachusetts	Sewage, chlorinated hydrocarbons.
	Pensacola, Florida	Creosote, pentachlorophenol.
	Picatinny Arsenal, New Jersey	Trichloroethylene.
Ground and surface water.	Globe, Arizona	Trace metals, acid ground water.
Surface water	Arkansas River headwaters, Colorado	Trace metals.
	Calcasieu River, Louisiana	Synthetic organic chemicals.
	Whitewood Creek, South Dakota	Arsenic.

appearance in the stream of some of the individual chemicals in the contaminant plume. This knowledge is not only valuable to local managers, it can also be used to improve general computer models of contaminant transport. The models can in turn be used at other sites that have similar conditions and problems.

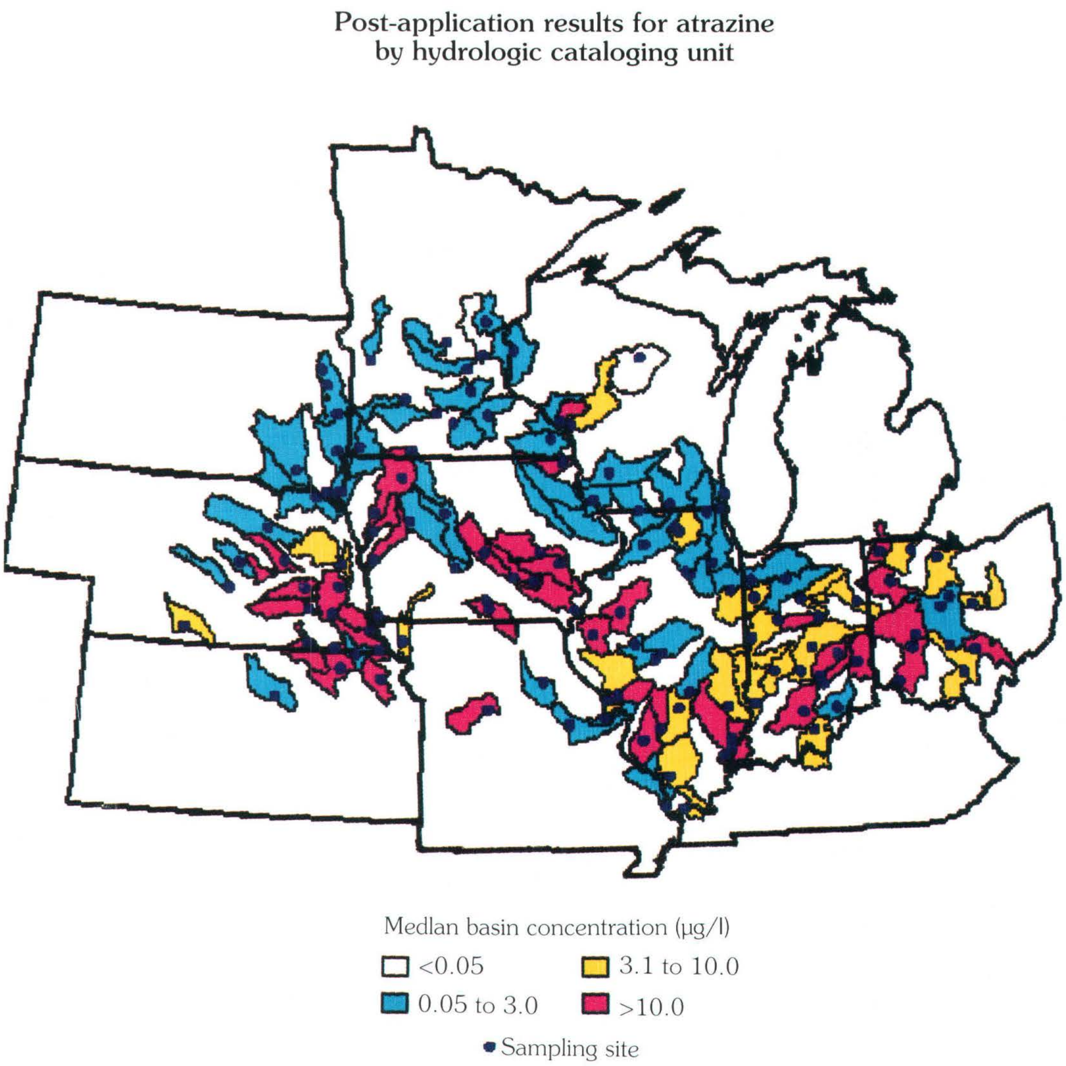
Studies under the Toxic Substances Hydrology program outline the environmental processes that control the transformation, availability, and transport of surface- and ground-water contaminants. Although much of the work has been conducted at a small number of field sites, the accumulated knowledge of the processes controlling contaminant behavior can be applied on a wider scale at other contaminated sites. The program continues to provide information that is useful in mitigating existing and future ground- and surface-water contamination problems throughout the country and in various geographic settings.

Atrazine in Streams of the Midwestern United States

By Donald A. Goolsby

Atrazine is one of the most extensively used pre-emergent herbicides in the United States. About 80 million pounds of atrazine are used each year, about 70 percent of which are applied in 12 Midwestern States for weed control in the production of corn and sorghum. Atrazine and its metabolic degradation products are being transported into surface- and ground-water resources of this region.

A study in Iowa, conducted by USGS scientists in cooperation with the Iowa Department of Natural Resources, shows that 18 percent of 355 municipal wells contain detectable concentrations of atrazine. In municipal,



Study area for Midwestern herbicide reconnaissance showing cataloging units sampled, location of sampling sites, and geographic distribution of atrazine concentrations during a post-application sampling period in 1989.

Herbicides and metabolites detected in pre-application, post-application, and fall low-flow samples collected during 1989

[Values in micrograms per liter; reporting limits are 0.05 microgram per liter for all compounds except cyanazine, which is 0.2 microgram per liter; <, less than. Ametryn, prometryn, and terbutryn were not detected]

Herbicide or metabolite	Detections (in percent) Pre-application	Post-application	Fall 1989
Triazines			
Atrazine	91	98	76
Deethylatrazine[1]	54	86	47
Deisopropylatrazine[1]	9	54	0
Cyanazine	5	63	0
Simazine	7	55	3
Metribuzin	2	53	0
Propazine	0	40	<1
Prometon	0	23	6
Acetanilides			
Alachlor	18	86	12
Metolachlor	34	83	44

[1]Atrazine metabolites.

domestic, and irrigation wells in Minnesota, Missouri, and Nebraska, atrazine is detected in 30 percent or more of the wells sampled. Atrazine concentrations in many of the wells exceed 3 micrograms per liter, the proposed maximum contaminant level (PMCL) for drinking water established by the U.S. Environmental Protection Agency.

Until recently, most concern about contamination of water resources with atrazine and other agricultural chemicals has been focused on ground water; contaminated surface water has received scant attention, except in a few small watersheds. To develop information on the occurrence and distribution of atrazine and other agricultural chemicals in surface water in the Midwest, USGS scientists conducted a reconnaissance in 1989 under the Toxic Substances Hydrology program (see p. 53).

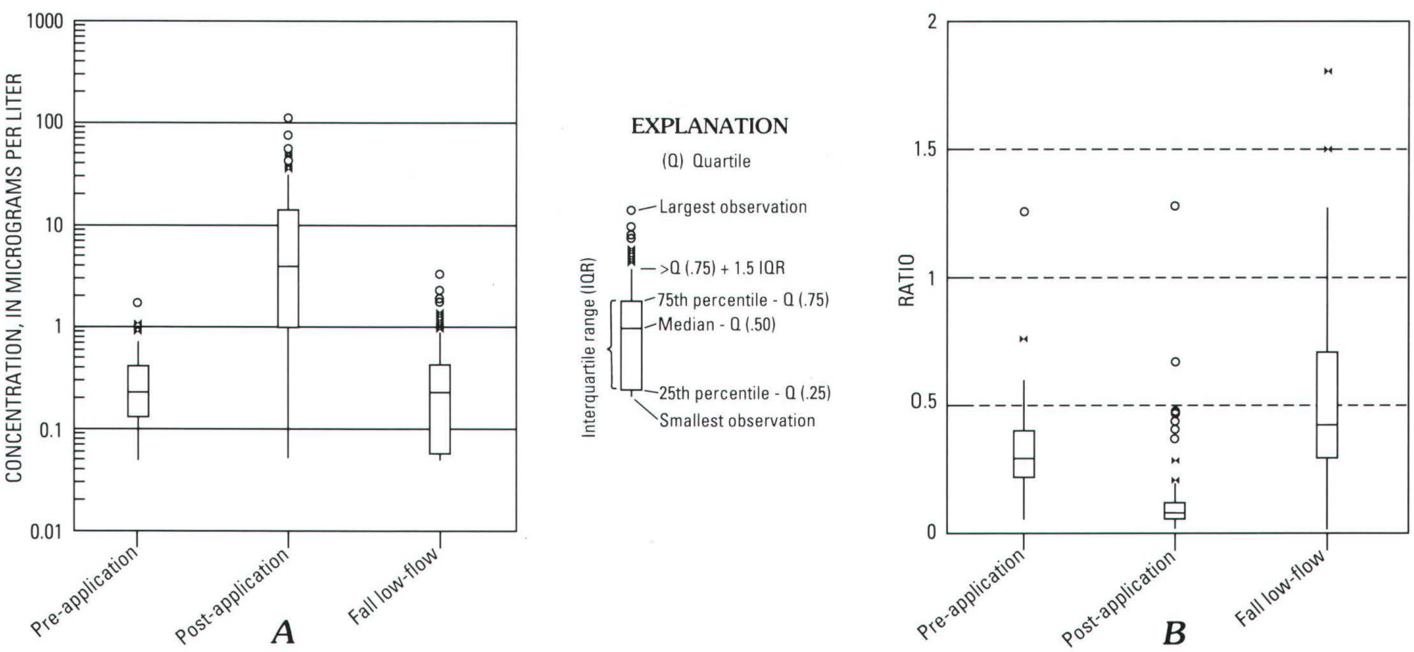
About 150 streams in 122 hydrologic cataloging units, geographically distributed across 10 Midwestern States, were sampled three times—before herbicide application, during runoff just after herbicide application, and in the fall during low-flow conditions. The median size of the drainage basins sampled is about 800 square miles and the aggregate drainage area of the basins is about 200,000 square miles. All of the samples were screened for atrazine, and most were subsequently analyzed for 10 additional herbicides and 2 atrazine metabolites (see table).

Results from the reconnaissance show that detectable concentrations of atrazine persist year round in most streams throughout the Midwest. During spring and early summer runoff following herbicide application, atrazine concentrations increase by one to two orders of magnitude and then decrease to pre-application levels by fall. For an undetermined time following herbicide application, more than one-half of the streams sampled had atrazine concentrations higher than the 3 micrograms-per-liter PMCL, and more than one-fourth of the streams had concentrations of 14 micrograms per liter or higher. Because of the random design of the reconnaissance, these results are believed to be typical of streams throughout the Midwest.

Low concentrations of atrazine were detected in 76 percent of the stream samples collected in the fall when streamflow is derived primarily from ground water. This result strongly suggests that the alluvial

A, *Distribution of atrazine concentrations in Midwestern streams during pre-application, post-application, and fall low-flow sampling periods in 1989.*

B, *Ratio of deethylatrazine to atrazine in Midwestern streams during pre-application, post-application, and fall low-flow sampling periods in 1989.*



aquifers contributing baseflow to these streams are contaminated with low concentrations of atrazine and are a nonpoint source for contamination of streams during baseflow periods. This result also underscores the need for further study of the exchange of water and contaminants between surface- and ground-water systems.

Atrazine was the most frequently detected of the 11 herbicides and 2 metabolites measured during each of the three sampling periods (see table). The second most frequently detected compound was the atrazine metabolite deethylatrazine. This compound is not applied as an herbicide but is largely derived from the breakdown of atrazine by soil microorganisms. Notably, little information is available at this time about the toxicity and health effects of deethylatrazine or other atrazine metabolites. The ratio of deethylatrazine to the parent compound, atrazine, is lowest in late spring and early summer after herbicide application and highest in fall when the principal source of water in streams is from ground water. This ratio may prove to be useful in determining sources and mechanisms for atrazine contamination of surface and ground water.

USGS hydrologists are continuing research on the occurrence, distribution, and fate of atrazine and other agricultural chemicals in water resources of the Midwest. Current research includes studies of the temporal distribution of several herbicides, including atrazine and its metabolites, in spring and summer storm runoff; the occurrence, distribution, and deposition rates of atrazine in atmospheric wet deposition; and the regional distribution of atrazine and other agricultural chemicals in ground water.

Drought in California, 1987–90

By Richard A. Hunrichs

California marked its fourth consecutive year of drought in 1990. Precipitation, runoff, and reservoir storage have been below normal during each water year from 1987 to 1990. Stream runoff in the Sacramento River basin in the relatively wet northern part of the State is a major source of water for State and Federal water-supply projects. Runoff is also a widely used indicator of the status of the State's water supply. On the basis of runoff in the Sacramento River basin, California Department of Water Resources (DWR) personnel classified the 1987, 1988, and 1990 water years as critically dry.

A critically dry year is that which occurs about 1 year in 10 in the record of a particular region. Runoff during the 1989 water year was below average but was sufficient to prevent the year from being classified as critically dry. As late as March (the last month of California's winter storm season), water-supply forecasts showed a greater than 50 percent chance that 1989 would be a critically dry year. A series of March storms, however, brought plentiful rain and snow over the northern half of the State and temporarily moderated the severity of the drought.

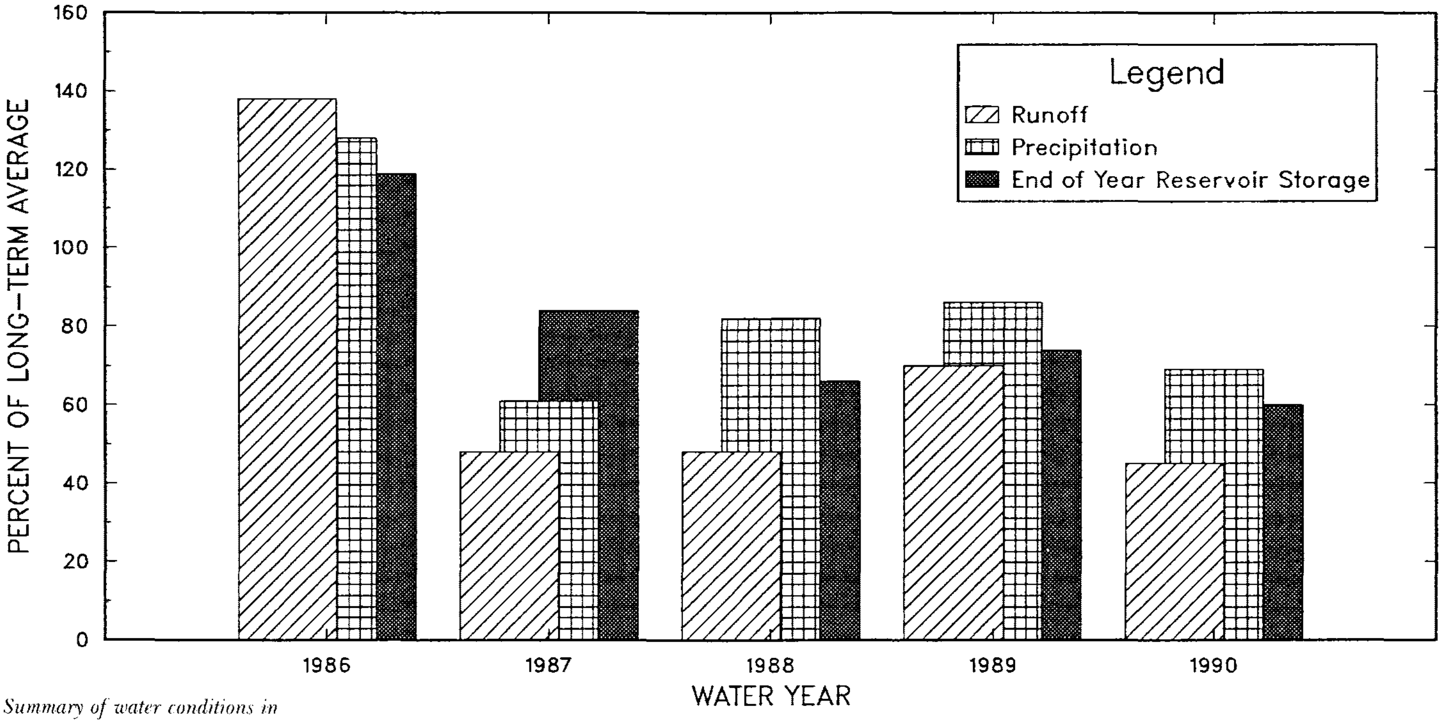
Historic Perspective

Droughts are a recurring feature of California's climate. To help put the current drought in perspective, hydrologists from the USGS water resources office in Sacramento, in cooperation with DWR personnel, examined streamflow records from the Sacramento River basin and from unregulated long-term stations located throughout California. When considered individually, no single year of the current drought ranks as extreme. When considered as a whole, however, the drought aspect of the last 4 years is more evident.

For the Sacramento River basin, two consecutive critically dry years have occurred only twice before, from 1933 to 1934 and from 1976 to 1977. Three consecutive critically dry years are unprecedented in the historical record, and three critically dry years during a 4-year period have occurred only once before, from 1931 to 1934, during the Dust Bowl Era. The current 4-year drought has three critically dry years, two of which are consecutive (1987–88, 1990). Even though the drought is less severe in southern California, that area's dependence on transfers of water from the northern part of the State gives the current drought a statewide importance.

Prior to the drought of 1987–90, the droughts of 1928–37 and 1976–77 were considered to be the most severe in the State's history. Comparing the current drought to these historic droughts provides perspective, but comparisons are difficult because the droughts have different durations. The severity of multiyear droughts can be measured by the accumulated deficit in streamflow (departure below the mean) during the drought. Periods of drought of the same duration can be directly compared by ranking their accumulated deficits.

Ranked by accumulated deficits, the droughts of 1928–37, 1976–77, and 1987–90 (in the central part of the State) are equivalent in severity. The drought of 1928–37 is



Summary of water conditions in California, 1986–90 water years. Values are in percent of average. (Data from the California Department of Water Resources.)

the State's most severe drought, however, when the duration, the magnitude and areal extent of accumulated deficits, and the severity of individual years are taken into account. The current drought will have to continue for several more years before it would rival the drought of 1928–37.

Impact of the Drought

Because of the recurrent nature of droughts in California, considerable effort has been made to lessen their effects. Water supplies have been developed and are managed to provide dependable supplies to major agricultural areas and population centers and, more recently, for the protection of environmental quality. Isolated dry years and the first year of protracted droughts have only limited adverse effects on human activities. The most seriously affected areas are wildlands and nonirrigated agricultural lands. Water-supply problems were minimal in 1987, however, because surface-water storage was carried over from 1986.

During 1988 and early 1989, water shortages affected about one-third of California's population and more than 40 percent of the State's irrigated agriculture. Many areas had insufficient rainfall for dry-farmed crops, and ranchers from 42 counties were accepted into Federal emergency feed programs. Drought emergencies were declared in 14 counties. Many urban areas instituted mandatory or voluntary water conservation measures.

Where available, ground water was used to compensate for deficiencies in surface-water supplies. In general, ground-water supplies were adequate, but water shortages occurred in localized areas of excessive drawdown and in some upland and coastal areas where ground-water reservoirs are small.

In 1989, managers in both of the State's two major water projects, the State Water Project and the Federal Central Valley Project, announced anticipated reductions in water deliveries of as much as 50 percent. The wet weather in March 1989 brought relief to many water users, however, and permitted full delivery of agricultural water supplies. Drought restrictions were eventually lifted in most areas of the State. Water restrictions continued along the central coast, which did not benefit from the March rains and is not a part of any of the State's large water projects.

In 1990, no relief from spring rains was forthcoming. Deliveries of State and Federal project water are reduced as much as 50 percent for agricultural customers, and some municipal and industrial contractors have lesser reductions. Only once before (1977) in the history of the water projects were such reductions necessary.

In response to the reductions in surface water, farmers are modifying irrigation practices, turning to ground-water supplies (often an expensive alternative), taking land out of production, and changing crop rotation. Reduction in irrigation water causes salt to accumulate in the soil and has a long-term impact on agricultural production. Reduced agricultural production causes substantial economic losses in many areas. Agricultural advisors are warning orchard crop growers that attempting to stretch water supplies by inadequate irrigation may kill trees.

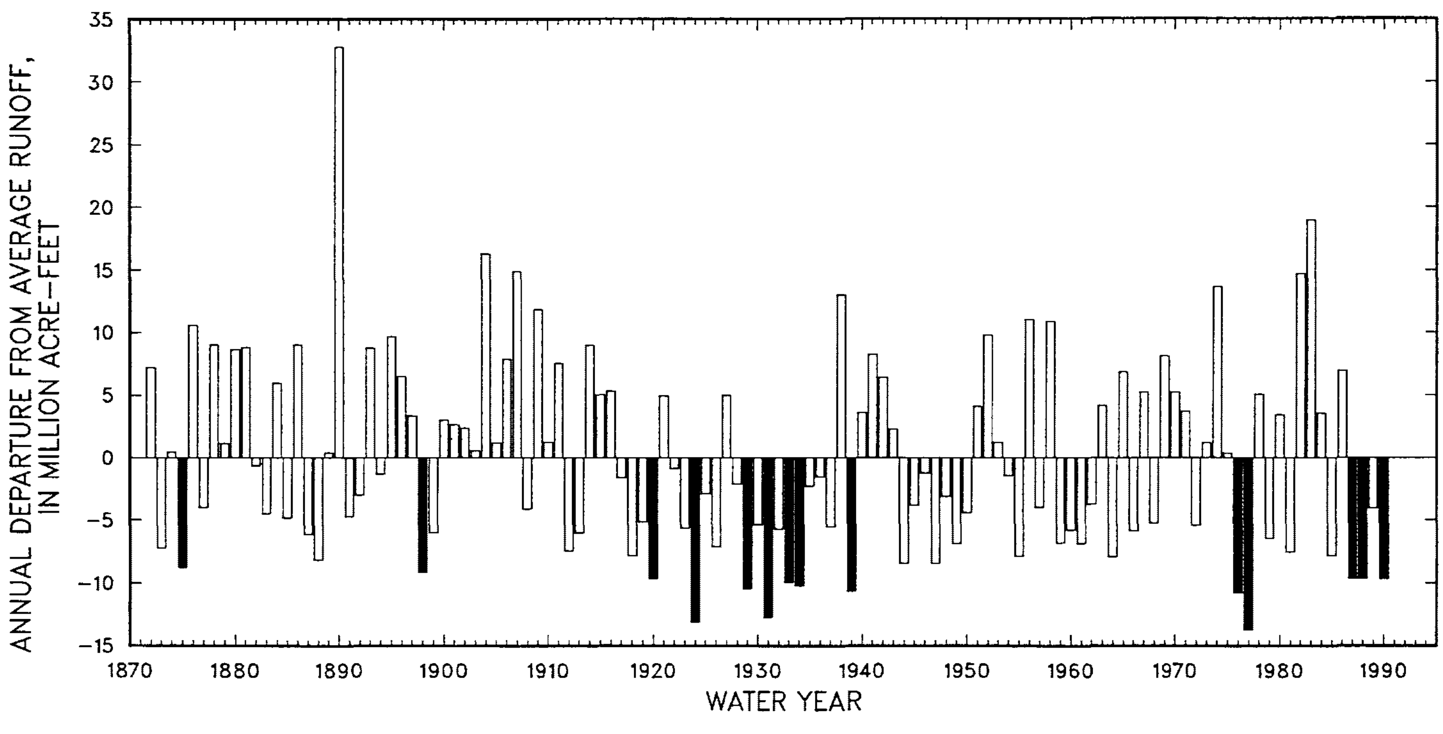
Most urban areas of the State are instituting drought restrictions. Southern California was little affected during the first 3 years of the drought because of diverse sources of water supply—northern California, the eastern Sierra Nevada, and the Colorado River basin. In 1990, however, this area is also faced with possible shortages.

The response of urban water users to the drought of 1976–77 demonstrated that major reductions in urban water use are possible. Conservation measures include voluntary and mandatory rationing, educational programs, the use of water-saving devices in homes, decreased irrigation of landscapes, reuse of industrial water, altered rate (price) structures, and penalties (including the threat of jail sentences) for misuse. Santa Barbara is probably the most adversely affected community in the State, and a strict mandatory water conservation program has been enacted to cut water use by 45 percent. It is now illegal to water lawns in Santa Barbara.

The reduction in streamflow has caused a hydroelectric-power generation decrease, which has forced the use of alternative and more costly sources of power. Because utilities expect hydroelectric-power generation to be 40 percent below normal, rate increases may be necessary to offset reduced production from hydroelectric sources.

As the drought continues, demands on ground-water sources increase as surface supplies in many areas become stressed. The resulting drawdown leads to serious overdraft in some basins. Using the 1976–77 drought as an indicator, ground-water use during the current drought can be expected to increase about 50 percent above the amount used during a normal year. The increased withdrawals in many areas are already causing excessive drawdown, water-quality problems, and seawater intrusion into some coastal basins. The result is that public water supplies in some areas may not meet recommended standards for drinking water; depleted ground water has increased the potential for land subsidence and associated reduction in storage capacity of aquifers because of compaction; and some areas now prohibit drilling new wells and restrict pumping from present wells.

Recreational activities, and the associated economic benefits for many businesses and



Annual 1872–1990 departure from average discharge in the Sacramento River basin. Solid areas are years classified as critically dry by the California Department of Water Resources. The Sacramento River basin discharge is the combined flows from the upper Sacramento, Feather, Yuba, and American River basins, adjusted to represent unimpaired runoff. Flows from 1872 to 1905 are estimated from historical data. (Data from the California Department of Water Resources.)

communities, are also adversely affected by the drought. Low streamflows and reservoir levels restrict boating and fishing. Extreme fire danger has led to the closing or restricted use of wildlands. The drought has been extremely hard on fish and wildlife. Decreased releases of water downstream from reservoirs and high air temperatures have resulted in a fourth straight year of poor anadromous fish spawn. For some species, the problem is now compounding: reduced populations that hatched during the first year of drought are returning to even worse conditions. Reservoir fisheries are also being adversely affected by low water levels. The flooding of some waterfowl refuges is incomplete, and forage and cover for upland wildlife is reduced.

The drought has had a devastating effect on California's timberlands. Trees weakened by the drought are being killed by insects and disease. In the Lake Tahoe basin, about 20 percent of the trees are already dead, and even more trees are in jeopardy this year. The danger of forest fires is exacerbated by the presence of this added dry fuel. In Yosemite National Park, California's famed sequoias were sprayed with a fire-retardant to protect them from threat of fire.

Forecast for 1991

DWR forecasters estimate that if runoff is 70 percent of normal next year, there is a 65 percent chance that most of the State's water needs would be met. Carryover storage in reservoirs is well below normal, however, so reservoir storage would not recover from depleted levels. The forecasters also estimate that if runoff is 5 percent above normal, reservoir storage levels would return to normal and that most of the State's water need would be met as well. Because the winter storm season brings most of the State's annual precipitation, it may be spring 1991 before we know if California is in for a fifth straight year of drought or if the dry spell will be broken.

National Mapping Program

Continuing Evolution in Mapping Technology

By Lindy Mann

The initial cycle of detailed topographic mapping covering the conterminous 48 States, begun more than 50 years ago, was completed by the USGS during fiscal year 1990. Having accomplished this significant milestone, the USGS National Mapping Division is focusing on updating the more than 57,000 maps generated and making them available in digital form. New automated methods for processing spatially related data are streamlining map production techniques as well as revolutionizing the application of this information to land and resource management issues.

The conterminous United States and Hawaii are mapped as quadrangles, each covering 7.5 minutes of latitude and longitude. The 7.5-minute mapping program began in the late 1930's in a cooperative effort with the Tennessee Valley Authority. Most of the 7.5-minute quadrangle maps are printed at a scale of 1:24,000 (1 inch on the map represents 2,000 feet on the ground). For a few areas, 1:25,000-scale maps are published in which contours are depicted in meters.

The mainland of Alaska has been mapped at a scale of 1:63,360 (1 inch represents 1 mile). A few areas of the Alaska peninsula and most of the Aleutian Islands are mapped with very general reconnaissance maps because the persistent cloud cover over these areas makes it difficult to acquire the aerial photography needed for map compilation. The final map completed in the first cycle of the national program was the Seneca quadrangle south of Canyon City in Grant County, Oreg.

One of the key components in the evolution of the National Mapping Program is the conversion of the 1:24,000- and 1:25,000-scale topographic maps to digital form. The resulting data will be made available to Federal, State, and public users through the National Digital Cartographic Data Base, which the USGS is assembling as the largest repository of map information on the United States and its territories.

Geographic information system (GIS) technology has emerged as 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 relationships. 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 decisionmaking for many scientific, engineering, and planning purposes.

The completion of the initial cycle of topographic mapping marks the beginning of a major new responsibility for the USGS. As fiscal year 1991 began, the USGS was assigned the role for the Interior Department of coordinating and standardizing digital cartographic data through the Federal Geographic Data Committee (as directed in the Office of Management and Budget Circular A-16, Revised). In this role, the bureau will serve as the Federal data base manager and coordinator for spatially referenced digital data.

Building Partnerships for Geographic Data Sharing

By Michael A. Domaratz

Increasingly, the analysis of spatial data—geographic and cartographic information in computer-readable form—is a requisite part of understanding and responding to complex societal problems. Computerized tools for handling spatial data, such as geographic information systems, are cost-effective means of managing large volumes of spatial data and performing these analyses. As important as these tools have become, their effectiveness ultimately depends on the availability and quality of the digital spatial data analyzed. The immediate need for high-quality spatial data and the cost of collecting the data are two factors that encourage new partnerships among users in Federal, State, and local governments. These partnerships prevent wasteful duplication of effort and permit increased dedication to solving problems rather than to collecting data.

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.

Building innovative partnerships and improving coordination processes also increase the Nation's ability to solve future societal problems and to compete more effectively in the world marketplace. The development of a national digital spatial data infrastructure, including linkages at all levels of society, will enable sharing and efficient transfer of digital spatial data between producers and users, thus increasing the availability and timeliness of spatial information.

The Federal Interagency Coordinating Committee on Digital Cartography (FICCDC) coordinates the digital cartographic data activities of Federal agencies. In a 1989 memorandum rechartering the FICCDC, the Director of the Office of Management and Budget (OMB) noted the evolving nature of data handling technology and the need for Federal Government programs to evolve with this technology. The Director asked the FICCDC to evaluate its role in coordinating Federal digital spatial data use and to review and recommend revision to OMB Circular A–16, the coordinating mechanism.

In its report, the FICCDC recommended that the breadth of coordination activities be increased by adding such types of spatial data as geologic, resource, cultural and demographic, and ground transportation; that the name of the committee be changed to the Federal Geographic Data Committee to reflect the broader coordination responsibility; and that the new committee and its responsibilities be incorporated in a revised and expanded Circular A–16.

The primary objective of the new Federal Geographic Data Committee is to promote the coordinated development, use, sharing, and dissemination of surveying, mapping, and related spatial data. Subcommittees will coordinate activities related to 10 spatial data categories, including topographic map, soil, wetland, geologic, geodetic, vegetation, cadastral, ground transportation, cultural and demographic, and certain international boundaries. These activities will identify standards of accuracy, content, and format, facilitate exchange of information and transfer of data, and coordinate collection of spatial data. Working groups will respond to issues common to all spatial data categories, such as standards, technology, and liaison with the non-Federal spatial data user community.

The new committee will promote the development, maintenance, and management of spatial data bases. Specifications for these systems will ensure data reliability, compatibility, and consistency so data may be used with confidence. The committee will also encourage the development of standards and specifications that foster the exchange and multiple use of data and promote data sharing. An additional important focus of the new committee is to provide guidance and promote coordination among Federal, State, and local government agencies, the private sector, and academia with the objective of developing a partnership for a national digital spatial data infrastructure.

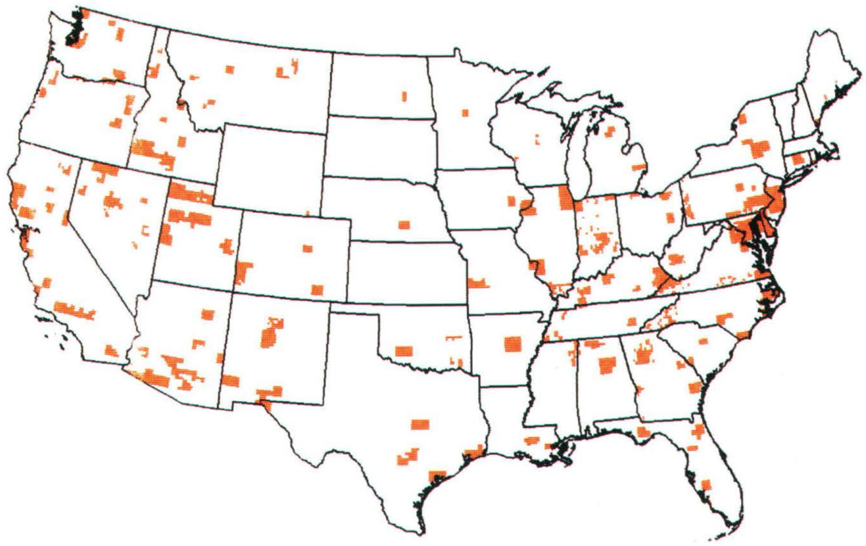
The revision of Circular A–16 provides the framework for coordinating the programmatic and technical aspects of expanding Federal spatial data activities and for coordinating activities for certain categories of spatial data that are national in scope. The revision also supports development of common standards and specifications that remove the impediments to sharing data; promotes technology development, transfer, and exchange; and encourages sharing of data not only among Federal agencies, but also among State and local government agencies, the private sector, and academia.

Cartographic Data Aid Response to National Emergencies

By Lindy Mann

Current cartographic information in both digital and graphic form assists in local and regional planning and in responding to national emergencies. The cartographic data depicted on the more than 57,000 topographic maps covering the Nation at scales of 1:24,000 (49 States) and 1:63,360 (Alaska) are periodically reviewed for updating. These topographic maps and related digital cartographic data are critical national resources that can be used to provide a benchmark for environmental analysis, for planning purposes to help mitigate national emergencies, for determining damages from natural disasters, and as source data for preparing other map products.

Maps are periodically revised to reflect recent natural and cultural changes and to correct deficiencies and inaccuracies in older maps. To accomplish a national map revision program in a systematic manner and to ensure that the highest priorities are addressed, the USGS annually solicits map requirements from Federal, State, and local agencies. Joint funding agreements between individual States and the USGS help expedite the needed revision of existing topographic maps. Annually, the USGS has mapping agreements with 25 or more States, and the support provided by the USGS ranges from



More than 3,000 of the 57,000 U.S. topographic maps are being revised in fiscal year 1990 as part of the USGS National Mapping Program.

revision of existing maps to preparation of cartographic data in digital form. The revision program is managed by the National Mapping Division, and cartographic production is done in centers in Reston, Va.; Rolla, Mo.; Denver, Colo.; Menlo Park, Calif.; and Sioux Falls, S. Dak.

More than 3,000 topographic maps are currently in the revision program, and between 3,000 and 5,000 maps are inspected annually to determine the need for revision. Some maps require only minor updates, while others require major changes. Revision may require scheduling new aerial photography; establishing field control and, when needed, field inspecting map features depicted on a map manuscript before printing; and obtaining source information such as boundary and coastline changes and names that are to be shown on the revised maps.

Often, priorities change suddenly when a natural disaster occurs. Hurricane Hugo is a prime example. Many areas in South Carolina were declared disaster areas by the Federal Emergency Management Agency. These areas are depicted on parts of 280 1:24,000-scale maps, 55 of which cover areas that sustained severe damage. Several of these maps are now scheduled for revision. To generate up-to-date maps of the State areas affected, suitable source materials, such as aerial photographs, are needed to revise existing maps and digital cartographic data.

To provide current information for production of topographic and soil classification maps, orthophotographs, map products for land management and land use and land cover and for damage assessments of natural events and planning purposes to mitigate risks associated with natural disasters, a National Aerial Photography Program was developed and implemented. This Federal program, which is managed by the USGS, is funded by five major Federal agencies and a few States. Under contract, private companies photograph selected State areas annually. The program is designed to provide complete photographic coverage of the conterminous United States about every 5 years. This national data base of current information is available to all users through the USGS Earth Science Information Centers (see "Guide to Information and Publications," p. 94) and provides an easily accessible source to help in many aspects of national emergencies.

Revision of existing maps still requires cartographers to perform field work in the areas affected by natural and cultural changes, to search for documentation on boundary changes, and to acquire horizontal and vertical map control where needed. However, most revision work is done in offices where information from aerial photographs, existing map data, and cartographic data in digital form is reviewed and analyzed. The USGS is implementing new technologies and acquiring modern digital equipment to expand and improve the production of new maps and data and to accelerate map revisions and, therefore, accessibility to the latest cartographic data.

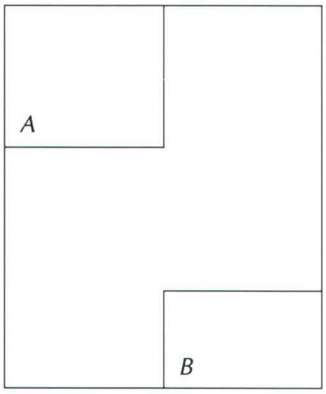
Users of maps and cartographic data repeatedly tell us that current information is a critical need. Likewise, it is important to have current information readily available for land management studies, including wetlands and

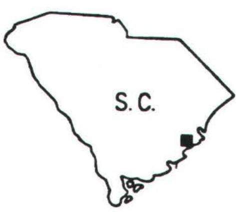
S.C. LAND RESOURCES CONSERVATION COMMISSION

S.C. LAND RESOURCES CONSERVATION COMMISSION

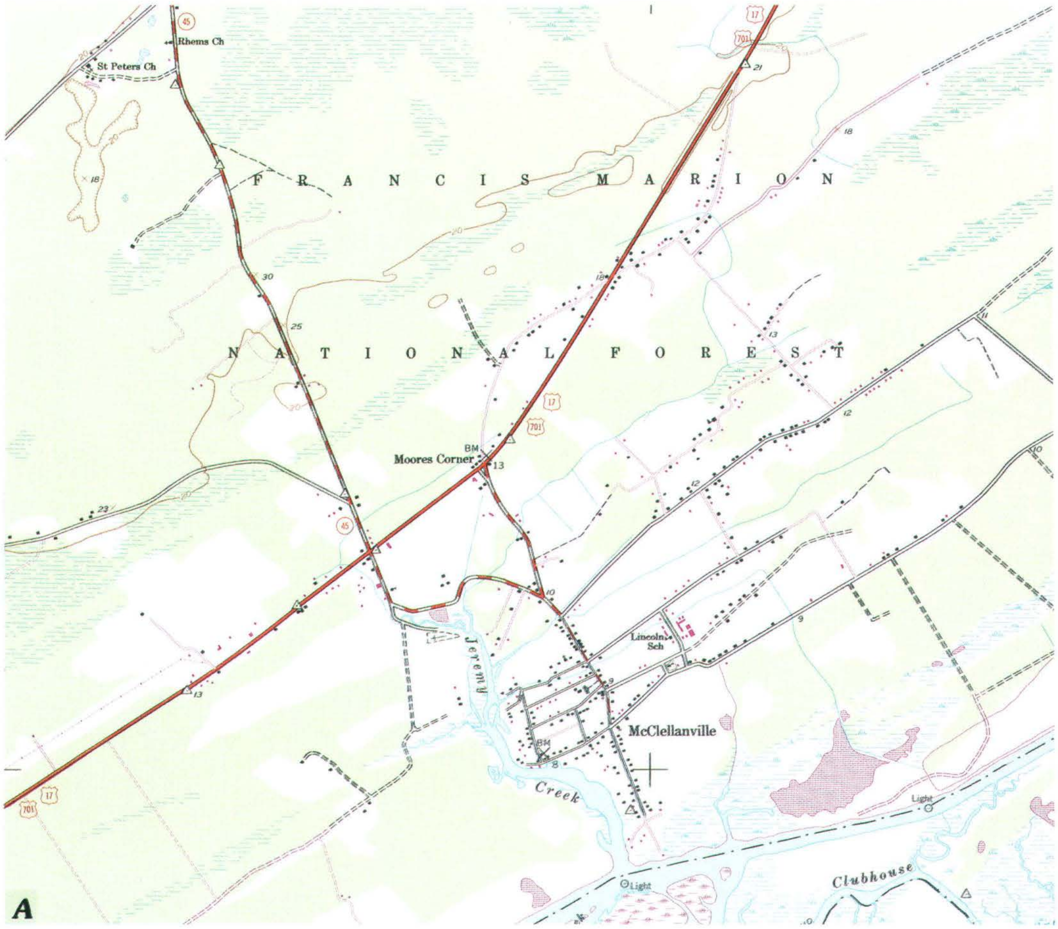
Hurricane Hugo left its mark on many coastal communities in South Carolina, as evidenced by these beach homes and a parking lot in the Folly Beach area.

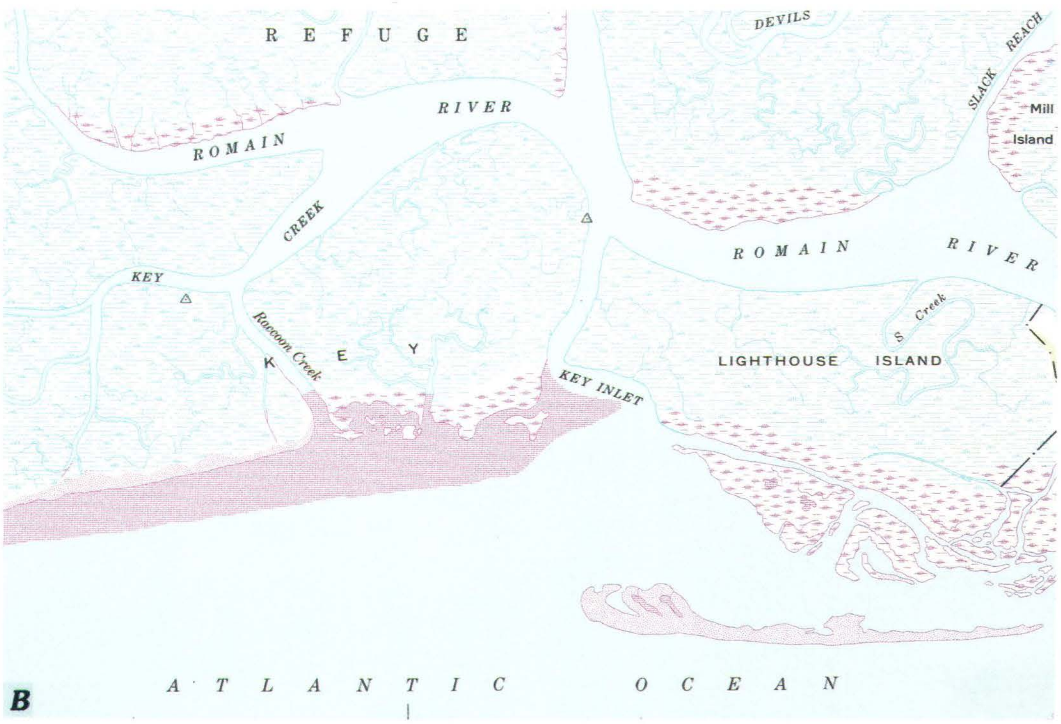
Hurricane Hugo and previous storms have altered land features since the McClellanville, S.C., 1:24,000-scale topographic map was revised in 1973. Other changes, such as the construction of new or improved roads, new subdivisions, and other cultural changes, have also occurred and have increased the need for revision.



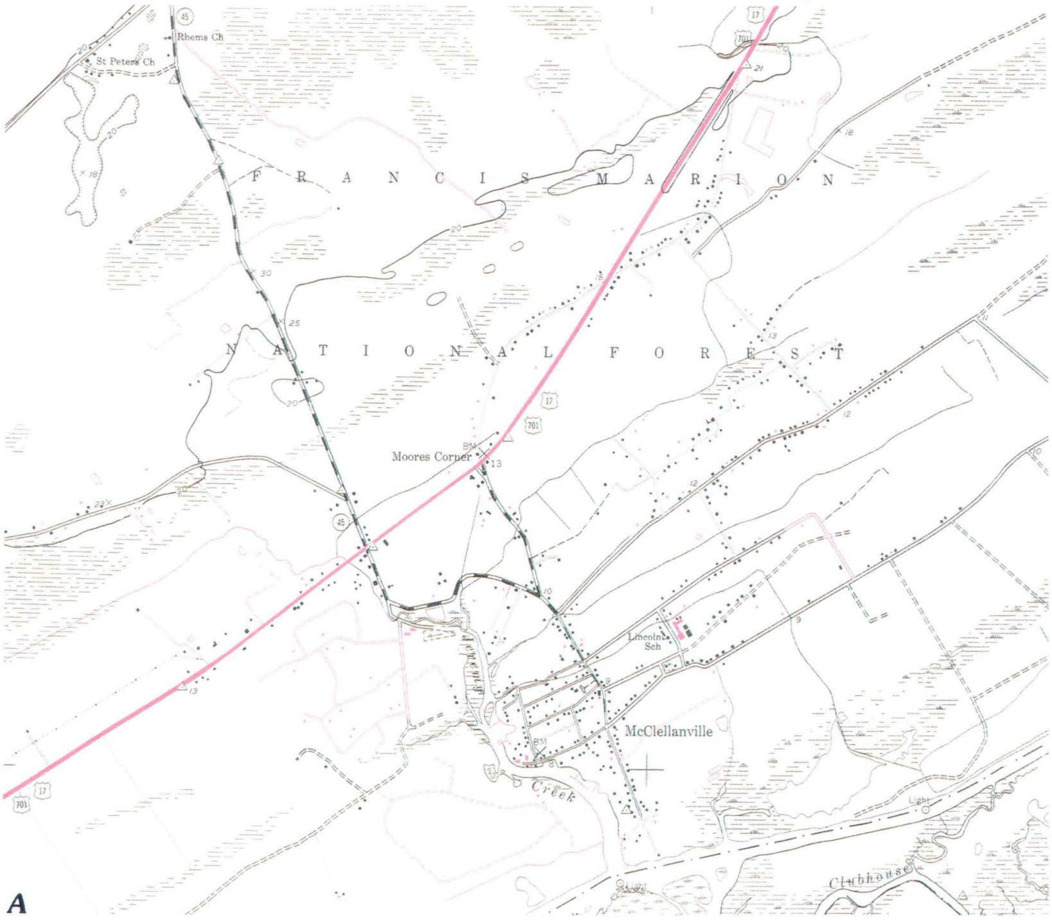


Map location



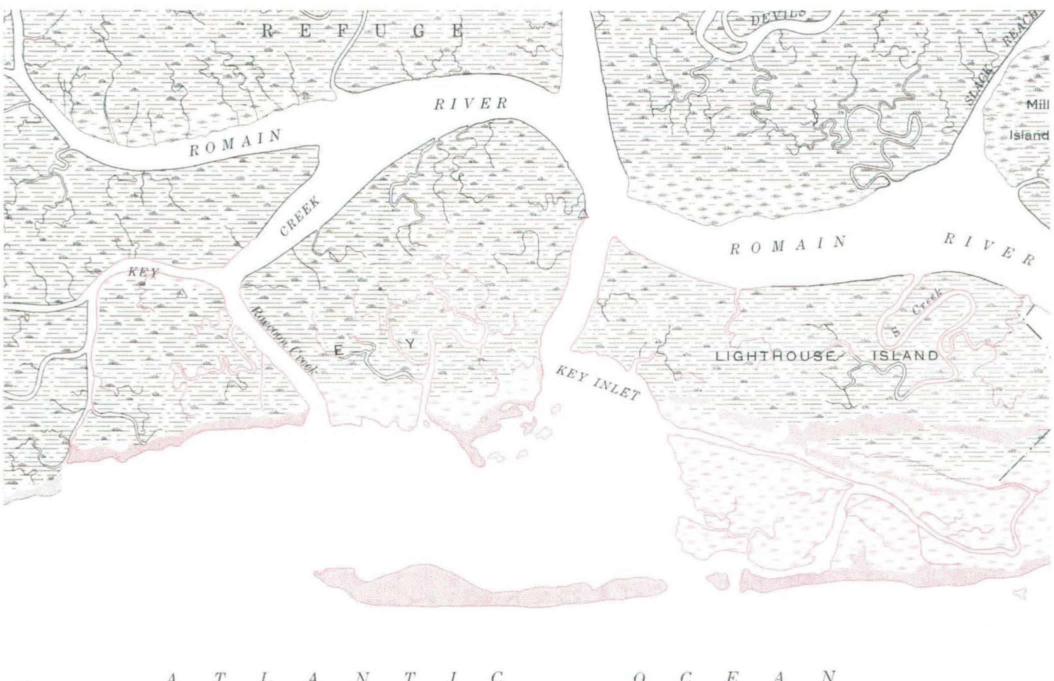


coastal areas, for various analyses and inventories, for use in geographic information systems, and for developing strategies and plans in cases of national emergencies. The USGS ensures that the Nation has available current cartographic data through its continuing efforts toward revision of map graphics and digital data.



A

A, *Black-and-white 1:40,000-scale photographs, acquired by the National Aerial Photography Program in 1989 just before Hurricane Hugo, were used to revise this portion of the map. Revised (1989–90) features are shown in red.*



B

B, *Combination of black-and-white 1:40,000-scale photographs, acquired by the National Aerial Photography Program just before Hurricane Hugo, and color 1:15,000-scale photographs, acquired by the National Oceanic and Atmospheric Administration just after Hurricane Hugo, were used to revise this portion of the map. Revised (1989–90) features are shown in red.*

Digital Revision of the New Jersey State Base Map

By David E. Catts and Robin G. Fegeas

In a pilot effort, the USGS is updating the 1:500,000-scale State base map of New Jersey by using all-digital techniques. This entirely digital environment stretches the limits of technology in a number of areas. The most dramatic development is map generalization—the extremely complicated process of combining many detailed maps covering the State at mostly 1:100,000 scale into just one map at the much smaller and less detailed scale of 1:500,000. This process is easy to do manually but difficult to accomplish digitally.

The production of the new New Jersey State base map is the lead project of a modernization activity that is evaluating the current state of geographic information system (GIS) technology and its integration into USGS map production processes. Although the work is based on extensive knowledge and techniques developed in earlier projects, many new technical areas are being explored. Research investigations include developing automated feature generalization routines, enhancing stream ordering algorithms for hydrographic feature identification and selection, assessing alternative automated methods of text placement, and compiling software, without significant reprogramming, for universal application to production projects.

The USGS 1:500,000-scale State base map for New Jersey is a natural selection for this project because the map was originally printed in 1978 and had been scheduled for manual revision. Also, the production location is near a GIS research laboratory, which provides ready access to expertise and the latest computer resources.

The digital data required for production of the new New Jersey State base map are assembled or created from various State and Federal sources, including available USGS 1:100,000-scale digital line graph (DLG) files, 1:250,000-scale land use-land cover political boundary files, and Geographic Names Information System data. Digital bathymetric data are supplied by the USGS Exclusive Economic Zone sea floor mapping effort and are supplemented with National Ocean Survey charts. The State of New Jersey provides information on the location of State lands and the use and ownership of railroad lines. Existing State base map topographic contours are being scanned and vectorized (converted into line data), and several options are being explored to generate the urban area tint.

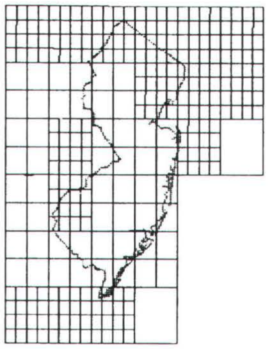
GIS technology allows data from these varied sources to be integrated into a data base by converting map coordinates according to a series of identified common control points. Other integration steps follow, depending on the data source. In most cases, non-DLG data are extensively edited manually (in the digital environment) to conform to the 1:100,000-scale DLG base data.

The use of the 1:100,000-scale DLG data files themselves, as well as other data at a scale of 1:250,000 or smaller, includes edge matching and paneling together of numerous files, each covering a small area, into combined areal coverages (fig. 1). Generalization, reducing the amount of map detail, is a significant aspect of manual map production. This process had to be translated into equivalent computer instructions for digital production. A digital filtering process reduces the number of features and the number of coordinates required to describe the remaining features. The resultant computer data storage for the project files is reduced by as much as 88 percent. Figure 2 shows the results of generalizing 1:100,000-scale DLG data to 1:250,000 and 1:500,000 scales.

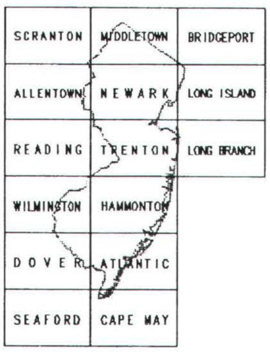
Actual map production of the New Jersey State base map includes developing graphic symbology sets. Much of the symbology used in editing and correcting the data did not exist previously and has been developed for this and future projects. The symbology must be developed for final graphicproduction, and the negatives for map publication must be created directly on a high-resolution digital plotter. Finally, the actual conversion from the 1:500,000-scale digital base data to a set of digital graphic images for plotting requires an additional filtering process and a resolution of any symbology overprinting problems.

The digital-to-graphic techniques being developed during data preparation stages make the digital revision of the New Jersey State base map a truly ground-breaking enterprise. At present, it is still costly and labor intensive to perform this work in an entirely digital environment. The lessons learned and technology developed in this project will go far toward accomplishing cost-effective digital integration, revision, map generalization, and map production.

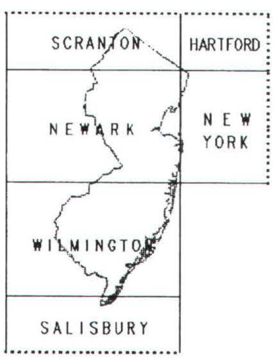
Discrete 1:100,000-scale DLG source data base units.



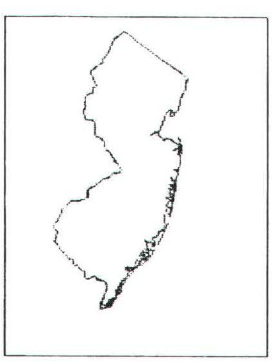
Paneled 1:100,000-scale coverage. Generalization to 1:250,000 scale.



Paneled 1:250,000-scale coverage. Generalization to 1:500,000 scale.



Paneled 1:500,000-scale coverage. Symbolization for graphic output.



◀ ***Figure 1.*** *Conversion of multiple digital line graph (DLG) sections to a single smaller scale map of continuous coverage. The creation of continuous coverage requires edge matching, paneling, and generalizing to combine area coverages at various format stages and scales.*

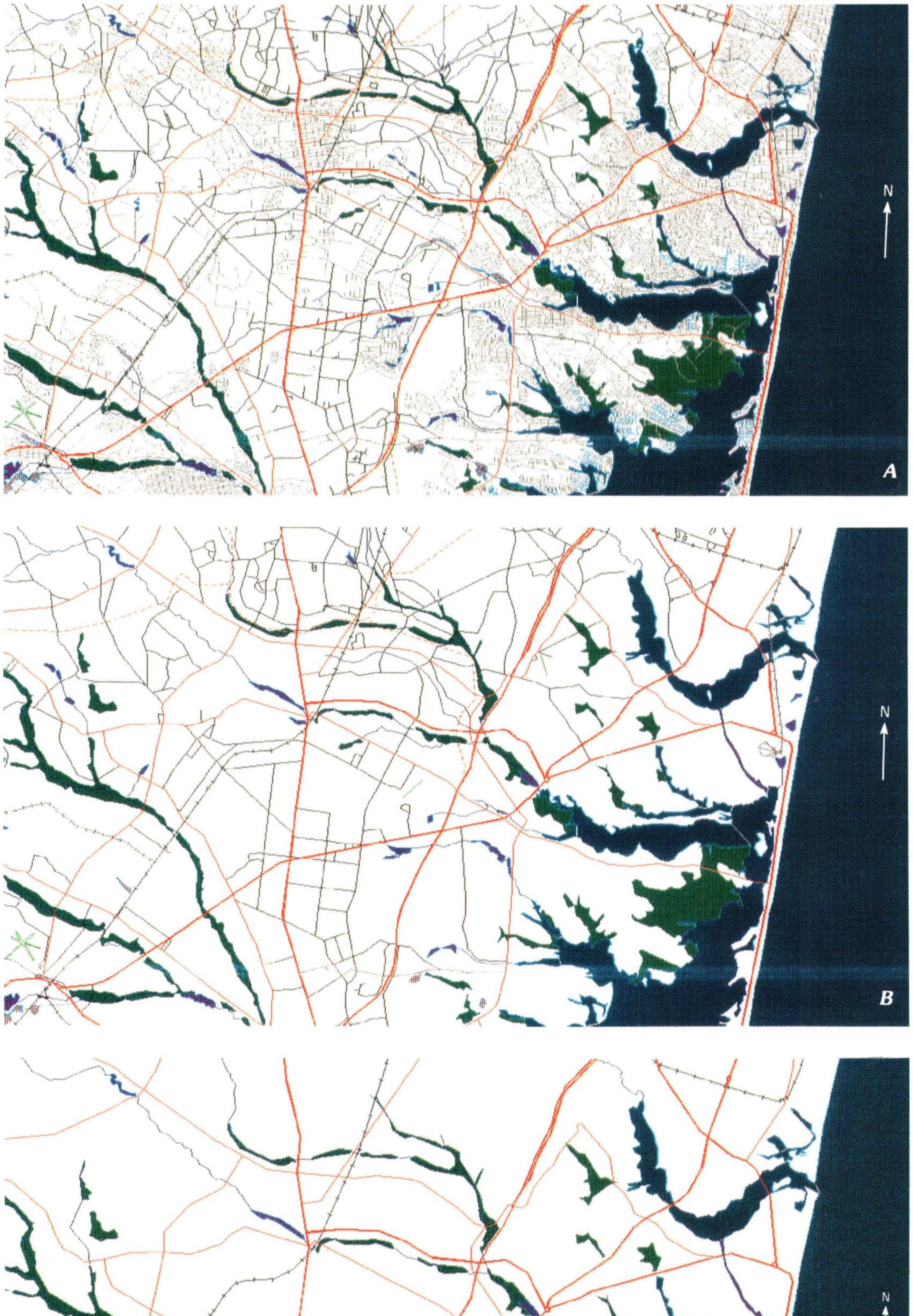


Figure 2. **A**, *The 1:100,000-scale digital line graph data content for hydrography and transportation categories is generalized to produce,* **B**, *1:250,000-scale and,* **C**, *1:500,000-scale data. The area shown is the southeast corner of the Trenton, N.J., 1:100,000-scale quadrangle and is not to scale. The area includes Point Pleasant and vicinity and is approximately 20 miles across.*

Using GIS to Link Health and Earth Science Data Bases

By David R. Wolf

The National Center for Health Statistics (NCHS), one of the Federal Centers for Disease Control, is the principal Federal organization having legislative authority to collect statistics on many health-related issues. Currently, the USGS and the NCHS are investigating the potential for spatial association between national earth science data bases and disease mortality data bases.

GIS (geographic information systems) and statistical techniques are being used to explore the possibility of spatial relationships between the environment and human health, which may reveal patterns of association that otherwise are difficult or impossible to detect. For demonstration purposes, ultraviolet-B radiation measurements and malignant melanoma mortality data are being spatially and statistically analyzed.

USGS water-quality data also may be examined and spatially analyzed in conjunction with other U.S. public health data bases. Examination of indigenous (endemic) nephritis in Yugoslavia has led to a spatial investigation in the United States for kidney disease of similar origins. Additional disease candidates for study include certain types of cancer and other mortality and morbidity conditions occurring in the U.S. population.

Quality Map Products From Digital Data

By Thomas M. McCulloch

Digital spatial data serve a wide range of users, many of whom use the data as base information in geographic information system (GIS) applications. The GIS provides users with a flexible and diverse set of computer tools for integrating, analyzing, and displaying different types of data.

A network of GIS research laboratories supports studies relating to GIS development, image processing, visualization, and spatial data research, collection, and exchange. The state-of-the-art software and hardware systems in the laboratories are used in cooperative projects among the USGS, Federal agencies, and State, regional, and local agencies. The projects demonstrate the use of GIS hardware and software in combining and analyzing spatial data to solve specific problems.

As GIS technology matures, more users are taking advantage of proven GIS capabilities to build digitally based systems for making standard topographic and thematic maps. Producing these graphic maps from digital data is particularly important because, as the data are revised, new maps will be needed to reflect the latest information available in the data.

The USGS produces and distributes planimetric digital spatial data in digital line graph (DLG) format. The DLG data are based on two models that represent, in computer-readable form, the information shown on a printed map. These models are the DLG–3 model, the current standard for content, and the DLG–E model, designed to support advanced cartographic and GIS applications. The DLG–3 model is built on vector-based data obtained primarily by converting to computer-readable form the center line of symbols from USGS quadrangle maps. The model uses basic spatial elements, topological relationships, and descriptive attributes to digitally portray the cartographic features of published maps.

The DLG–E model is also vector based but is derived primarily from image sources, published maps, and existing DLG–3 data. The model adds a feature structure and specific nontopological relationships such as flow direction to a reorganized set of spatial elements and a broader set of descriptive attributes, including names for selected features. The DLG–E model is designed to represent a wide range of geographic spatial information, including additional features and attributes the user may define.

The feature structure for the DLG–E model is implemented through a set of rules for handling the more than 200 features shown on a standard topographic quadrangle map. To represent so broad a domain of features, a wide array of rule sets, such as extraction specifications, representation rules, symbol specifications, and product generation rules, are needed to support the effective implementation of the DLG–E data model. This new data model and the rules supporting it will enable the USGS to generate up-to-date graphic products from existing digital data.

Graphic production systems are being designed to run on high-performance graphic workstations. The increased data handling capabilities and declining costs of these workstations make them an effective solution to the problem of producing graphic products from digital spatial data. GIS applications software running on a workstation can perform the data manipulations needed for cartographic symbolization and then generate a data file that can be plotted on existing large-format, high-quality plotters. From these film plots, press plates can be made to print the maps. The combination of digital spatial data and GIS's, once limited to demonstration projects in the GIS research laboratories, has expanded to enable the use of advanced data models and structures to produce publication-quality standard and thematic maps.

International Activities

Overview

Cooperative and assistance programs between the USGS and foreign countries transfer technology to other nations by providing advice and training. Funds for USGS technical assistance to foreign countries, including all training programs either within or outside the United States, are supplied by other Federal agencies, international organizations, or foreign governments. Some funds appropriated annually to the USGS for research are allocated to cooperative ventures with foreign counterpart organizations that in turn supply funding and (or) personnel and printing services.

Cooperative projects range from individual scientist-to-scientist discussions, correspondence, and exchange visits on topics of mutual interest to jointly staffed, formally organized, bilateral scientific research and multilaterally coordinated investigations that focus on various scientific phenomena. USGS scientists also serve as officers, committee members, or participants in international organizations, commissions, and associations.

Currently the USGS and counterpart agencies in 47 countries have 71 agreements under which cooperative research may be undertaken; another 16 agreements are multinational, regional, or worldwide in scope. In fiscal year 1990, investigations conducted under these agreements include:

- Data collection by remote sensing from AVHRR, Landsat, and SPOT imagery,
- Surveying and mapping to produce base, topographic, geologic, and other thematic maps,
- Surveying and mapping in polar regions to assess changes in glaciers, ice-sheets, and climate,
- A worldwide International Strategic Minerals Inventory and, in individual countries, research, assessment, and modeling of mineral resources,
- Assessment of worldwide resources of oil and gas under the World Energy Resources Program and, in individual countries, research, assessment, and modeling of energy resources, such as petroleum, coal, peat, and geothermal,
- Research, assessment, and modeling of surface- and ground-water resources in various countries and regions,
- Activities to mitigate geologic and hydrologic hazards, predictive investigations and monitoring for volcanic eruptions, and global research on geophysics, seismicity, and earthquakes,
- Exploration research in marine geology, and
- Research, assessment, and modeling for climate-change and atmospheric-deposition programs.

The strengthening of earth science institutions in other countries, training of foreign nationals, and exchange of scientists are all integral to USGS international programs. During fiscal year 1990, 155 nationals from 41 countries received training in the United States. Fifty-seven visiting scientists from 15 countries conducted research either at USGS or other installations in the United States as arranged by the USGS. USGS personnel trained more than 78 foreign scientists and technicians, either individually or in groups, in their respective countries. Overseas training was concentrated in those countries that have long-term projects—Saudi Arabia, Pakistan, Bangladesh, Abu Dhabi UAE, Indonesia, Venezuela, and Bolivia.

In the spirit of international openness and cooperation underway, new and expanding programs in the Soviet Union and in Eastern European countries are providing exciting opportunities for USGS scientists and their counterparts in these nations to enhance their scientific knowledge of the world. The joint studies at Lake Baikal and in the Soviet Far East are examples of the effective scientific cooperation that is being fostered. Finally, continuing partnerships with nations in Central and Latin America underscore the longstanding commitment of the USGS and the Nation to pursue scientific investigations and cooperation in our own Hemisphere.

Lake Baikal in the Soviet Union

By Paul P. Hearn, Steven M. Colman, and Peter W. Lipman

Located just north of the Mongolian border in southeastern Siberia, Lake Baikal is the oldest (25–30 million years old), the deepest (1,056 feet), and by volume

Mission

International studies in science and technology are an important adjunct to the domestic program of the U.S. Geological Survey. Authorization for foreign investigations is provided by the Organic Act, the Foreign Assistance Act, and related legislation. Activities are conducted under bilateral or multilateral agreements that require approval by the U.S. Departments of the Interior and State. The following factors are used to determine if potential studies are in the interest of the U.S. Government and should be pursued:

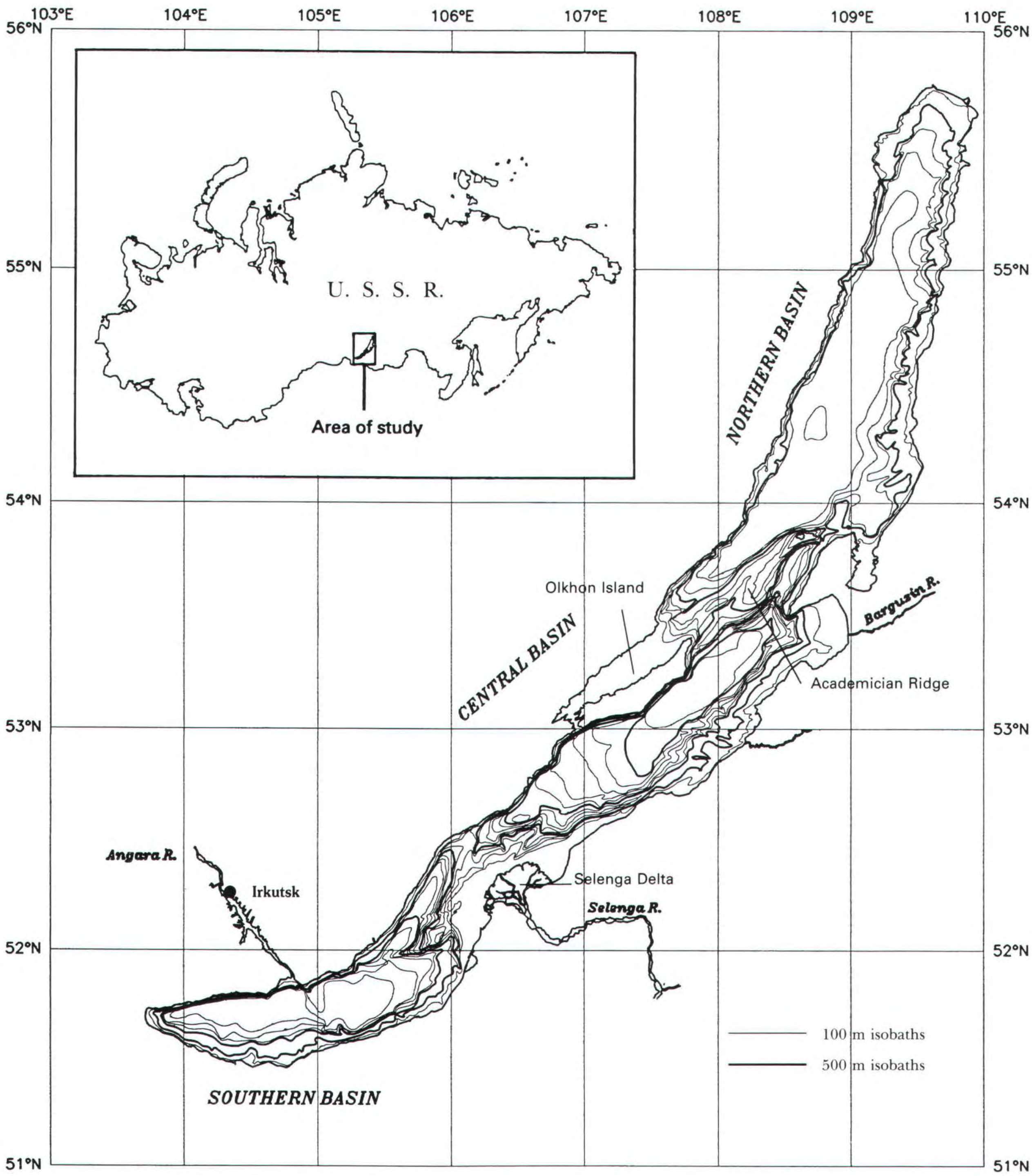
- *Domestic research objectives will be expanded in scope and achieved through the comparative studies of scientific phenomena nationally and internationally.*
- *Information about existing and potential foreign resources of interest to the United States will be obtained and incorporated in worldwide data bases.*
- *Scientific knowledge, understanding, expertise, and reputation of the USGS and of the United States in the earth sciences will be broadened and appropriately recognized internationally.*
- *Relations with foreign counterpart institutions will be developed and maintained, and the programs will facilitate scientific cooperation, technology transfer, and data exchange.*
- *International programs of other Federal agencies, academia, and the private sector will be supported; in particular, the Department of State will receive adequate scientific information required to formulate foreign policy objectives and decisions.*

(5,600 cubic miles) the largest lake in the world. Lake Baikal is the most prominent feature of the Baikal rift zone, an area extending from northwestern Mongolia to southeastern Siberia, where movements of the Earth's crust have created a series of troughs and depressions. The Baikal rift, which has been the site of numerous large magnitude earthquakes during the past 100 years, is still active. The extreme age of the lake also makes Baikal an incredibly rich page in the world's geologic record; lake deposits will provide critical data for global change research.

Intracontinental Rift Comparison

In 1988 and 1989 geologists from the United States and the Soviet Union participated in a joint study to compare the Baikal rift zone with the Rio Grande region, a geologically similar rift zone extending from Texas to Colorado in the U.S. southwest. The exchange, which included field work in the United States and the Soviet Union, was sponsored by the Soviet Academy of Sciences, the U.S. National Academy of Sciences, and the USGS. Research focused on the sedimentary

Bathymetric map of Lake Baikal, digitized from a Soviet map. Inset shows location of Lake Baikal in eastern Asia.

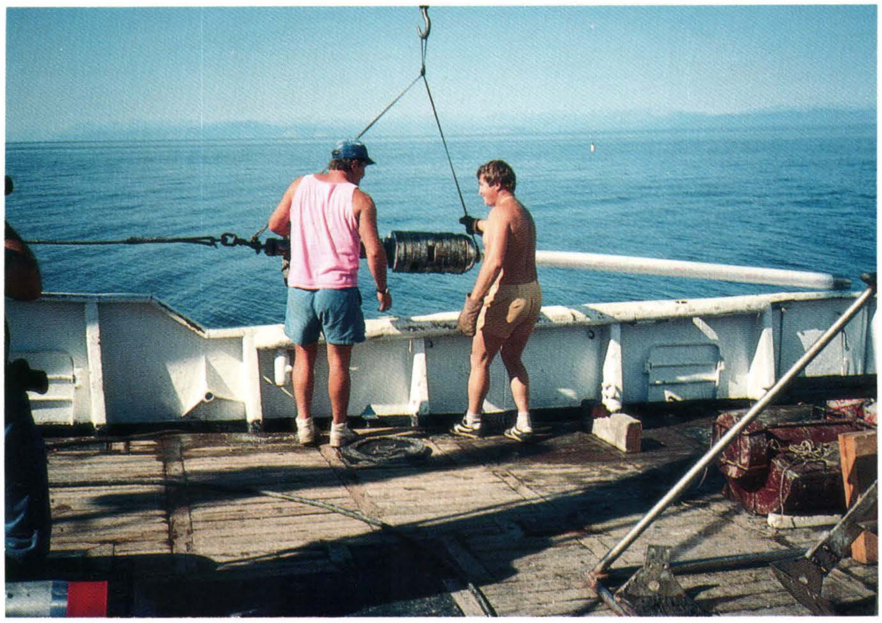


record of rift evolution, the relation of volcanic activity to rifting, the study of deep rift structures by geophysical methods, and the relation of the rifts to the overall geologic evolution of the surrounding areas.

Despite contrasts in geologic setting, both rift systems are similar in the timing and structural character of their development and have similar geophysical signatures. Volcanic activity, on the other hand, is much more extensive in the Rio Grande rift area than in the Baikal region. Longer term cooperative exchanges will (1) provide more data on the timing of rifting by using radiometric analyses, (2) determine the exact mechanisms of rifting, (3) examine the deep structure of the rift areas by using geophysical methods, and (4) study the composition of rift related rocks.

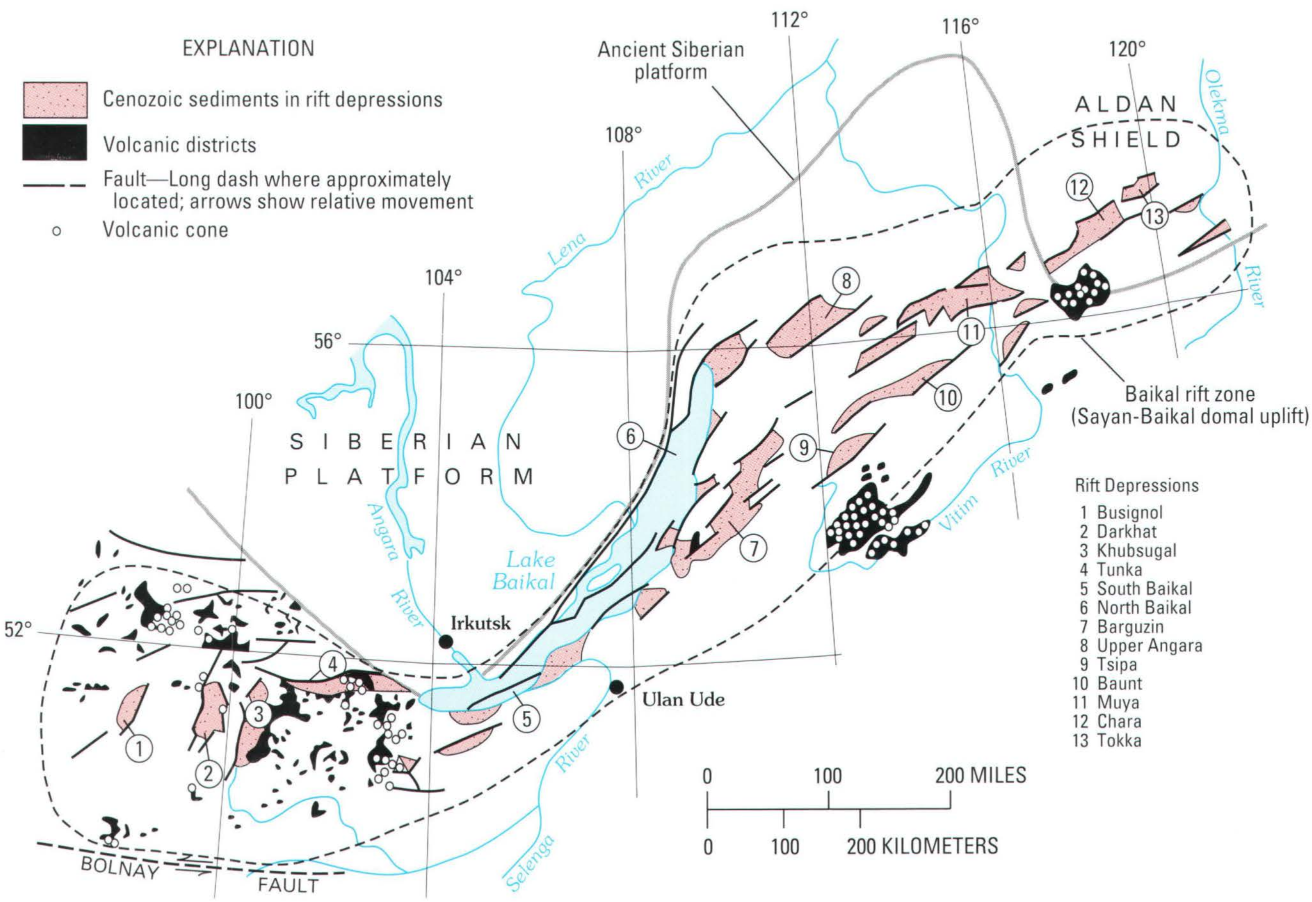
Paleoclimate Research on Lake Baikal

As the Baikal rift has opened during the last 25 million years, as much as 2.5 miles of sediment have accumulated on the bottom of the lake. By studying plant and animal matter

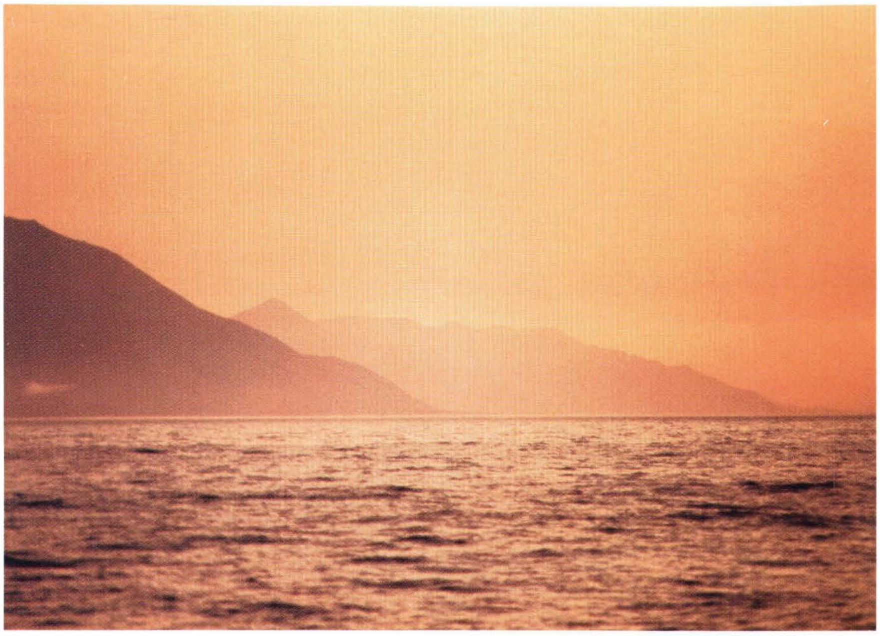


PAUL P. HEARN

In Lake Baikal, U.S. and Soviet geologists deploy a giant gravity corer from the R/V Vereschagin, *a research vessel of the Limnological Institute in Irkutsk.*



The general regional geologic setting of the Baikal rift, southeastern Siberia.



PAUL P. HEARN

Sunset on Lake Baikal near the northern end of Olkhon Island.

preserved in these sediments and the composition of lake sediment and pore water, scientists can reconstruct a record of past climatic conditions.

Baikal is an especially promising site for paleoclimate studies. The high-latitude location (52 to 58° N.) makes the lake particularly sensitive to changes in the Sun's radiative heat input; these changes are caused by long-term variations in the shape of the Earth's orbit. Also, the extreme seasonal contrast of the highly continental climate in southeastern Siberia makes Baikal an ideal location to record annual variations. Finally, unlike most other lake systems existing today, the sediments preserved in Baikal were not scoured by advancing ice sheets during the last ice age. Consequently, Baikal sediments represent one of the longest and most complete continental records of climate change in the world.

During the summer of 1990, scientists from the USGS and from U.S. universities conducted a joint field study on Lake Baikal. They collected samples from miles below the sediment surface and cores of bottom sediments at several sites in the lake.

These data and samples represent the first stage of a proposed 5-year joint U.S.–U.S.S.R. paleoclimate study on Lake Baikal. The proposed research will apply micropaleontologic, isotopic, geochronologic, sedimentologic, and geochemical methods to reconstruct a record of climate change in southeastern Siberia during the last 1 to 2 million years. The USGS contribution to this effort is the Climate Change Program. The involvement of U.S. universities is being supported through the National Science Foundation.

The Soviet Far East and Alaska

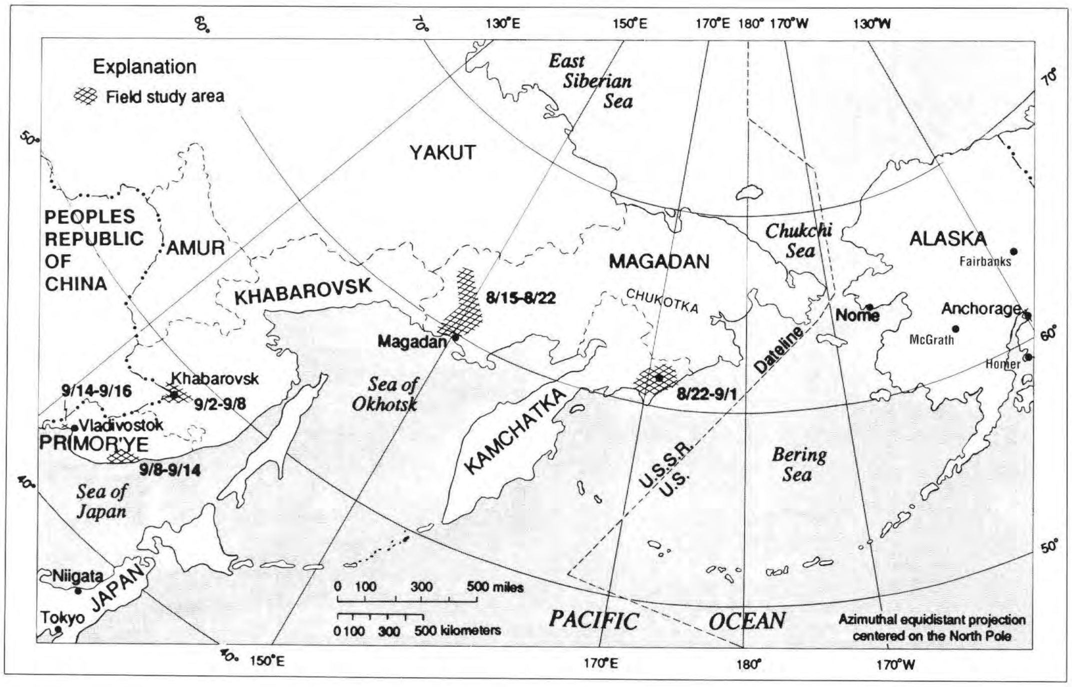
By Warren J. Nokleberg, William W. Patton, Jr., and Paul P. Hearn

Mineral Deposits.—The formation of mineral deposits in the Soviet Far East and Alaska is the focus of a cooperative project by the USGS with the Far East Branch of the Soviet Academy of Sciences, the Soviet Ministry of Geology, and the Alaska Division of Geological and Geophysical Surveys (DGGS). This project will allow scientists from both countries to (1) conduct collaborative field studies of lode mineral deposits, bedrock geology, and tectonics in both regions, (2) publish a series of metallogenic maps that show the distribution of rocks associated with specific types of ore deposits and their relations to the overall geologic evolution of the area, and (3) publish interpretive articles describing the formation of mineral deposits in the context of the geologic and tectonic history of the two regions.

USGS and DGGS geologists visited ore deposits in the Magadan and Primor'ye regions of the Soviet Far East when project work began in 1989. In 1990 the U.S. team continued work on a series of metallogenic and tectonic maps of Alaska. In addition, two groups of Soviet geologists took part in 5 weeks of detailed field studies in Alaska and interpretive discussions at USGS facilities. In Alaska, the Soviet geologists examined various lode mineral deposits in areas near Nome, Fairbanks, McGrath, Homer, and Anchorage.

WARREN J. NOKLEBERG

U.S. and Soviet members of the metallogenesis project at the Democrat granite-hosted gold deposit, south of Fairbanks, Alaska.

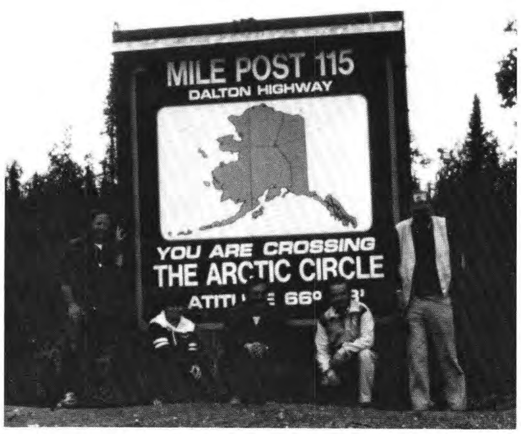


Areas of investigations by joint U.S. and Soviet metallogenesis projects in Alaska and the Soviet Far East.

At scientific workshops, geologists from private industry, universities, and government agencies made considerable progress on developing a common approach for compilation of the mineral-deposit maps and the preparation of scientific publications.

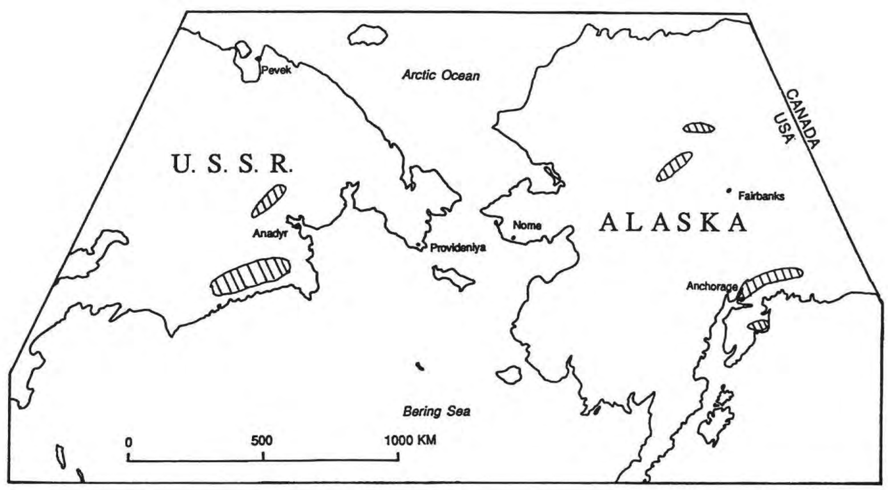
Ophiolitic Terranes.—Ophiolites are igneous rocks that represent slices of oceanic crust preserved in zones where crustal plates have collided in the past. These rocks commonly host commercial deposits of chromium and other metals. In 1989 USGS geologists began a cooperative project with geologists from the Soviet Academy of Sciences to study occurrences of these rocks in Alaska and northeastern U.S.S.R. The project began in 1989 when two Soviet geologists visited key ophiolite localities in Alaska and discussed project responsibilities for the U.S. and Soviet temas. Work continued in 1990 when geologists from USGS and DGGS visited the Chukotka region of the Soviet Far East.

The final product of this project is a 1:2,500,000-scale map of ophiolitic terranes in both areas, including tables summarizing the lithology, geochemistry, age, mineral deposits, and geologic setting of the terranes. The map and tables will be published in Russian by the Soviet Academy of Sciences and in English by the USGS.



WARREN J. NOKLEBERG

U.S. and Soviet members of the ophiolite project during field studies conducted in Arctic Alaska in 1989. This was the first crossing of the Arctic Circle in Alaska by geologists from the Soviet Far East.



Regions of Alaska and northeastern Soviet Union to be covered by joint ophiolitic terrane map. Ophiolitic terranes in patterned areas were investigated by the U.S. and Soviet teams in 1989 and 1990.

Cooperative Mineral Activities in Latin America

By Norman J Page, Charles G. Cummingham, Gregory E. McKelvey, and others

The USGS Center for Inter-American Mineral Resource Investigations (CIMRI) encourages and advances studies of nonfuel mineral resources in South America, Central America, and the Caribbean. Headquartered in Tucson, Ariz., CIMRI projects include mineral information exchange, cooperative investigations and research, and training aimed at assisting Latin American countries in developing their mineral economies.

Training and Technology Transfer

CIMRI personnel develop and collect information relevant to mineral resources including geology, geochemistry, geophysics, remote sensing, and mineral deposits and occurrences for countries in the Caribbean and the Americas. The center contributes information to several computer data bases including the Mineral Resources Data System (MRDS), which is available to the public through Minerals Information Offices (MIO) in Washington, D.C.; Tucson, Ariz.; Reno, Nev.; and Spokane, Wash.

Coverage of mineral deposits and occurrences in the states of Sonora, Baja Sur, Baja Norte, and Chihuahua in Mexico, the Guayana Shield of Venezuela, the Altiplano of Bolivia, northern Chile, and Honduras has been greatly expanded. The Tucson MIO has taken the lead in assisting CIMRI in collecting, translating, and entering Latin American data in MRDS. Publicly available information and resources include bibliographies of geosciences related to mineral resources for Bolivia and the Guayana Shield of Venezuela and a partial bibliography of geophysical information on the Caribbean and the Americas, as well as archives of maps, books, and papers on Latin American earth science.

In a symposium on the mineral resources of the Chihuahua Desert, CIMRI representatives presented data on mineral deposits and occurrences in northern Mexico. At the Exposición Latinoamericana de Minería in Santiago, Chile, grade and tonnage models were shown to be applicable in the search for ore deposits that are amenable to small-scale mining, which does not require large capital outlays. While small-scale mining can be conducted on large deposits, certain deposits are particularly amenable to small-scale operations. By grading deposit sizes from smallest to largest, an explorationists can select deposit types that have appropriate size ranges for small-scale mining.

Deep weathering in the tropical climates in parts of Latin America has produced thick and extensive lateritic soils. These soils are rich in secondary oxides of iron or aluminum or both. Recently, concentrations of gold that form mineable deposits have been identified in laterites. By developing tonnage and grade models for these lateritic-saprolite-gold deposits, Latin American scientists now have another tool to aid in mineral exploration.

The USGS began a 2-year training project in May 1990 for earth scientists from the national geological institutes of Peru, Bolivia, and Chile. Investigations are centered on volcanic-hosted, epithermal gold-silver deposits of the Central Andes. The project, funded by the Inter-American Development Bank, includes some of the latest technology and concepts in mineral deposits, volcanology, geochemistry, and remote sensing. The project field areas are within a volcanic field of the central Andes and include known mining districts, as well as unexplored areas of altered rocks. Training includes learning how to use thematic mapper images from the Landsat 5 satellite to map the distribution of volcanic centers and related altered rock in the high Andes.

CIMRI Program Highlights

Venezuela

Cooperative investigations by the USGS and Tecnica Minera, C.A. (TECMIN) on mineral resources of the Guayana Shield in Venezuela are funded by the Corporación Venezolana de Guayana. As part of the USGS–TECMIN program, the USGS is preparing a set of 1:500,000-scale geologic and tectonic framework maps of the Guayana Shield based on an integration of available coverage of aeromagnetic data, radiometric data, gravity data, side-scanning radar, aerial photographs, and reconnaissance field work.

The first of these maps is of the Puerto Ayacucho region and shows a large granitic intrusion, which is suitable for use as building stone, along with potentially mineralized rock and several gold deposits. Three, previously unknown, ringlike structures have been identified during data interpretation and assembly of the map. One of the structures is associated with uranium and may be a large carbonatite intrusion. Numerous small to medium sized buried magnetic bodies are also depicted on the map; it is effectively a representation of the top 6 to 9 miles of the Earth's crust in this area. This map series is the foundation for a detailed mineral-resource appraisal (completion: 1991) of the Guayana Shield.

Bolivia

The Ministry of Mines and Metallurgy and the USGS have a cooperative project with the Geologic Survey of Bolivia (GEOBOL). The project is funded by the Trade and Development Program, established by the International Development Cooperation Agency, to undertake a mineral resource assessment, coordinated by CIMRI, of the Altiplano-Cordillera Occidental of Bolivia.

As part of this work, geologic maps of the Altiplano prepared by GEOBOL at 1:250,000 scale were scanned into a computer system. These maps are used to compile a digital Altiplano-Cordillera Occidental geologic map, which will be published at a scale of 1:500,000 in a USGS Bulletin. Remote sensing imagery for the entire Altiplano is being analyzed to map mineralized and altered rock. Existing aeromagnetic data for nearly half of the Altiplano are obtained by GEOBOL, and these data, combined with new aeromagnetic data currently being contracted, will provide coverage for nearly 70 percent of the area.

Collaborative teams of USGS and GEOBOL scientists are visiting known and suspected mineral occurrences found during an extensive review and cataloging of the unpublished literature in Bolivia. Mineral occurrence data on about 300 sites are already in the MRDS. Field work is completed in areas of known copper mineralization and regions containing industrial mineral potential. The remainder of the field work, including investigations into precious metals, will be completed by the end of 1990.

Uruguay

Cooperative investigations are underway in Uruguay by the USGS and the Dirección Nacional de Geología y Minas. Geophysical, geological, geochemical, and drill data are evaluated with comparable information obtained from the Dirección Nacional de Geología y Minas for intrusive rock in the Cerro Mahoma area near San Jose de Mayo. This information and further field examinations established that some of the rock in this Precambrian intrusion is suitable for use as an ornamental stone, called granito negro. This intrusive rock may also contain copper-nickel-platinum-group minerals.

Chile

Mineral resources of the Taitao ophiolite in southern Chile are being studied by the USGS in conjunction with the Colorado School of Mines and the Servicio Nacional de Geología y Minería de Chile. This research project is supported in part by the National Science Foundation.

Remote southern Chile remains a frontier for basic geologic study and mineral-resource development. This region, which has many similarities to the mountainous region of western North America from the eastern face of the Rocky Mountains to the Pacific Ocean, holds promise for mineral wealth. The Taitao region offers a unique location for studying the plate tectonic process of collision between an oceanic ridge and the continental boundary and any associated mineralization. Here, on the Chile rise, new ocean floor is forming by upwelling of the Earth's mantle and submarine volcanism, and the ocean ridge is being subducted below the South American continental plate.

Geologic mapping, geochemical evaluation of rock and stream sediment, and petrology from the Taitao Peninsula are being used to understand the origin of the rock and to determine mineral-resource potential. The rock of the Taitao Peninsula is a likely host for deposits of platinum-group metals, chromium, copper, and gold. Field investigations uncovered an occurrence of copper and zinc mineralization. The results of this study have implications for the mineral-resource potential of areas further south in Chile where ridge-continent collision has occurred in the more distant geologic past.

Future Plans

CIMRI will continue to provide geoscience information relevant to the mineral resources of the Caribbean and the Americas with the goal of synthesizing information on large regions in Latin America, such as the Andes. Discussions for developing mineral-resource assessment programs in Honduras, Argentina, and Uruguay and for a study of gold placers of the eastern Andes are underway.

Computer-Assisted Map Revision—Bolivia

By Richard D. Sanchez

One of the most significant mapping problems facing many Latin American countries today is the revision of outdated base maps. Because of the increasing cost of acquiring aerial photography—a key source of information for map revision—the Inter-American Geodetic Survey of the U.S. Defense Mapping Agency joined the USGS, under the auspices of the Pan American Institute of Geography and History, in examining the potential use of computer-assisted techniques and SPOT (Satellite Pour l'Observation de la Terre) and Landsat thematic mapper (TM) data to detect changes at the scale of 1:50,000.

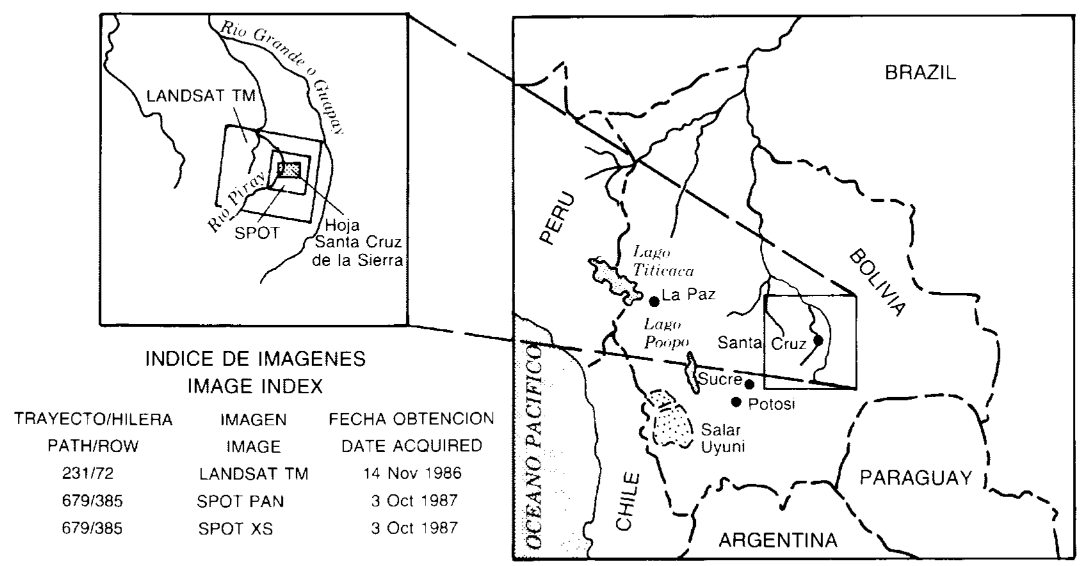
Computer-assisted techniques are distinct from the conventional cartographic techniques used for photointerpretation and map revision. These techniques were developed with the use of a personal computer and include the image processing of electro-optical sensor data and the superpositioning of digitally scanned map overlays for visual interpretation of change. The 1:50,000 scale was chosen because it is the standard scale for the topographic map series in Bolivia.

The test area selected is in the eastern piedmont region of the Andean Cordillera Oriental in the province of Santa Cruz, Bolivia. This relatively flat area of woodlands, cultivated fields, and pastures lies within the Amazon basin. Its principal river is the Rio Piray. Santa Cruz de la Sierra, the departmental capital, is a rapidly growing center of commerce and a gateway to eastern neighboring nations.

To detect changes, a digital map file for time A is overlaid on a raster image file for time B; the two files are compared, and new information is noted. In a comparison of the 1967 planimetric data (time A) of the Santa Cruz area with a 1987 SPOT panchromatic image (time B), the tremendous expansion of the urban area and the striking increase in roads and other cultural features are readily apparent. On the SPOT image, cultivated fields, pastures, and woodlands are distinct from the urbanized area.

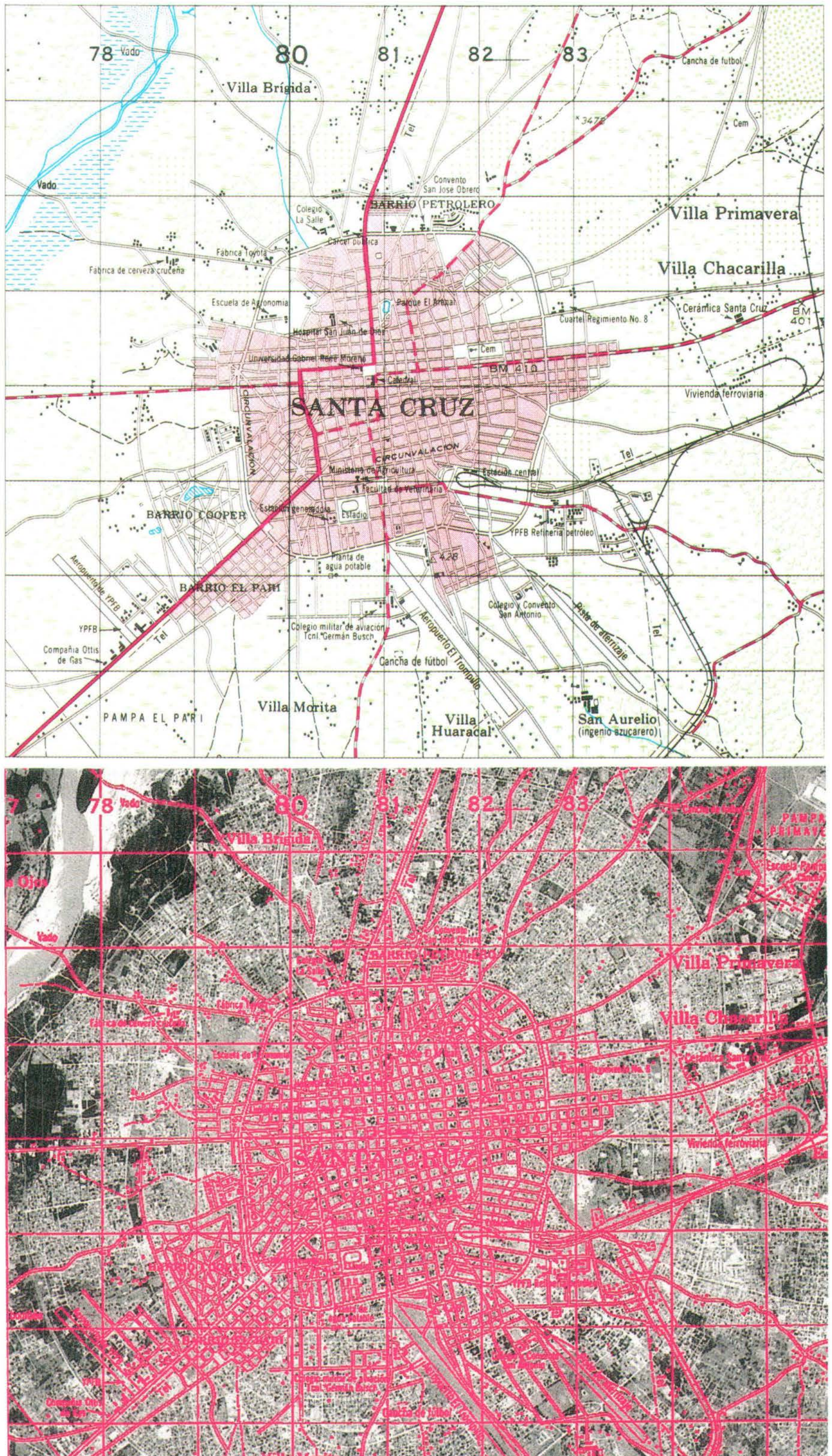
Approximately 75 percent of the revised features on the Santa Cruz de la Sierra map were detected by using a combination of SPOT panchromatic and Landsat TM imagery and computer-assisted techniques. Problems were encountered in the identification of certain features, such as urban structures, that require greater spatial detail or resolution than the satellite imagery can provide. Even though satellite images can detect new buildings and other structures and define new urban or suburban areas, supplemental aerial photographs or ground surveys may be required for the revision of intensely developed areas.

The joint effort showed that map revision at 1:50,000 scale is possible when the appropriate satellite images and other source information are used in conjunction with field verification. As a result of the findings in the Bolivia project, Mexico has asked the USGS to provide technical assistance in developing the capacity to do computer-assisted change detection and map revision using satellite data. Similar interest has been expressed by Venezuela.



TRAYECTO/HILERA PATH/ROW	IMAGEN IMAGE	FECHA OBTENCION DATE ACQUIRED
231/72	LANDSAT TM	14 Nov 1986
679/385	SPOT PAN	3 Oct 1987
679/385	SPOT XS	3 Oct 1987

Location of Santa Cruz, Bolivia.



The tremendous growth in urban area and changes in other cultural patterns in Santa Cruz, Bolivia, become readily apparent when 1967 planimetric map data are overlaid on 1987 SPOT panchromatic imagery of the same area.

Saudi Arabia—New Directions

By Kenneth A. Sargent and Paul Williams

The USGS and the Saudi Arabian Directorate General for Mineral Resources (DGMR) of the Ministry of Petroleum and Mineral Resources have begun a new 5-year study project. Cooperative work agreements with the Saudi Arabian government date to as early as 1944 and include extensive regional geologic mapping and mineral exploration. This latest agreement includes gold exploration, evaluation of the Al Jalamid phosphate region, and the initiation of a geohazards program.

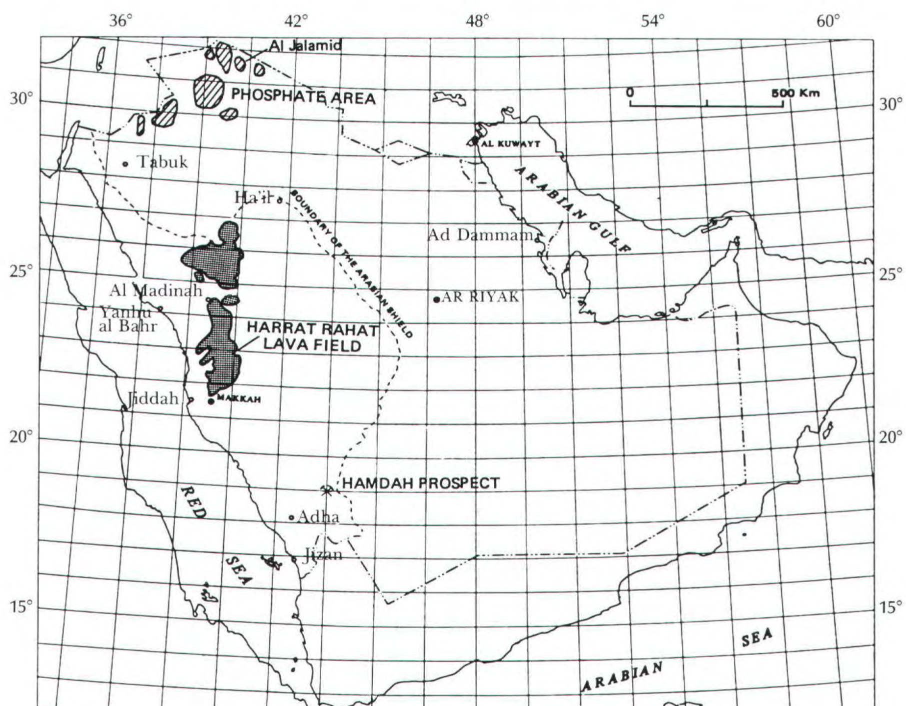
Gold Exploration

The USGS provides cooperative support for investigating mineral belts and certain gold prospects. Current investigations include the Hamdah prospect, an ancient gold mining site located in the southern Arabian shield about 340 miles southeast of Jiddah. Recent core drilling of the bedrock at the Hamdah site indicates an average gold grade as high as 0.18 ounces per ton. In addition, more than 200,000 tons of ancient mine dump, having as much as 0.21 ounces per ton of gold, may be present. Data from current drilling, mapping, and sampling may substantially increase gold reserve estimates.

Phosphate Exploration

The DGMR and USGS conducted reconnaissance exploration in Saudi Arabia in 1965 to determine if the Middle East-Egyptian phosphate province extended into the northern region of the Kingdom. This study reveals phosphate-rich desert pavement, derived from what was to become known as the Umm Wu al phosphate deposit, to be part of the Sirhan-Turayf basin, which is approximately 42,000 square miles in area. Later geologic mapping and stratigraphic studies delineate phosphate deposits at Thaniyat and Al Jalamid. The potentially economic phosphorites of Saudi Arabia occur at three horizons in rocks of the Sirhan-Turayf basin west of the northwest-trending, gently north-plunging Hail arch. Rocks in the basin are cut by northwest-trending normal faults.

The Al Jalamid deposit has the greatest economic potential of all the known phosphorite deposits in Saudi Arabia. The deposit contains about 15.7 percent phosphorite, has a thickness of about 10.5 miles, and occurs in the lowermost of the three horizons. The beds in the deposit dip gently to the west. The rock commonly contains small solution cavities, and approximately 25 percent of the phosphorite is friable (easily broken or crumbled) or semifriable. Data from the few deep boreholes that penetrated unoxidized rock outside the



Locations of current investigations in Saudi Arabia.

boundaries of Al Jalamid indicate that unweathered phosphatic rock is organic rich and contains dolomite, an important industrial mineral.

Geohazards Program

The Ministry of Petroleum and Mineral Resources has become increasingly concerned about geohazards in the Kingdom. Assessments of volcanism, earthquakes, and ground failures were assigned to the USGS by the DGMR at the start of the new 5-year agreement. Chief among the efforts in the geohazards program are studies supplementing earlier work in volcanoseismicity at the Harrat Rahat lava field in west-central Saudi Arabia where, in A.D. 1256, fissure eruptions of olivine basalt threatened the city of Al Madinah. A full color geologic map of the lava field completed by DGMR will be published in 1991. Planning is underway to develop a telemetered network of seismographs at the Harrat Rahat lava field, and detailed gravity work has begun. Evaluations of earthquake and ground-failure hazards will begin in fiscal year 1991.

Coal Resources in Pakistan

By Peter D. Warwick

Results of an ongoing project between the USGS and the Geological Survey of Pakistan (GSP) indicate that known and mined coal fields in the southern Sindh Province are not isolated coal occurrences. The project began in 1985 and is sponsored by the U.S. Agency for International Development as part of its Energy Planning and Development Project in Pakistan. Goals of the project are to train GSP geologists in various aspects of geology, improve GSP physical facilities, and increase the knowledge of Pakistan's coal resources.

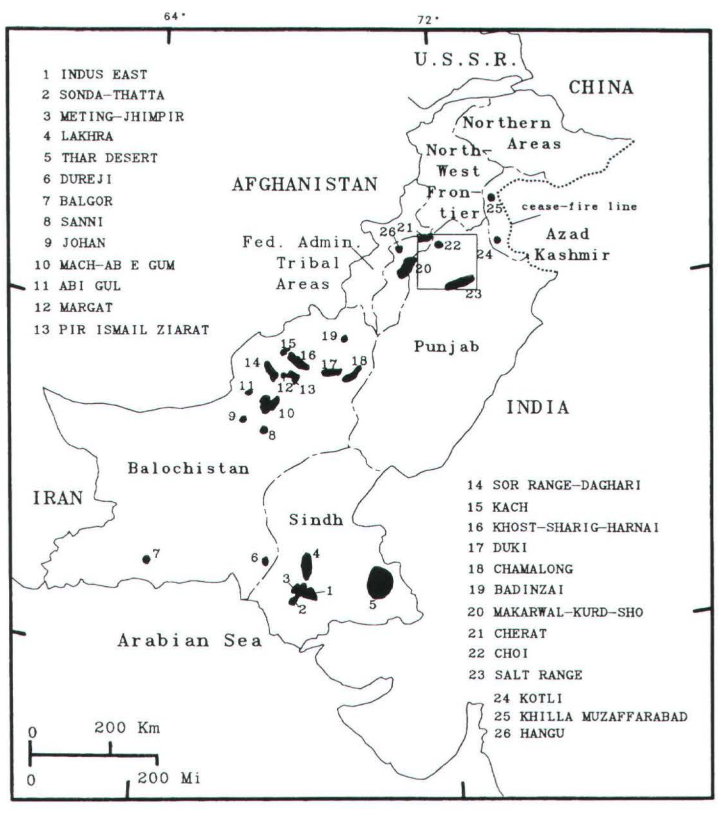
Much of southern Sindh, including the Thar Desert, appears to be underlain continuously by strata that contain coal beds. The Indus Valley Construction Company, a private drilling contractor, and the GSP drilled 68 holes as part of efforts to map and assess the quantity and quality of the coal resources of the Lakhra, Sonda-Thatta, and Indus East coal fields in Sindh. Such coal-bearing strata may have been deposited on the low-relief leading margin of the Indian subcontinent as it moved across the equator from the southern hemisphere before its collision with Asia some 20 to 25 million years ago.

More than 400 core and mine samples were collected from the same coal fields for analysis and determination of major, minor, and trace elements; also, lithologic logs were prepared from descriptions of rock cuttings and cores. Geophysical logs were obtained for the drill holes to aid in stratigraphic correlations. The coal in these fields ranges from lignite to subbituminous. Table 1 shows the estimates of coal-bed thickness, coal resources, and heating potential for samples from the Lakhra, Sonda-Thatta, and Indus East coal fields. Analytical results indicate that the coal beds contain an average of 33.1 percent oxygen, 28.4 percent moisture, 27.9 percent volatile matter, 25.2 percent fixed carbon, 18.3 percent ash, and 4.7 percent sulfur.

Data for selected coal fields in Pakistan

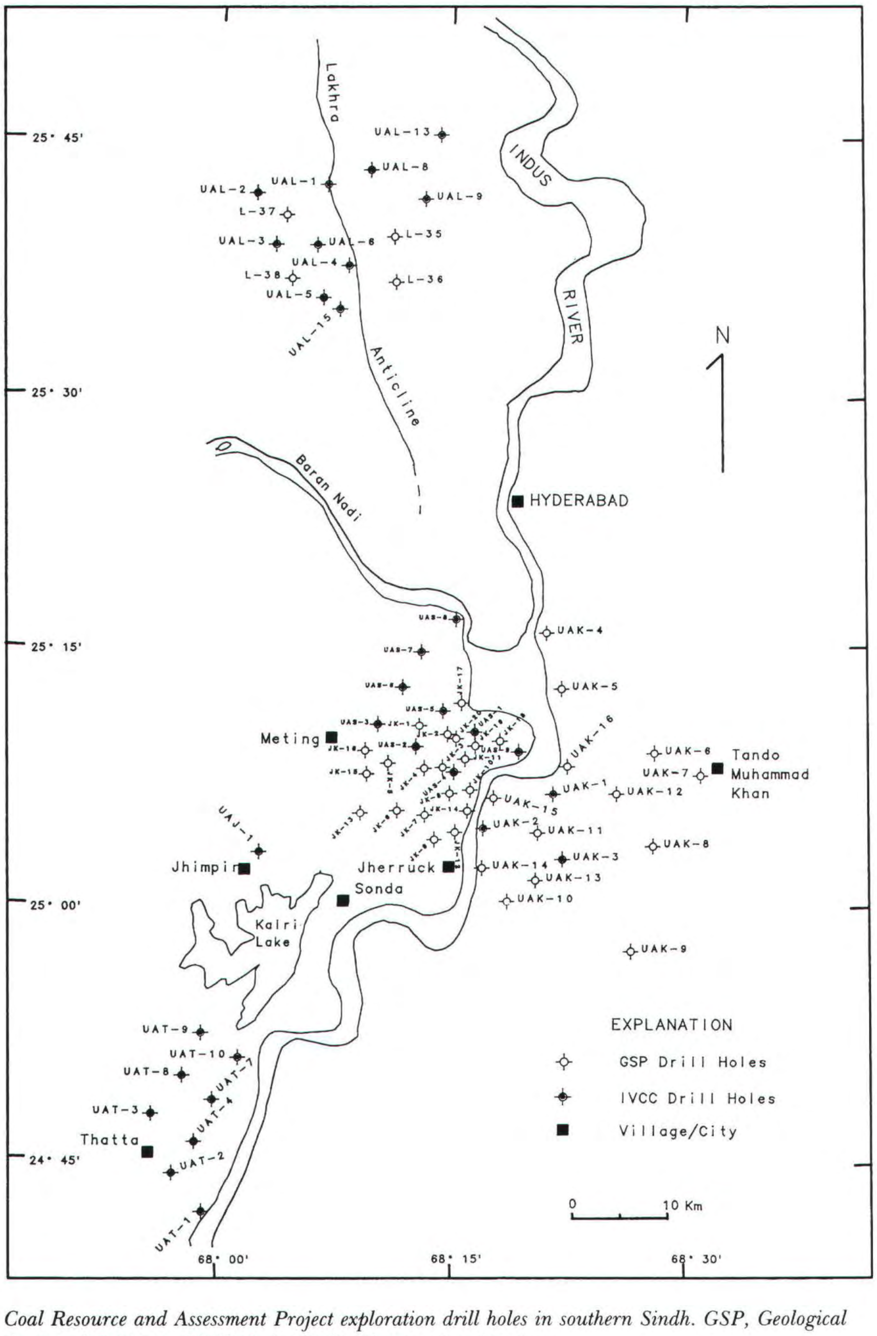
Field	Bed thickness (in feet)	Resources estimate (in millions of tons)	Heating potential (in Kcal/kg)
Lakhra	≤16	1,080	1,280–5,250
Sonda-Thatta...	≤21	3,700	1,610–4,830
Indus East	≤8	1,683	3,500–4,950

A second phase of the project, begun in 1987, includes surface exploration in the Salt Range coal field in the Punjab Province; the Sor Range and Khost-Sharig-Harnai coal fields in the Balochistan Province; and the



Location of Pakistan coal fields and occurrences. Box shows Punjab regional framework area.

Makarwal and Cherat coal fields in the North-West Frontier Province. To supplement coal exploration work in the Salt Range-Potwar Plateau coal-bearing area, a regional framework study was begun in 1988. This study provides training to GSP geologists and technicians who work with USGS counterparts in various geologic disciplines and provides a comprehensive evaluation of the geologic framework of Pakistan's coal fields by mapping at a scale of 1:250,000. Besides continued exploratory drilling and field studies, regional framework studies are planned for the Balochistan and Sindh coal fields. The project has been extended and is scheduled for completion in 1993.



Coal Resource and Assessment Project exploration drill holes in southern Sindh. GSP, Geological Survey of Pakistan. IVCC, Indus Valley Construction Company.

Bangladesh—Results of a 10-Year Program

By M. Dean Kleinkopf and John W. Whitney

June 1990 marked the end of a 10-year program between the USGS and the Geological Survey of Bangladesh (GSB) to accelerate exploration for mineral resources and to modernize the GSB. The GSB is charged with exploring and identifying metallic and industrial mineral deposits, as well as conducting basic geologic mapping, and providing geotechnical advice for use in urban and suburban planning. The cooperative effort between the United States and Bangladesh seeks to modernize GSB facilities and initiate effective programs in systematic geologic mapping of unconsolidated sediments, mineral exploration, geophysics, geochemistry, engineering geology, biostratigraphy, neotectonics, laboratory studies, drilling, and scientific publishing and information management.

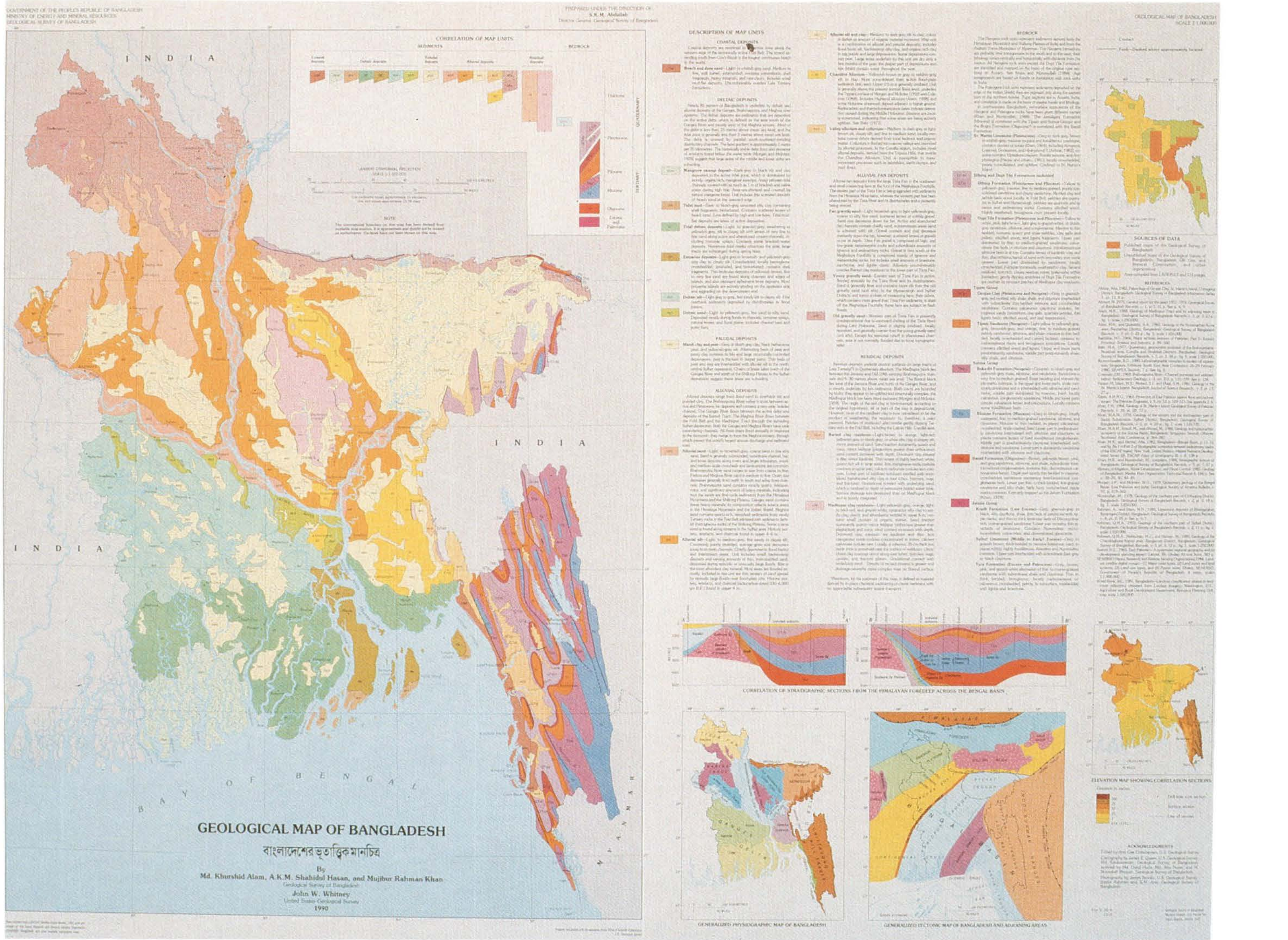
Coal and Mineral Potential

Bangladesh is situated on one of the great deltas of the world, formed principally by the Ganges, Brahmaputra, and Meghna Rivers that carry millions of tons of sediment yearly into Bangladesh. The surficial sediments are derived mainly from 5-million-year-old deltaic and alluvial deposits in the Himalaya Mountains.

The main resource commodities in Bangladesh are coal, glass sand, white clay, brick clay, and aggregate. Project scientists discovered two coal fields in northwestern Bangladesh by using geophysical exploration techniques and subsequent drilling. Estimates of coal resources are as much as 500 million tons of bituminous-rank coal. The coal occurs in thin sedimentary rock overlying crystalline rock that occurs at depths of a few hundred to a few thousand feet below the surface; coal horizons were delineated by negative gravity anomalies. At least nine other negative gravity anomalies indicate possible minable coal-bearing areas as revealed by seismic techniques and corehole drilling.

Training Assistance

To improve the technology for mineral exploration and to modernize the GSB, visiting USGS scientists conducted field and laboratory studies with GSB colleagues in five study areas. Short courses were taught on the interpretation of soils, aerial photographs, and Landsat images. Seminars were presented in micropaleontology, palynology, age-dating,



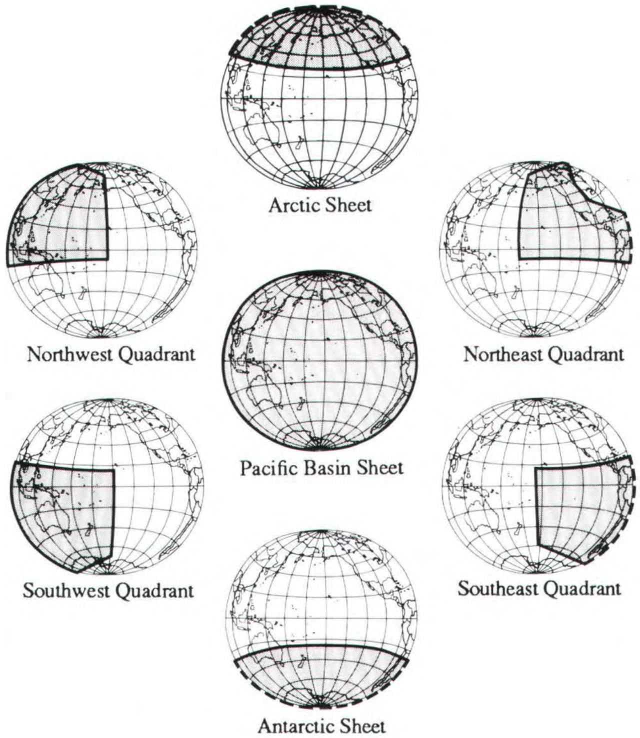
Geologic map of Bangladesh, scale 1:1,000,000.

geophysics, geological mapping of unconsolidated sediment, and geotechnical properties and measurements for engineering geology; all seminars stressed the importance of multidisciplinary studies. Seventeen of the younger GSB officers completed master of science degrees in overseas universities. Forty-five senior- and middle-level GSB officers participated in on-the-job training programs at USGS facilities in the United States for periods ranging from 1 to 6 months.

Accomplishments

Achievements of the project include establishing digital computer technology at GSB, discovery of two new coal fields, and discovery of new geologic evidence suggesting recent faulting and subsidence. Also, uplift of major landforms was identified as the possible cause of the shifting of major river drainages and related earthquake and flood hazards. Modern geoscience laboratories in geochemistry, biostratigraphy, petrology and mineralogy, engineering geology, and geophysics were equipped with new instruments and now provide capabilities for high-precision analyses in exploration and geologic studies. A new 1:1,000,000-scale geologic map of Bangladesh and companion gravity and magnetic anomaly maps were prepared.

GSB personnel gained training, technology, and expertise in managing a national geological survey. Similarly, the project provided USGS scientists an opportunity to study one of the largest deltas in the world, to refine Quaternary mapping and modern dating techniques, and to improve existing models for deltaic depositional environments and mineral resources assessments.



Boundaries for the six 1:10,000,000-scale circum-Pacific maps and the 1:17,000,000-scale Pacific basin sheet. Large parts of both the Arctic and Antarctic sheets are not shown on these index maps.

Mapping Half the World

By George Gryc

The Circum-Pacific Map Project (CPMP) began in 1973 as a joint endeavor of the Circum-Pacific Council for Energy and Mineral Resources and the USGS. The council is a nonprofit, nongovernmental organization founded to encourage international cooperation in the study of the geology and resources of the Pacific basin and the lands that form its rim. The final 61 maps of the CPMP, when complete, will portray more than one-half of the Earth's surface.

The objectives of the CPMP are to (1) outline the distribution of resources in the Pacific basin, (2) depict the relation between the latest geologic and tectonic data and known energy and mineral resources, (3) aid in the exploration for new resources, (4) compile new basin-wide geologic and resource data sets, (5) relate oceanic to continental geology, (6) focus on gaps in knowledge and encourage research to complete them, and (7) provide a mechanism for scientific cooperation among Pacific nations.

The CPMP is directed by a Council Map Committee. Scientific and technical coordination, cartography, and, since 1990, publication are being carried out by the USGS. Although maps are the main products, planning, compiling, and publishing geoscience data is of equal value. The American Association of Petroleum Geologists previously published, and still distributes, the earlier map products.

Data are compiled by six panels of the Council Map Committee and include international experts who live and work in the Pacific region. The CPMP has several unique and innovative aspects:

- Unlike most previous compilations, the maps include geologic and resource data for both land and ocean areas and have projection points in the mid-Pacific.
- A new series of equal-area, 1:10,000,000- and 1:7,000,000-scale base maps depicts data with minimal distortion.
- Base map information and most of the already published data sets on the thematic maps are computerized, and computer technology is being used in preparing the thematic maps.
- Several new data sets have been specially prepared for the map series; among these are sea-floor sediment, manganese nodule distribution, sedimentation rates, earthquake first-motion solutions, plate-motion vectors, Deep Sea Drilling Project borehole columns, and oceanic crustal ages.
- A new international network of voluntary and nonreimbursed scientific cooperation has been established among Pacific nations.

The circum-Pacific region is divided into seven areas: the four quadrants of the Pacific basin, the Arctic Ocean basin, all of Antarctica, and the entire Pacific basin. Base maps for each region have a scale of 1:10,000,000 on a Lambert Azimuthal equal-area projection and are individually centered to minimize distortion. The base map for the entire basin is a single sheet and has a scale of 1:17,000,000. Base maps and color geographic maps are part of the published series. In addition, there are thematic maps for each region and plate-tectonic, geodynamic, geologic, energy resources, mineral resources, and tectonic maps for the entire basin.

Publication of the base and geographic maps began in 1977, and thematic map publication began in 1981. Special themes of tectonostratigraphic, sea-floor materials, and natural hazards are compiled and published for the entire Pacific basin. In addition, a special map showing global change in the Pacific basin is being compiled, and color proof of a map showing sedimentary basins in the southeast quadrant is being reviewed. Thirty-six maps are now printed, and 25 more are in various stages of completion.

Information Systems Activities

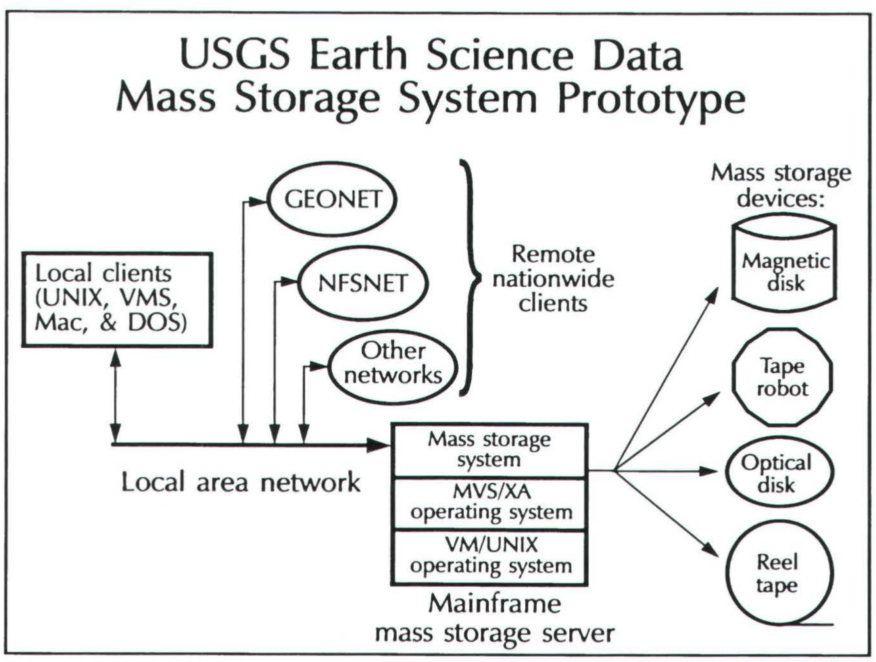
Mass Storage System for Earth Science Data

By Joe Aquilino and Tod Huffman

For the past 25 years, the USGS has used computer technology to help collect and store large volumes of cartographic, geologic, hydrologic, and other earth science data. In the past, these data were stored in mainframe computers. As data requirements and computing technology became more sophisticated, data-collection and data-base activities became more distributed, that is, centered around local or regional computer networks. Within these networks, minicomputer, microcomputer, and new high-performance workstations have become the primary means for data collection and storage.

As these distributed computer data-base environments expand, conventional approaches to data storage and archiving are inadequate. There is, therefore, an increasing need to upgrade, expand, and modernize the storage, management, and retrieval of archival data. A central USGS data storage facility of the future must consider the following:

- Global climate change, digital cartographic, geographic information systems, water resources, and geologic data, as well as international data exchange and Departmentwide administrative and financial data, will continue to increase significantly. Present hardware and software technology and physical space are insufficient to store current data holdings nor are they capable of handling expansive data growth during the next decade.
- Many data bases are constantly changing, and the most recent updates must be available to scientists to carry out investigations.
- Some data, such as administrative, financial, and unpublished scientific data, are intrinsically proprietary. Access to such data is usually restricted in some way.
- As geographically dispersed data-base developers create their own archiving methods, the resulting diversity of archival environments makes data aggregation and sharing difficult.
- Traditional magnetic tape archiving requires considerable physical space for tape storage, as well as expensive manpower to do tape mounts, when around-the-clock availability is necessary.
- The complexity and cost of computer communications necessary to aggregate distributed



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 coordinates, manages, and operates voice, data, and radio 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.

data for use in nationwide archival and retrieval systems are increasing.

- Providing standardized and systematic archival services for centrally stored, as opposed to distributed, data is far more effective, efficient, and less expensive.

During 1990, the USGS developed a prototype mass storage system. The design for the mass storage system focuses on a simple, straightforward solution to storing and retrieving very large files in a networked computing environment. The primary requirements of this design include the following:

- A storage system that has potential for organizing, storing, and managing any set of data files, regardless of where the client is located geographically.
- Virtually unlimited file storage capability (no system-imposed expansion limits). Initially this capability will approximate 1 terabyte (10^{12} bytes) of storage capacity that can be expanded simply by adding units of storage hardware.
- A very large file server accessible to any local area subnetwork via USGS telecommunications facilities.
- Access to the very large file server by using simple file transfer, management, and storage system command structure and syntax. Regardless of the diverse computing environments of users, the connection between client and file server will be explicit. All data file transmissions to and from the server, as well as queries and data histories, will be activated by the user; the user will have full control over the archive process.
- Compatibility with various communication networks and storage hardware.
- Good file security mechanisms that allow the owner to control access to data.
- The ability to share data files among diverse computer environments.
- A storage server that is constant over evolving generations of client hardware and operating systems.
- Accessibility, 24 hours a day and 7 days a week, at a low cost per gigabyte (10^9 bytes) of storage.

This mass storage system will eventually replace data archiving functions now associated with the existing mainframe computer. The system will embody all the advantages available in the current mainframe storage environment as well as vastly increase file storage capabilities, improve efficiencies in the use of file system hardware, have a new hierarchical library structure, and reduce storage costs.

For the scientific workstation and distributed data-base activities in nonmainframe environments, such as UNIX, VAX/VMS, Macintosh, and MS/DOS microcomputers, this mass storage system will have filename, directory structure, and command syntax conventions that are familiar to users of these environments, support common network standards and file transport facilities, allow sharing of data between these environments, and improve file security.

The mass storage system user, whether using UNIX, VAX, Macintosh, MS/DOS, or IBM-like mainframes, will learn one file server interface that will work the same for all systems. Standard commands will be available for connecting to the mass storage system; establishing or listing the contents of the user directory and detailed file descriptions and histories; storing and retrieving file(s) or hierarchical groups of files; adding, changing, and deleting files or directories; and invoking help commands. Through a file import-export capability, archived files can be stored in and retrieved from diverse system and storage media formats, and data sharing and disseminating can be made across various computing environments and data formats.

Mass storage system software for the existing mainframe and a robot tape storage device will be used to test a 1 terabyte mass storage system during 1991. A sample of representative data-base activities and scientific disciplines will be used to evaluate the system. This mass storage prototype will become the basis for developing the hardware, software, and basic data backup and archiving techniques necessary to handle the very large USGS data bases of the future.

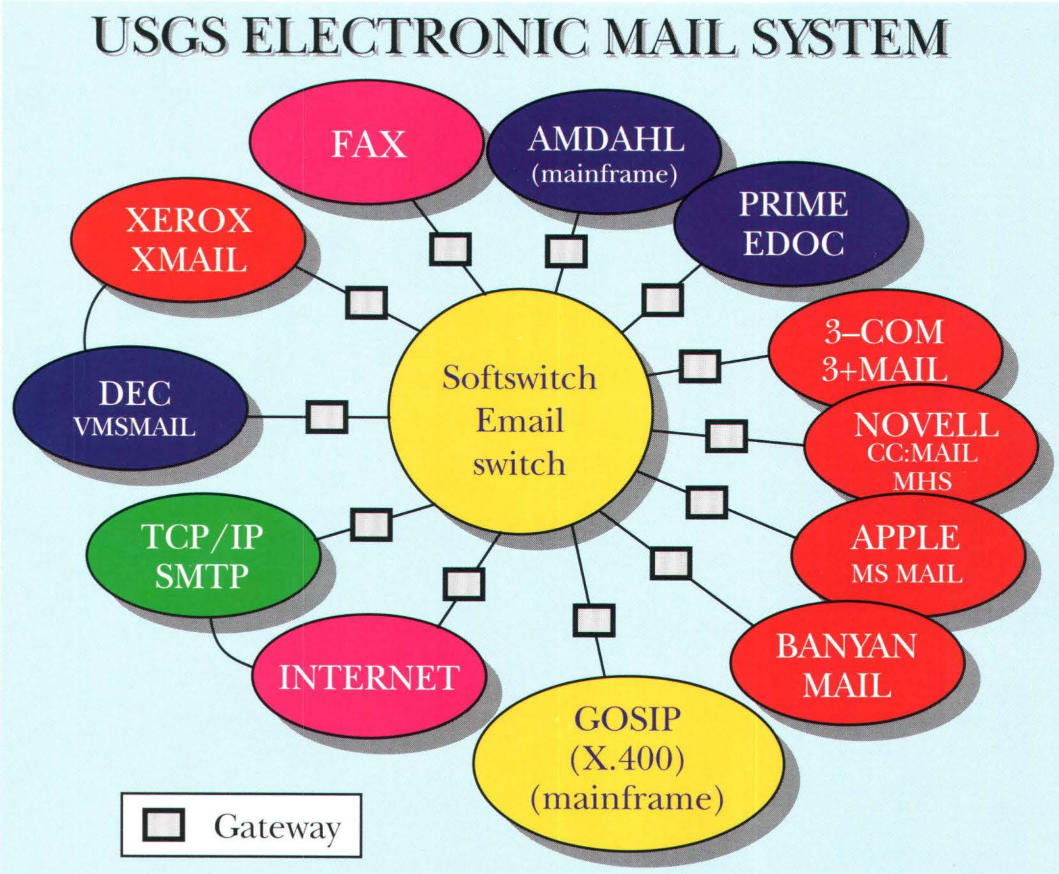
Electronic Mail

By Paul Celluzzi

Computer electronic mail (Email) is fast becoming a vital part of everyday business life. Email, which has evolved from simple message sending to complex information exchange, provides an efficient method of transferring information in electronic form. This information may be simple text messages, complex documents, graphics, facsimile, or binary programs. In the future, Email will even include voice and video annotation.

Email is an effective method for moving documents, messages, and data and has improved information flow and strengthened communication within the USGS. Throughout the bureau, scientists are recognizing the advantages offered by Email technology for communicating with colleagues and for conducting joint research from geographically dispersed locations.

The USGS is investigating technology that will allow information of all types to be



moved across different computer systems, application environments, and organizational boundaries. The diverse computer hardware and communication systems in use, however, complicate achieving a bureauwide system. Because each system has its own proprietary Email, implementing a single Email system is impractical. Instead, an alternative is to integrate the many separate USGS systems and connect to non-USGS systems. This approach gives each user the freedom to choose the Email system that best addresses local applications, provides for minimal disruption to existing user applications, preserves the investment in existing software, and avoids expensive retraining of users, who are able to continue to use their familiar local Email.

A central electronic Email switch will provide the necessary protocol conversion and mail routing when a user is sending information from one Email system to another. Also, a common central directory of user names and addresses will give USGS employees the ability to transfer electronic information to any user, regardless of computer system or Email software, simply by knowing the destination address. The sender will not need to know where the destination user is physically located, what computer system is being used, or on what Email system the destination user is registered.

Email is an end-user technology that, to be truly successful, must conform to design criteria that address user needs. The system must be universally accessible to users, allow transmission of different data types, be easy and inexpensive to use, be executable from within the user's local computing environment, and support interfaces to Email systems external to the USGS.

In the future, all USGS Email systems will support a standard convention for mail interchange that is part of a broader communication protocol suite known as GOSIP (Government Open Systems Interconnection Profile, discussed in "Open Systems Communication Standards," p. 88).

Arctic Data Interactive—A Hypermedia System

By Denise A. Wiltshire

In May 1988, the USGS and representatives from the Arctic research community established a cooperative program for managing and exchanging global environmental change data. The Arctic was selected as the focus for a data management project because

Figure 1. Computer screen from Arctic Data Interactive hypermedia system.

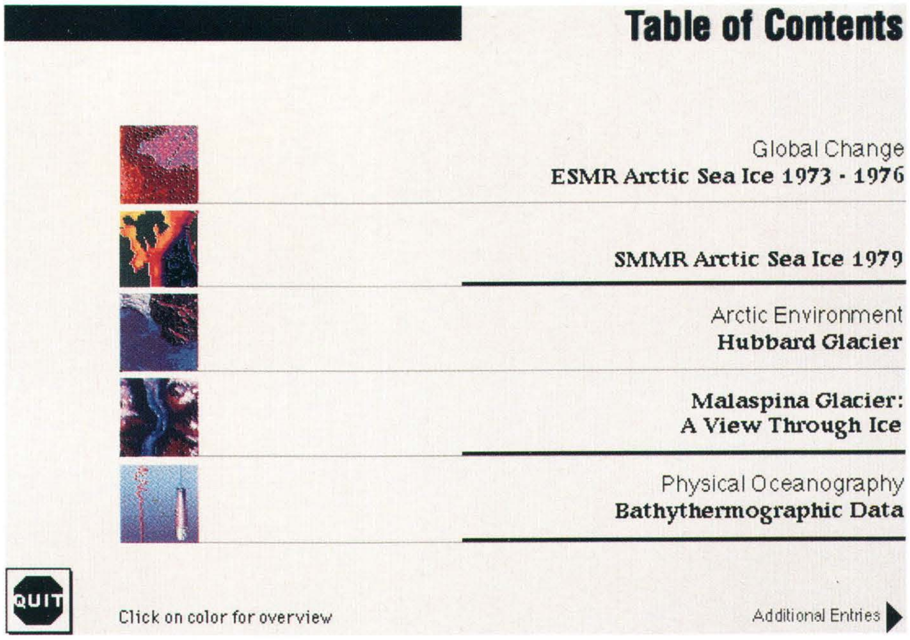
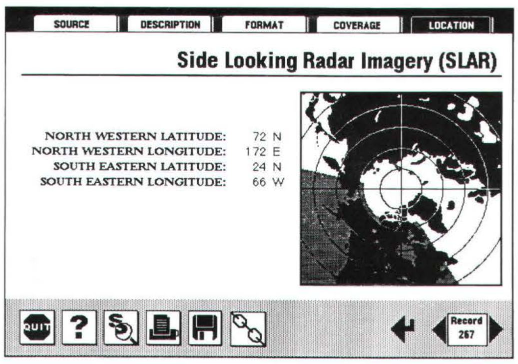


Figure 2. Computer screen from Arctic Environmental Data Directory section of the hypermedia system.



(1) climate models suggest that the Arctic will be one of the first areas to respond to changing climate, (2) the magnitude of environmental change will be greater in the Arctic than on other areas of the Earth's surface, and (3) the Arctic scientific community is a relatively small group that has a need to improve access to data and information from remote locations.

The USGS is an active member of the Arctic Environmental Data Directory Working Group, which is sponsored by the Interagency Arctic Research Policy Committee (IARPC). The working group is composed of representatives from government agencies and academia. A goal of the working group is to establish easy access to, and hence improve the dissemination of, earth science data and information about the Arctic.

As a first step, the working group developed the Arctic Environmental Data Directory, which contains more than 300 references to Arctic data sets maintained by U.S. Government agencies and other institutions. To meet the data management goals of the IARPC, the working group developed a pilot study, known as the Arctic Data Interactive (ADI), to integrate information to be published using compact disc-read only memory (CD–ROM) technology. The ADI prototype includes the following multimedia elements:

- Arctic Environmental Data Directory,
- Bibliographic information,
- Full text of research reports and short papers (including illustrations), and
- Arctic data sets.

The project will also develop an electronic journal prototype that will include a mix of textual, numeric, and spatial data and related software for data analysis. The data will be in standard formats to correspond with other applications software such as spread sheets, graphics, and image processing.

The design of the ADI prototype is based on the concept of hypertext technology. Hypertext, also known as hypermedia, is defined in the computer and information science literature as a software environment for developing nonsequential data-base-management systems. Hypertext techniques create associative links between structured and unstructured information that may include data, text, graphics, imagery, and sound. A hypertext link, conceptually similar to a footnote or a parenthetical phrase, directs the reader to related points or topics for further research.

A hypertext system is characterized by a user interface having icons (graphic representations) and multiple windows on a computer monitor. Icons for different functions allow readers to browse through information by following associative links between bibliographies, numeric data, textual information, and spatial imagery.

The goal of USGS experimentation with hypermedia technology is to integrate a broad range of multimedia formats into one

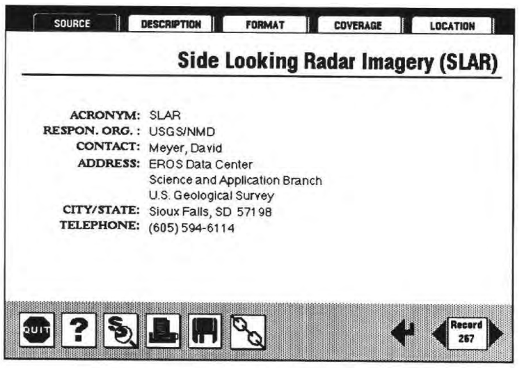


Figure 3A. The link icon indicates related material is available within the hypermedia system. See figure 3B.

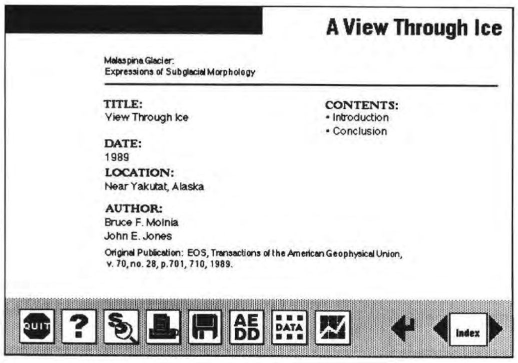


Figure 3B. Screen showing example of related information contained in hypermedia system as a result of choosing the link icon shown in figure 3A.

product, ADI, that allows access to Arctic digital data and information. The ADI hypermedia prototype is based on a printed journal format and, therefore, includes a series of papers listed in a table of contents (fig. 1). The reader can browse through the articles within the electronic journal by selecting an item from the table of contents or by choosing a link icon from within a section. By choosing the link icon, the reader then moves to related material. For example, the reader can begin searching through a data directory that is provided within the ADI (fig. 2).

While browsing the data directory, the reader can choose to link to the actual data set that may contain tabular numeric data (fig. 3*A*) or spatial imagery (fig. 3*B*). Upon reviewing the data set, the reader can then link to the full text of a journal article that provides analysis of the data. In addition to providing spatial data, such as side looking airborne radar data, the ADI includes image processing software that allows the reader to analyze data, such as the ice thickness of an Alaskan glacier.

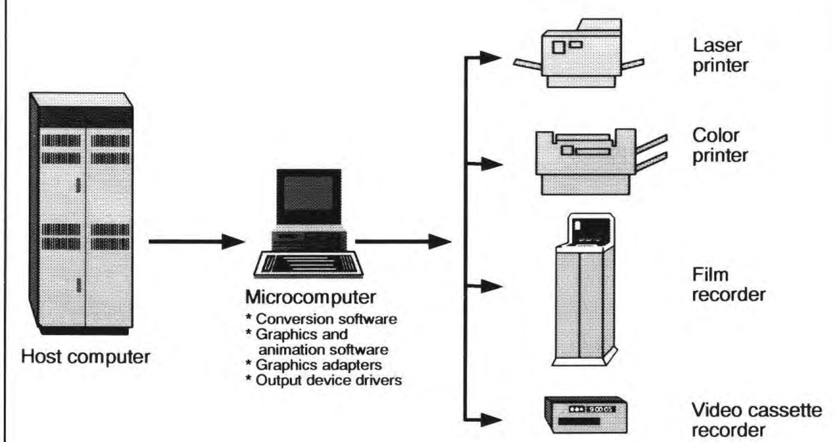
ADI will be distributed to Arctic researchers and policymakers who use CD–ROM technology. Although the hypermedia prototype was developed for Arctic data and information, this technology can be applied to any subject. On the basis of the effectiveness of ADI as both a learning and a research tool, the USGS is considering related projects to produce other hypermedia systems on such topics as natural hazards reduction and the water quality of major river basins in the United States.

Microcomputer Graphic Presentations

By Brian Schachte

As a leader in the earth sciences and cartography, the USGS continually presents research projects and findings to the scientific community and to public audiences. Research itself has been greatly improved by new computing technologies, which enable earth scientists to analyze, model, and display complex data sets more quickly and efficiently than ever before. Presenting these results, however, is hampered by these same technological advances because, until recently, user-specific hardware and software could not be linked to communications and presentation materials or equipment.

Microcomputer animation and graphics software now make it possible to capture, manipulate, and enhance computer-based data. Connecting the microcomputer to various output devices produces illustrations



Microcomputer graphics capabilities provide access to a variety of output devices.

that can be carried easily for use at scientific meetings and at other presentations.

Postproduction printers, both color and gray scale, produce publication-quality illustrations. High-resolution color-image copiers produce high-quality paper and overhead transparency hard copies. Microcomputer-based film recorders produce 35-millimeter slides and 4- by 5-inch or 8- by 10-inch color negatives. Large-format posters can be made from these negatives. A series of images, output to a video cassette recorder (VCR), when combined with voice-over, music, and animated titling on a video tape, provides researchers and scientists with a presentation product that requires only a television and a VCR.

Microcomputer graphics at the USGS have produced several video cassette recordings, including one about national streamflow conditions and another about sedimentary basin analysis as it pertains to petroleum geology. These two videos contain a series of complex images that represent spatially oriented research projects.

Whether the final presentation product is paper or overhead transparency, 35-millimeter slides or video tape, the use of microcomputer graphics makes it possible to demonstrate current research and results more easily and effectively.

Open Systems Communication Standards

By Paul Celluzzi

The diverse nature of the USGS mission requires a computing and communication environment to match this diversity. Over the years, different computer systems have proliferated and evolved independently of the issues of compatibility with other computer systems or an overall bureau-wide computing strategy. There is now, however, an increased need to exchange information and to integrate applications.

The USGS situation is not unique; major compatibility issues exist throughout government and industry. In response, mechanisms are being developed to connect incompatible computer systems. A major initiative, sponsored by the International Standards Organization (ISO) and supported by contributions from national and international standards agencies, has resulted in an internationally accepted model for data communication and standards that define the protocols for communication among different computer systems. These standards are referred to as open system standards because they are published in the public domain and have unrestricted availability. Open standards provide universal connectivity among computer systems.

The U.S. Government, under the direction of the National Institute for Standards and Technology, has adopted a set of specifications from the ISO standards that is collectively known as GOSIP (Government Open Systems Interconnection Profile). GOSIP defines a common method for government computer systems to communicate. Because GOSIP is published as a government FIPS (Federal Information Processing Standard), implementation of GOSIP is mandatory for all Federal agencies. A series of releases by the Federal Government will put GOSIP into effect.

The first release of GOSIP defines lower level communication protocols and file transfer and electronic mail applications. Later releases will include specifications for terminal login, Email directory services, compound document content architecture, and additional network options. Eventually, all government computer and communication systems will be required to conform to GOSIP. Government systems will then be connected and able to share resources.

The advantages of compatibility among computer systems are obvious; the USGS is now emphasizing the use of open systems protocols. A transition plan, in preparation, will convert the current USGS mix of proprietary and restricted protocols to GOSIP compliance. This approach initially provides for the use of existing protocols, then parallel and mixed protocols, and finally full GOSIP protocol to achieve a gradual transition having minimal impact on existing applications.

Eventually all USGS computer systems will be able to communicate and share resources regardless of the type of system. The GOSIP protocols will create a single standard for networking. Benefits to the USGS include a single standard that greatly simplifies the design, implementation, operation, and management of complex networks and reduces the costs of procuring and implementing the networks. Also, the investment in networks is protected from future changes because of the adoption of industry standard protocols. A growth path is established for changing and expanding networks. Finally, the resulting integration of diverse systems into a single manageable network provides a pathway to distributed processing and integrated applications across computer systems.

Administration

New Quarters for Distribution and Drilling-Core Research Centers

By Eddie G. Powell

In 1990 the map distribution and core research centers moved to Building 810 in the Denver Federal Center. Building 810 had served as a regional supply depot for more than 20 years, but, because of improvements in the Nation's transportation system, it was decided to reduce the number of Federal supply depots. The Denver facility was closed in 1987. The General Services Administration offered the 665,000 square foot building to the USGS. This newly acquired space provides an excellent opportunity to consolidate the map distribution functions of the National Mapping Division and to expand the drilling-core research center of the Geologic Division. These moves also permitted expensive leases to be discontinued. After renovations were completed, a dedication ceremony was held June 27, 1990, to commemorate the opening of the two centers in Building 810.

In 1948 the USGS established map distribution branches in Washington, D.C., and Denver, Colo. The objectives were, and remain, to collect, warehouse, distribute, and sell map publications. Over the years, the emphasis has changed from providing base maps internally for portraying geologic and hydrologic information to providing to the public all published earth science information through the Map Distribution Center and more than 3,500 private U.S. map dealers.

Today, the consolidation of the map distribution branches in Building 810 provides an international users' center for all USGS published earth science information. Seventy-two employees manage more than 7 acres of warehouse space and provide professional and recreational users with access to approximately 125,000 different map and book publications. Eleven million products are distributed or sold annually, resulting in revenues in excess of 7.5 million dollars.

In 1974 the USGS established a drilling-core research center in Denver. The objectives of the center are to collect, permanently store, and make available to all earth scientists valuable core material from boreholes drilled chiefly for oil and gas. Since its establishment, the center has grown rapidly both in space occupied and in the diversity of material stored and processed. The center currently occupies about 120,000 square feet of floor space in Building 810 and provides archival storage for many kinds of geologic material, such as mineralized granite, volcanic rock, and oil shale.

The center contains 1 million linear feet of core from more than 6,300 wells from all over the United States that were donated by oil and gas companies, mining companies, and other organizations. Of these, 3,700 cores have been slabbed and are available for viewing. The remainder can be made available upon request. Facilities for examination of core material are provided. The center is used daily by scientists from industry, government, and academia.

Building 810 houses centers for map distribution and drilling-core research.

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.

Aluminum can recycling at the National Center.

WILLIAM R. RECKERT

Recycling Program

By John E. Cordyack

In 1990 the USGS expanded its longstanding commitment to recycling. A new program includes recycling map, computer, and office paper, aluminum plates used in map production, and aluminum beverage cans and recovering silver from photographic processing. In addition to direct monetary benefits, this recycling program benefits the environment by saving energy required to produce new products, by reducing the impact on landfills, and by fighting litter.

In March 1990 the USGS began participation in the General Services Administration program to recycle all high-grade office paper. All National Center employees in Reston, Va., were given desk-top containers for collecting recyclable office paper. In the first 3 months of this program, more than 120 tons of paper were recycled. The USGS regional centers in Denver, Colo., and Menlo Park, Calif., also initiated paper recycling programs that resulted in more than 100 tons of paper collected this year. In terms of natural resources, 148,500 gallons of oil and 3,674 trees are saved by the recycling of this 220 tons of paper.

For many years the aluminum plates used in the map production process have been recycled at the National Center. Over 38,000 pounds of these plates were recycled this year. A recycling station at the National Center is now in place for aluminum cans collected by employees. Proceeds from the can recycling effort benefit the Federal Children's Center (see "Child Care," p. 91). The USGS plans to expand the can recycling program to the regional centers in 1991.

Silver is recovered from the materials used in the photographic laboratories at Reston, Va.; Rolla, Mo.; Sioux Falls, S. Dak.; Denver, Colo.; and Menlo Park, Calif. More than $28,000 in silver was recovered in fiscal year 1990. Recycling programs for laser printer cartridges and composting plant materials have been in effect since mid-1990.

Automation in the Office of Personnel

By Eliot J. Christian

Great strides have been taken in automating the USGS Office of Personnel including four major systems: the Personnel Action System, the Automated Vacancy Announcement Distribution System, Personnet, and the paperless Time and Attendance System.

Personnel Action System.—The USGS Personnel Action System (PAS) automates the processing of personnel action requests known as SF 52 (Standard Form 52). PAS supports on-line processing for SF 52 preparation throughout all offices of the USGS and supports many of the tasks that follow from the request. The system automatically creates electronic transactions that update the Departmental payroll-personnel system.

The Administrative Division and the Information Systems Division (ISD) collaborated to develop PAS. A major hurdle was to obtain permission for using electronic signatures to supplant the need for paper copies of personnel actions. Security features of the system design were approved and electronic signatures were established.

The system has many useful features, such as detailed status tracking and flexible access controls. The system includes an automated interface to the Automated Vacancy Announcement Distribution System. PAS has won accolades throughout the Department and is now being seen as a prototype for the SF 52 portion of a future Departmental Federal Personnel Payroll System. Other Federal agencies have expressed interest in the system.

Automated Vacancy Announcements.—The traditional process of preparing, printing, and distributing vacancy announcements is time consuming. The Automated Vacancy Announcement Distribution System (AVADS) applies automation to this process by transmitting vacancy announcement information to designated USGS installations weekly. As with PAS, AVADS was a collaborative effort between the Administrative Division and the ISD.

Before AVADS, each USGS administrative office circulated or posted more than 1,000 individual announcements as they were received, and many announcements were subsequently mailed to field office sites. AVADS provides one listing of vacancy announcements that is circulated or posted each week.

In addition to the full text of each announcement, AVADS provides an index of all current announcements. Vacancies can be browsed through on-line, and there is also a microcomputer version. Since AVADS transmits directly to the designated field sites, the system cuts the time needed for recruitments and facilitates the timely receipt of vacancy information. Printing and mailing expenses are reduced by using electronic rather than hard copy distribution.

Personnet.—Personnet is a subscription service offering thousands of pages of cross-indexed and up-to-date information on personnel law, manuals, regulations, and related legal decisions available on networked CD–ROM (compact disc read only memory) devices. Personnet allows any personal computer user to electronically access current information on Federal personnel law and on both Federal and Departmental manuals, regulations, and related precedent legal decisions. Stand-alone CD–ROM's provide access to Personnet in the Rolla, Mo., and Atlanta, Ga., personnel offices.

By using the networked Personnet CD–ROM subscription service, all the relevant information is provided on-line together with comprehensive textual and index retrieval mechanisms and cross-indexing. Electronic access not only allows much faster and more accurate access to the information but also offers the ability to conduct extensive searches based on words in context. Replacement updated CD–ROM's are provided every 60 days, and interim bulletins of pending updates are provided on magnetic media every 15 days.

Time and Attendance.—A paperless Time and Attendance System based on personal computers was implemented in the Administrative Division and the Office of the Director. Plans are to expand the system to other users within the USGS. Also, other Federal agencies have expressed interest. The system is based on a program that was implemented at the U.S. Department of Commerce. The USGS enhanced the initial version and created a product that is applicable throughout the bureau. Users have been pleased to find that the resulting system provides a drastic reduction in errors.

The Department of Commerce has, in turn, replaced its own version of the system with the USGS developed system to take advantage of the improvements. The system has been demonstrated to other bureaus within the U.S. Department of the Interior and other Federal agencies. Currently, the Time and Attendance System is being enhanced to include core hours, flextime, and other refinements.

JIM PARLE AND PEYTON FLORENCE

Federal Children's Center in Herndon, Va.

Child Care

By Kathleen B. Rutledge

The growing influx of women into the workforce has made child care a significant human resources issue for the 1990's. According to the Hudson Institute in its report, "Civil Service 2000," more than half of the mothers having children under the age of 1 year work outside the home, and more than half of the women who work have children under the age of 18. The USGS has joined an increasing number of Federal agencies in providing child care support for its employees in the form of on-site or near-site child care centers.

Under current law, Federal agencies can pay for space, utilities, maintenance, security, and start-up costs for child care centers when the agency determines that these are necessary expenses for recruitment and retention of employees. The General Services Administration (GSA), as part of its child care support program, will pay certain construction costs associated with developing or modifying Federal space to accommodate child care centers. These costs are billed back to agencies later through rent charges.

The USGS opened its first on-site child care center in Menlo Park, Calif., in June 1987. The GEOKIDS Daycare Center serves 60 families from two Federal agencies and more than a dozen local firms in a cooperative operation. In a grass-roots endeavor, parents established the center by raising funds, obtaining licenses, and hiring caregivers. Although the USGS pays space and utilities costs on an ongoing basis, all operating expenses are covered by tuition and an active fund-raising program.

The USGS participates with 12 other Federal agencies in a child care center in Sacramento, Calif. The Cottage Kids Children's Center opened in December 1989 and accommodates 60 children. In Denver, the USGS has joined with other bureaus of the U.S. Department of the Interior to provide child

JIM PARLE AND PEYTON FLORENCE

Inside the Herndon Federal Children's Center.

JIM PARLE AND PEYTON FLORENCE

care on-site for 104 children at the Denver Federal Center. This center, which opened in May 1988, is operated under the auspices of the Denver Cooperative Administrative Support Unit.

The most recent and ambitious child care center opened on October 31, 1990, in Herndon, Va., just down the road from the USGS National Center in Reston. This center, 3 years in the making, is the result of the combined efforts of six Federal agencies located in Reston: the USGS, the Minerals Management Service (another bureau of the Department of the Interior), the National Aeronautics and Space Administration, the Central Intelligence Agency, the Defense Mapping Agency, and the Defense Communications Agency. The USGS served as lead agency, and representatives from the group contracted with a child care consultant who paved the way for the many steps required to develop a center from scratch.

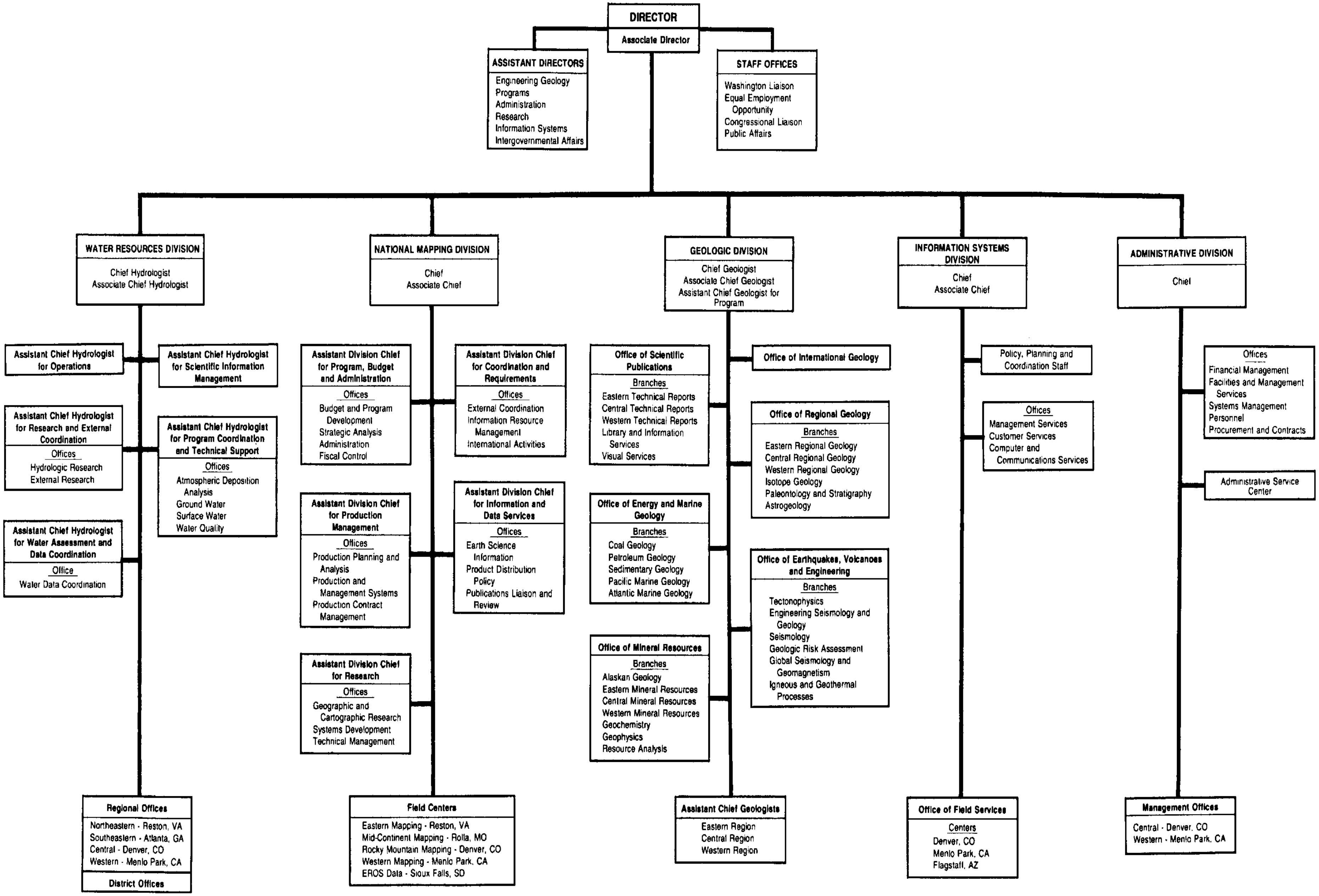
Working with GSA, the group found suitable space located within a predetermined radius of the participating agencies; GSA leased the space and provided construction oversight for the use of design specifications prepared by the participating agencies. The agency representatives incorporated as the Federal Children's Center and elected a Founding Board of Directors, which undertook tasks ranging from obtaining permits and licenses to selecting and purchasing furniture, toys, and equipment. The Board oversaw the hiring of staff, development of curriculum, selection of a food service program, and establishment of policies such as hours of operation, application procedures, and a fee structure.

The Federal Children's Center is unique in the Reston area in that it addresses the severe shortage of space within the community for the care of infants. Sixty percent of the available 99 slots are for children ages 3 and under, and 20 of these spaces are reserved for children as young as 3 months old. The Center has the capacity to expand to 150 children if necessary. Plans are being made for an emergency drop-off program for parents whose child care arrangements are interrupted, and the Board is looking into programs for after school and summer vacation care.

As with other USGS child care centers, operating expenses will be covered by tuition and fees. A scholarship program, for those needing tuition assistance, will be established with funds from the Center's future participation in the Combined Federal Campaign, from an aluminum recycling program (a can collection site is on the grounds of the National Center), and from parent-sponsored fund-raising activities.

The USGS will continue to support efforts to assist employees in finding affordable, quality child care close to the workplace. Employees in Flagstaff, Ariz., have developed a proposal for a child care center for 30 children, including participation by other local Federal agencies; this proposal is being evaluated for funding support. In addition, as centers are developed by other Federal organizations, the USGS will respond to invitations to participate where employee needs for child care assistance are evident.

ORGANIZATION OF THE U.S. GEOLOGICAL SURVEY
U.S. Department of the Interior



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 99508–4664

Room G–84
605 West 4th Ave.
Anchorage, AK 99501

California:
Federal Bldg., Room 7638
300 N. Los Angeles St.
Los Angeles, CA 90012

Room 3128
532 Bldg. 3
345 Middlefield Rd.
Menlo Park, CA 94025

504 Custom House
555 Battery St.
San Francisco, CA 94111

Colorado:
169 Federal Bldg.
1961 Stout St.
Denver, CO 80294

Room 1813
504 Denver Federal Center, Bldg. 25
Box 25046
Denver, CO 80225–0046

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

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:
678 U.S. Courthouse
W. 920 Riverside Ave.
Spokane, WA 99201

Water Information

Water-Source Data

To obtain assistance in locating sources of water data, identifying sites at which data have been collected, and obtaining specific information, write:

U.S. Geological Survey
National Water Data Exchange
421 National Center
12201 Sunrise Valley Dr.
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:

U.S. Geological Survey
Office of Water Data Coordination
417 National Center
12201 Sunrise Valley Dr.
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:

U.S. Geological Survey
Hydrologic Information Unit
419 National Center
12201 Sunrise Valley Dr.
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:

U.S. Geological Survey
Geologic Inquiries Group
907 National Center
12201 Sunrise Valley Dr.
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

Minerals Information Office*
845 N. Park Ave., #100
Tucson, AZ 85719

*Joint ventures of the USGS and the U.S. Bureau of Mines.

U.S. Bureau of Mines
Minerals Information Office
c/o Mackay School of Mines
University of Nevada, Reno
Reno, NV 89557–0047

U.S. Bureau of Mines
Minerals Information Office
U.S. Courthouse, Room 656
W. 920 Riverside Dr.
Spokane, WA 99201

Maps

Topographic and Thematic

To buy maps of all areas of the United States and to request USGS catalogs, pamphlets, and leaflets (limited quantities free), write or visit:

U.S. Geological Survey
Map Distribution
Building 810
Denver Federal Center, Box 25286
Denver, CO 80225

To buy Alaska maps, residents of Alaska may write or visit:

U.S. Geological Survey
Alaska Distribution Section
New Federal Building, Box 12
101 12th Avenue
Fairbanks, AK 99701

Aerial Photographs and Satellite Images

To obtain information on aerial photographs and satellite and space images, write or visit:

U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198

Books and Reports

To buy USGS book publications, to request USGS circulars, or to obtain information on the availability of microfiche or paper-duplicate copies of open-file reports, write:

U.S. Geological Survey
Books and Open-File Reports
Federal Center, Box 25425
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:

U.S. Geological Survey
Distribution Support Section
582 National Center
12201 Sunrise Valley Drive
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

Budget Information

USGS budget authority for fiscal year 1990, by appropriation, for surveys, investigations, and research (SIR)
[Dollars in thousands]

Activity/Subactivity/Program element	Fiscal year 1990[1] enacted
National Mapping, Geography, and Surveys	**$111,527**
National Map and Digital Data Production	46,007
Cartographic Data and Map Revision	40,066
Thematic and Special Data	4,461
SLAR	1,480
Information & Data Systems	14,598
National Data Base Management	7,662
Information Dissemination Services	3,977
Global Change Data Systems	2,959
Research and Technology	18,348
Cartographic and Geographic Research	8,070
National Cartographic Requirement Coordination and Standards	3,821
Geographic and Spatial Information Analysis	6,457
Advanced Cartographic Systems	32,574
Geologic and Mineral Resource Surveys and Mapping	**200,388**
Geologic Hazards Surveys	66,196
Earthquake Hazards Reduction	46,443
Volcano Hazards	17,596
Landslide Hazards	2,157
Geologic Framework and Processes	33,802
National Geologic Mapping	19,132
Deep Continental Studies	3,020
Geomagnetism	1,710
Climate Change	3,001
Coastal Erosion	6,939
Offshore Geologic Surveys	26,450
Offshore Geologic Framework	26,450
Mineral Resource Surveys	46,836
National Mineral Resource Assessment Program	23,872
Strategic and Critical Minerals	9,708
Development of Assessment Techniques	13,256
Energy Geologic Surveys	27,104
Evolution of Sedimentary Basins	5,200
Coal Investigations	7,288
Oil and Gas Investigations	5,577
Oil Shale Investigations	577
Geothermal Investigations	5,869
Uranium/Thorium Investigations	2,087
World Energy Resource Assessment	506
Water Resources Investigations	**$152,904**
National Water Resources Research and Information System-Federal Program	83,250
Data Collection and Analysis	24,198
National Water Information Clearinghouse	3,398
Coordination of National Water Data Activities	976
Regional Aquifer System Analysis	10,982
Core Program Hydrologic Research	8,565
Improved Instrumentation	1,656
Water Resources Assessment	1,352
Toxic Substances Hydrology	14,174
Nuclear Waste Hydrology	3,814
Acid Rain	2,895
Scientific and Technical Publications	2,228
National Water-Quality Assessment Program	7,039
Climate Change Hydrology	1,973
National Water Resources Research and Information System—Federal-State Cooperative Program	58,974
Data Collection and Analysis, Areal Appraisals, and Special Studies	55,070
Water use	3,904
National Water Resources Research and Information System—State Research Institutes and Research Grants Program	10,680
State Water Resources Research Institutes	5,600
National Water Resources Research Grants Program	4,322
Program Administration	758
General Administration	**18,081**
Executive Direction	4,701
Administrative Operations	11,471
Reimbursements to the Department of Labor	1,909
Facilities	**18,502**
National Center—Rental Payments to GSA	14,610
National Center—Facilities Management	3,892
Total, SIR	**$501,402**

[1] Funding shown represents current appropriated funding ($478,156), no-year appropriated funding for Mt. Redoubt ($6,256), and no-year emergency funding transfers for Loma Prieta and Hurricane Hugo ($5,000) and Earthquake Disaster Funding ($12,000).

USGS budget for fiscal years 1987 to 1990, by activity and sources of funds[1]

[Dollars in thousands; totals may not add because of rounding]

Budget activity	1987	1988	1989	1990
Total	**$620,585**	**$662,101**	**$670,897**	**$ 723,137**
Direct program	432,114	448,233	451,988	[1]501,510
Reimbursable program	188,471	213,868	218,909	221,628
States, counties, and municipalities	63,088	68,609	69,577	74,113
Miscellaneous non-Federal sources	13,667	12,775	14,194	15,151
Other Federal agencies	111,716	132,484	135,138	132,363
National Mapping, Geography, and Surveys	**118,462**	**120,845**	**126,457**	**141,069**
Direct program	88,542	90,541	94,235	111,528
Reimbursable program	29,921	30,304	32,222	29,542
States, counties, and municipalities	1,841	1,579	1,520	2,132
Miscellaneous non-Federal sources	10,276	10,021	10,804	10,278
Other Federal agencies	17,804	18,705	19,898	17,131
Geologic and Mineral Resource Surveys and Mapping	**209,553**	**224,028**	**215,882**	**241,739**
Direct program	169,239	177,278	178,329	200,472
Reimbursable program	40,314	46,750	37,553	41,267
States, counties, and municipalities	1,365	1,138	961	1,917
Miscellaneous non-Federal sources	938	368	682	2,022
Other Federal agencies	38,011	45,244	35,910	37,328
Water Resources Investigations	**254,288**	**278,380**	**287,154**	**295,128**
Direct program	142,130	149,471	145,635	152,904
Reimbursable program	112,158	128,910	141,520	142,224
States, counties, and municipalities	59,882	65,893	67,095	70,064
Miscellaneous non-Federal sources	2,437	2,354	2,700	2,839
Other Federal agencies	49,839	60,662	71,725	69,321
General Administration	**18,285**	**17,746**	**19,059**	**21,493**
Direct program	17,084	14,684	16,330	18,081
Reimbursable program (Federal)	1,201	3,062	2,729	3,412
Miscellaneous non-Federal sources	1	3	0	1
Other Federal agencies	1,200	3,060	2,729	3,411
Facilities	**15,109**	**16,252**	**17,450**	**18,502**
Direct program	15,067	16,214	17,421	18,502
Reimbursable program	42	38	29	0
Computer and administrative services to other accounts	**4,835**	**4,804**	**4,856**	**5,183**
Reimbursable program	4,835	4,804	4,856	5,183
Miscellaneous non-Federal sources	15	29	7	11
Other Federal agencies	4,820	4,775	4,849	5,172
Operation and maintenance of quarters	**52**	**45**	**38**	**23**
Direct program	52	45	38	23

[1] Direct program includes $478,156 for current year, $23,246 for no year, $84 for Contributed Funds, and $23 for Operation and Maintenance of Quarters.

USGS reimbursable funds from other Federal agencies for fiscal years 1987 to 1990, by agency

[Dollars in thousands]

Budget activity	1987	1988	1989	1990
Department of Agriculture	$ 1,247	$ 3,392	$ 3,638	$ 3,379
Department of Commerce	100	50	0	281
National Oceanic and Atmospheric Administration	7,993	6,138	5,327	1,448
Department of Defense	30,551	39,462	40,478	41,257
Department of Energy	24,361	26,800	31,630	29,574
Bonneville Power Administration	274	258	311	358
Department of the Interior	14,787	17,166	14,076	12,728
Bureau of Indian Affairs	4,280	4,664	2,190	2,018
Bureau of Land Management	1,748	1,773	1,317	1,239
Bureau of Mines	14	29	0	24
Bureau of Reclamation	6,647	6,715	5,926	6,119
Minerals Management Service	125	291	222	32
National Park Service	977	1,069	1,304	883
Office of the Secretary	538	1,983	2,206	1,343
Office of Surface Mining	260	352	264	106
Fish and Wildlife Service	198	290	648	964
Department of State	4,740	9,896	10,082	8,144
Department of Transportation	300	794	1,479	362
Environmental Protection Agency	2,726	3,591	3,096	5,279
National Aeronautics and Space Administration	4,380	4,877	4,952	5,607
National Science Foundation	472	535	630	2,328
Nuclear Regulatory Commission	1,834	1,589	1,797	1,917
Tennessee Valley Authority	101	269	170	217
Miscellaneous Federal agencies	13,030	13,371	12,623	14,312
Miscellaneous services to other accounts	4,820	4,775	4,849	5,172
Total	**$ 111,716**	**132,963**	**135,139**	**132,363**

U.S. Geological Survey Offices

Headquarters Offices	Central Region	Western Region
National Center **12201 Sunrise Valley Drive** **Reston, VA 22092** **(FTS prefix 959–)**	**Denver Federal Center** **Box 25046** **Denver, CO 80225** **(FTS prefix 776–)**	**345 Middlefield Rd.** **Menlo Park, CA 94025** **(FTS prefix 459–)**

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
Director's Representative—Central Region	Harry Tourtelot	(303) 236–5438	406 Denver Federal Center
Director's Representative—Western Region	George Gryc	(415) 329–4002	Western Region, Stop 144
Special Assistant to the Director for Alaska	Philip J. Carpenter	(907) 271–4138	4230 University Drive, Suite 201 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
Administrative Program Specialist	H.T. Davis	(703) 648–7203	201 National Center
Professional Services Specialist	William A. Schmidt	(703) 648–7221	118 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	Roy J. Heinbuch	(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
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
Associate Chief	Doug R. Posson	(703) 648–7106	801 National Center
Office of Customer Services, Chief	Virginia L. Ross	(703) 648–7178	805 National Center
Office of Computer and Communications Services, Chief	Wendy A. Budd	(703) 648–7103	807 National Center
Office of Management Services, Chief	Eliot Christian	(703) 648–7245	802 National Center
Office of Field Services, Chief	Fred B. Sower	(303) 236–4944	801 Denver Federal Center

National Mapping Division

Chief	Lowell E. Starr	(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

National Mapping Division—Continued

Eastern Mapping Center, Chief	K. Eric Anderson	(703) 648–6002	567 National Center
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	Allen H. Watkins	(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	William R. Greenwood	(703) 648–6601	911 National Center
Assistant Chief Geologist for Program	David P. Russ	(703) 648–6640	911 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	Glenn H. Allcott	(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	Jack H. Medlin	(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, Acting	Thomas E. Reilly	(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
Southeastern Region, Chief	James L. Cook	(404) 331–5174	Richard B. Russell Federal Bldg. 75 Spring St., SW., Suite 772 Atlanta, GA 30303
Central Region, Chief	James F. Blakey	(303) 236–5920	406 Denver Federal Center
Western Region, Chief	T. John Conomos	(415) 329–4403	Western Region, Stop 470

District Offices

Alabama	Hillary H. Jeffcoat	(205) 752–8104	520 19th Ave. Tuscaloosa, AL 35401
Alaska	Philip J. Carpenter	(907) 786–7100	4230 University Dr., Suite 201 Anchorage, AK 99508
Arizona	Robert D. Mac Nish	(602) 670–6671	375 N. 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) 978–4633	Rm. W–2234 Federal Bldg. 2800 Cottage Way Sacramento, CA 95825

Water Resources Division—Continued

District Offices—Continued

Colorado	Charles A. Pascale	(303) 236–4882	415 Denver Federal Center Box 25046 Denver, CO 80225
Connecticut (See Massachusetts)			
Delaware (See Maryland)			
District of Columbia (See Maryland)			
Florida	Irwin H. Kantrowitz	(904) 681–7631	227 N. Bronough St., Suite 3015 Tallahassee, FL 32301
Georgia	Jeffrey T. Armbruster	(404) 986–6860	6481–B Peachtree Industrial Blvd. Doraville, 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) 398–5353	102 E. Main St., 4th Floor Urbana, IL 61801
Indiana	Dennis K. Stewart	(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	Thomas L. Huntzinger	(913) 842–9909	4821 Quail Crest Pl., Lawrence, KS 66049
Kentucky	Alfred L. Knight	(502) 582–5241	2301 Bradley Ave. Louisville, KY 40217
Louisiana	Darwin D. Knochenmus	(504) 389–0281	P.O. Box 66492 6554 Florida Blvd. Baton Rouge, LA 70806
Maine (See Massachusetts)			
Maryland	Herbert J. Freiberger	(301) 828–1535	208 Carroll Bldg. 8600 La Salle Rd. Towson, MD 21204
Massachusetts	Ivan C. James II	(617) 565–6860	10 Causeway St., Rm. 926 Boston, MA 02222
Michigan	T. Ray Cummings	(517) 377–1608	6520 Mercantile Way, Suite 5 Lansing, MI 48911
Minnesota	William J. Herb	(612) 229–2607	702 Post Office Bldg. 180 E. Kellogg Blvd. St. Paul, MN 55101
Mississippi	Michael W. Gaydos	(601) 965–4600	Suite 710 Federal Bldg. 100 W. Capitol St. Jackson, MS 39269
Missouri	Daniel P. Bauer	(314) 341–0824	1400 Independence Rd., Stop 200 Rolla, MO 65401
Montana	Joe A. Moreland	(406) 449–5302	Drawer 10076, 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	William J. Carswell, Jr.	(702) 887–7600	Rm. 114 Federal Bldg. 705 N. Plaza St. Carson City, NV 89701
New Hampshire (See Massachusetts)			
New Jersey	Donald E. Vaupel	(609) 771–3902	Suite 206, Mountain View Office Park 810 Bear Tavern Rd. 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) 472–3107	P.O. Box 1669 343 U.S. Post Office and Courthouse Albany, NY 12201

Water Resources Division—Continued

District Offices—Continued

North Carolina	James F. Turner	(919) 571–4000	3916 Sunset Rd. Raleigh, NC 27608
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	220 N.W. 66th, Bldg. 7 Oklahoma City, OK 73116
Oregon (See Washington)			
Pennsylvania	David E. Click	(717) 782–3468	P.O. Box 1107, 4th Floor Federal Bldg., 228 Walnut St. Harrisburg, PA 17108
Puerto Rico	Allen L. Zack	(809) 749–4346	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	Rodney N. Cherry	(803) 750–6100	Stephenson Center, Suite 129 720 Gracern Rd. Columbia, SC 29210
South Dakota	Richard E. Fidler	(605) 353–7176	Rm. 408 Federal Bldg. 200 4th St., SW. Huron, SD 57350
Tennessee	Ferdinand Quinones-Marquez	(615) 736–5424	A–413 Federal Bldg. Nashville, TN 37203
Texas	Charles R. Burchett	(512) 832–5791	8011 Cameron Rd., Bldg. 1 Austin, TX 78753
Utah	Harvey L. Case III	(801) 524–5663	Rm. 1016 Administration Bldg. 1745 W. 1700 South Salt Lake City, UT 84104
Vermont (See Massachusetts)			
Virginia (See Maryland)			
Washington	Garald G. Parker, Jr.	(206) 593–6510	1201 Pacific Ave., Suite 600 Tacoma, WA 98402
West Virginia	David P. Brown, Acting	(304) 347–5130	603 Morris St. Charleston, WV 25301
Wisconsin	Warren A. Gebert	(608) 276–3801	6417 Normandy Ln. Madison, WI 53719
Wyoming	James E. Kircher	(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 1990. 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),
- Environmental Management (w),
- Highways (w);

Anniston, City of (w);
Birmingham, City of, Water Works Board (w);
Butler County Water Authority (w);
Coffee County Commission (w);
Dauphin Island Water Authority (w);
Geological Survey of Alabama (n,w);
Greenville, City of, Water Works and Sewer Board (w);
Huntsville, City of, Public Works (w);
Jefferson County Commission (w);
Mobile, City of (w);
Montgomery, City of, Water Works and Sanitary Board (w);
Sumter, County of (w);
Tuscaloosa, City of (w);
University of Alabama—Tuscaloosa (w).

Alaska

Alaska Department of—
- Natural Resources, Division of—
  - Geological and Geophysical Surveys (w),
  - Technical Services (w),
- Transportation and Public Facilities (w);

Alaska Energy Authority (w);
Alaska Industrial Development and Export Authority (w);
Anchorage, Municipality of (w);
Annette Islands Reserve Tribal Government (g);
Fairbanks North Star Borough (w);
Juneau, City and Borough of (w);
Kenai Peninsula Borough (w);
Matanuska Susitna Borough (w);
Sitka, City and Borough of (w);
University of Alaska, Fairbanks (g).

American Samoa

American Samoa, Government of (w).

Arizona

Arizona Department of—
- Environmental Quality (w),
- Water Resources (w);

Arizona State University (g);
Colorado Department of Highways (w);
Gila Valley Irrigation District (w);
Gila Water Commissioner, Office of (w);
Maricopa County—
- Flood Control District (w),
- Municipal Water Conservation District No. 1 (w);

Metropolitan Water District of Southern California (w);
Pima County Board of Supervisors (w);
Safford, City of, Water, Gas, and Sewer Department (w);
Salt River Valley Water Users Association (w);
San Carlos Apache Tribe (g);
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),
- Health (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);
Beebe, City of (w);
Independence, County of (w);
Little Rock Municipal Water Works (w);
North Little Rock Electric Department (w);
University of Arkansas—
- at Fayetteville (w),
- at Little Rock (w).

California

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),
- Conservation (g),
- Health Services (w),
- Parks and Recreation (g,w),
- Transportation (w),
- Water Resources—
  - Central District (Sacramento) (w),
  - Northern District (Red Bluff) (w),
  - San Joaquin District (Fresno) (w);

California Institute of Technology (g);
California Office of Emergency Services (g);
California Water Control Board, Colorado Region (w);
Carpinteria County Water District (w);
Casitas Municipal Water District (w);
Coachella Valley Water District (w);
Contra Costa County—
- Flood Control and Water Conservation District (w),
- Department of Health Services (w);

Crestline-Lake Arrowhead Water Agency (w);
Desert Water Agency (w);
East Bay Municipal Utility District (w);
East Valley Water District (w);
Eastern Municipal Water District (w);
Fox Canyon Groundwater Management Agency (w);
Fresno Metropolitan Flood Control District (w);
Georgetown Divide Public Utility District (w);
Goleta Water District (w);
Humboldt Bay Municipal Water District (w);
Imperial County Department of Public Works (w);
Imperial Irrigation District (w);
Indian Wells Valley Water District (w);
Inyo County Water Department (w);
Kings River Conservation District (w);
Los Angeles County Department of Public Works (w);
Los Angeles County Sanitation Districts (g);
Los Angeles Department of—
- City Planning (g),
- Water and Power (w);

Madera Irrigation District (w);
Marin County Department of Public Works (w);
Marin Municipal Water District (w);
Menlo Park, City of (g);
Mendocino County Water Agency (w);
Merced, City of (w);
Merced Irrigation District (w);
Metropolitan Water District of Southern California (g);
Mojave Water Agency (w);
Mono, County of (w);
Montecito Water District (w);
Monterey County Flood Control and Water Conservation District (w);
Monterey Peninsula Water Municipal District (w);
Oakdale-South San Joaquin Irrigation District (w);
Orange County—
- Environmental Management Agency (w),
- Water District (w);

Oroville-Wyandotte Irrigation District (w);
Palo Alto, City of (w);
Panoche Water and Drainage District (w);
Pechanga Indian Reservation (w);
Poway, City of (w);
Rancho California Water District (w);
Regional Water Quality-Lahontan Region (w);
Riverside County Flood Control and Water Conservation District (w);
Sacramento Municipal Utility District (w);
Sacramento Regional County Sanitation District, Department of Public Works (w);
San Benito County Water District (w);
San Bernardino Environmental Public Works Flood Control District (w);
San Bernardino Valley Municipal Water District (w);
San Diego, City of, Water Utility (w);
San Diego, County of, Department of—
- Planning and Land Use (w),
- Public Works (w);

San Francisco, City and County of, Bureau of Light, Heat, and Power (w);
San Francisco State University Foundation (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 Department (w);
Santa Maria Valley Water Conservation District (w);
Santa Ynez River Water Conservation District (w);
Scotts Valley Water District (w);
Siskiyou County Flood Control and Water Conservation District (w);
Sonoma County—
- Planning Department (w),
- Water Agency (w);

Tahoe Regional Planning (w);
Terra Bella Irrigation District (w);

Tulare County Flood Control District (w);
Turlock Irrigation District (w);
United Water Conservation District (w);
University of California—
at Berkeley (g),
Lawrence Livermore National Laboratory (g);
Ventura County Public Works Agency (w);
Water Resources Control Board (w);
Western Municipal Water District (w);
Woodbridge Irrigation District (w);
Yolo County Flood Control and Water Conservation District (w);
Yuba County Water Agency (w).

Colorado

Arkansas River Compact Administration (w);
Arvada, City of (w);
Aspen, City of (w);
Aurora, City of (w);
Bent, County of (w);
Boulder, City of (w);
Boulder, County of, Department of Public Works (w);
Breckenridge, Town of (w);
Broomfield, City of (w);
Castle Rock, Town of (w);
Centennial Water and Sanitation (w);
Cherokee Water and Sanitation District (w);
Colorado Department of Health (w);
Colorado Division of—
Mined Land Reclamation (w),
Water Resources, Office of the State Engineer (w);
Colorado Geological Survey (g);
Colorado River Water Conservation District (w);
Colorado School of Mines (g);
Colorado Springs, City of—
Department of Public Utilities (w),
Office of the City Manager (w);
Colorado Water Conservation Board (w);
Delta County Board of County Commissioners (w);
Denver, City and County, Board of Water Commissioners (w);
Denver Regional Council of Governments (w);
Eagle County Board of Commissioners (w);
Englewood, City of, Wastewater Treatment Plant (w);
Evergreen Metropolitan District (w);
Fort Collins, City of (w);
Fountain Valley Authority (w);
Garfield, County of (w);
Glendale, City of (w);
Glenwood Springs, City of (w);
Golden, City of (w);
Jefferson County Board of County Commissioners (w);
Longmont, City of (w);
Loveland, City of (w);
Lower Fountain Water-Quality Management Association (w);
Metropolitan Denver Sewage Disposal District No. 1 (w);
Moffat, County of (w);
Northern Colorado Water Conservancy District (w);
Northglenn, City of (w);
Pikes Peak Area Council of Governments (w);
Pitkin County Board of Commissioners (w);
Pueblo Board of Water Works (w);
Pueblo County Commissioners (w);
Pueblo County Department of Public Safety and Operations (w);
Pueblo West Metropolitan District (w);
Rio Blanco, County of (w);
Rio Grande Water Conservation District (w);
St. Charles Mesa Water Association (w);
Southeastern Colorado Water Conservancy District (w);
Southern Ute Indian Tribe (g,w);
Southwestern Colorado Water Conservancy District (w);
Steamboat Springs, City of (w);
Thornton, City of (w);
Trinchera Conservancy District (w);
Uncompahgre Valley Water Users Association (w);
Upper Arkansas Area Council of Governments (w);
Upper Arkansas River Water Conservancy District (w);
Upper Eagle Valley Water and Sanitation Districts (w);
Upper Yampa Water Conservancy District (w);
Urban Drainage and Flood Control District (w);
Ute Mountain Indian Tribe (w);
Vail Valley Conservation Water Authority (w);
Westminster, City of (w);
Yellow Jacket Water Conservancy District (w).

Connecticut

Connecticut Department of Environmental Protection (g,n,w);
Fairfield, Town of, Conservation Commission (w);
New Britain, City of, Board of Water Commissioners (w);
Norwich Sewer Authority (w);
South Central Connecticut Regional Water Authority (w);
Torrington, City of (w).

Delaware

Delaware Department of Natural Resources and Environmental Control (w);
Geological Survey (n,w).

District of Columbia

Department of Public Works (w);
Metropolitan Washington Council of Governments (w).

Florida

Boca Raton, City of (w);
Bradenton, City of (w);
Brevard County, Board of County Commissioners (w);
Broward County—
Environmental Quality Control Board (w),
Water Resources Management Division (w);
Cape Coral, City of (w);
Cocoa, City of (w);
Daytona Beach, City of (w);
Florida Department of—
Environmental Regulation, Bureau of Laboratories and Special Programs (w),
Natural Resources (w)—
Division of—
Marine Resources (w),
Recreation and Parks (Hobe Sound) (w),
Recreation and Parks (Tallahassee) (w),
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 Health and Environmental Services (w),
Department of Planning (w);
Jacksonville Electric Authority (w);
Jacksonville Beach, City of (w);
Lake County Board of County Commissioners—
Tavares (w),
Fort Myers (w);
Lake County Water Authority (w);
Lake Mary, City of (w);
Lee County Board of County Commissioners (w);
Madison, City of (w);
Manatee County—
Board of County Commissioners (w),
Port Authority (w),
Public Health Unit (w);
Marion County Board of County Commissioners (w);
Metropolitan Dade County Department of Environment Resources Management (w);
Miami-Dade Water and Sewer Authority (w);
Northwest Florida Water Management District (w);
Ocala, City of (w);
Palm Beach County Board of County Commissioners (w);
Perry, City of (w);
Pinellas, County of (w);
Polk County Board of County Commissioners (w);
Pompano Beach, City of (w);
Port Orange, City of (w);
Reedy Creek Improvement District (w);
Sarasota, City of (w);
Sarasota, County of (w);
South Florida Water Management District (w);
South Indian River Water Control District (w);
Southwest Florida Regional Planning Council (w);
Southwest Florida Water Management District (w);
St. Johns, County of (w);
St. Johns River Water Management District (w);
St. Petersburg, City of (w);
Stuart, City of (w);
Suwannee River Water Management District (Live Oak) (w);
Tallahassee, City of—
Electric Department (w),
Underground Utilities (w),
Water Quality Laboratory (w);
Tampa, City of (w);
Tampa Port Authority (w);
University of South Florida (g);
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);
Bibb County Board of County Commissioners (w);
Blairsville, City of (w);
Brunswick, City of (w);
California Air Resources Board (w);
Chatham County-Savannah Metropolitan Planning Commission (w);
Chestatee-Chattahoochee Resource Conservation and Development (w);
Clayton County Water Authority (w);
Cobb, County of (w);
Covington, City of (w);
Georgia Department of—
Natural Resources—
Environmental Protection Division—
Water Management Branch (w),
Water Quality Support Program (w),
Geologic Survey (n,w),
Transportation (w)—
at Atlanta (w),
at Forest Park (w);
Georgia Mountain Regional Development Center (w);
Georgia State University, Department of Geology (g,w);
Gwinnett, County of (w);
Helena, City of (w);
Macon-Bibb County Water and Sewage Authority (w);
Moultrie, City of (w);
Springfield, City of (w);
Summerville, City of (w);
Thomaston, City of (w);

Thomasville, City of (w);
Valdosta, City of (w);
Walton County Board of Commissioners (w).

Guam

Guam, Government of—
Environmental Protection Agency (w),
Public Utility Agency (w).

Hawaii

Hawaii, County of, Department of Water Supply (w);
Hawaii Department of—
Agriculture, Division of Agriculture Resource Management (w),
Land and Natural Resources (g), Division of Water and Land Development (w),
Transportation (w);
Honolulu Board of Water Supply (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);
Office of State Planning (n).

Idaho

College of Southern Idaho (w);
Idaho Department of—
Health and Welfare (w),
Water Resources (w);
Nampa, City of (w);
Nez Percé Tribe (w);
Shoshone, County of (w);
Shoshone-Bannock Tribes, (w);
Southwest Irrigation District (w);
Teton, County of (w);
Water District No. 01 (Idaho Falls) (w);
Water District No. 32D (Dubois) (w).

Illinois

Bloomington and Normal Sanitary District (w);
Cook County Forest Preserve 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, Special Studies (w),
Transportation—
Division of Highways (n),
Division of Water Resources (w);
Illinois Environmental Protection Agency (w);
Lake County Stormwater Management Planning Committee (n,w);
Metropolitan Water Reclamation District of Greater Chicago (w);
Springfield, City of (w).

Indiana

Carmel, Town of (w);
Elkhart, City of, Water Works (w);
Indiana Department of—
Environmental Management (w),
Highways (w),
Natural Resources (n), Division of Water (w);
Indianapolis, City of, Department of Public Works (w).

Iowa

Carroll County Health Department (w);
Cedar Rapids, City of (w);
Charles City, City of (w);
Des Moines, City of (w), Water Works (w);
Fort Dodge, City of (w);
Guthrie County Health Department (w);
Iowa Department of—
Transportation, Highway Division (w),
Natural Resources, Geological Survey Bureau (n,w);
Iowa State University (w);
Marshalltown, City of (w);
University of Iowa—
Institute of Hydraulic Research (w),
Hygienic Laboratory (w),
Physical Plant (w),
Sewage Disposal Plant (w);
Sioux City, City of (w);
Union Electric Company (w);
Waterloo, City of (w).

Kansas

Allen Creek Watershed District (w);
Arkansas River Compact Administration (w);
Board of Agriculture, Division of Water Resources (w);
Clay, County of (w);
Emporia, City of, Department of Public Works (w);
Geary, County of (w);
Harvey, County of (w);
Hays, City of (w);
Iowa Tribe of Kansas and Nebraska (w);
Kansas Department of—
Health and Environment (w),
Transportation (w);
Kansas Geological Survey (n,w);
Kansas State Board of Agriculture, Division of Water Resources (w);
Kansas State University Department of Agronomy (w);
Kansas University—
Center for Research, Inc. (w),
Department of Geology (w);
Kansas Water Office (w);
Linn, County of (w);
Olathe, City of (w);
Reno, County of (w);
Rock Creek Watershed District (w);
Sac and Fox Tribe of Missouri (w);
Sumner, County of (w);
Western Kansas Ground Water Management District #1 (w);
Wichita, City of (w).

Kentucky

Elizabethtown, City of (w);
Fulton, City of (w);
Jefferson, County of, Department of Public Works and Transportation (w);
Kentucky Department of Natural Resources and Environmental Protection Cabinet (w);
Kentucky State University (w);
Louisville Metropolitan Sewer District (w);
University of Kentucky, Kentucky Geological Survey (n,w);
University of Louisville (w).

Louisiana

Alexandria, City of (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),
Transportation and Development, Office of Public Works (n,w),
Wildlife and Fisheries (w);
Louisiana Geological Survey, Louisiana State University (g);
Sabine River Compact Administration (w);
St. John the Baptist Water Works (w);
University of New Orleans (g);
West Monroe, City of (w).

Maine

Androscoggin Valley Council of Governments (w);
Cobbossee Watershed District (w);
Greater Portland Council of Governments (w);
Kennebec Regional Planning Commission (w);
Maine Department of—
Conservation, Geological Survey (n,w),
Transportation (n);
Maine Low Level Radioactive Waste Authority (w);
North Maine Regional Planning Commission (w);
Penobscot Valley Council of Governments (w);
University of Maine (w).

Maryland

Anne Arundel County Planning and Zoning Office (w);
Baltimore County—
Department of Permits and Licenses (w),
Department of Public Works (w),
Office of Planning and Zoning (w);
Calvert County Courthouse, Planning and Zoning (w);
Caroline County Courthouse (w);
Carroll County Commission (w);
Howard County Department of Public Works (w);
Maryland Department of the Environment (w);
Maryland Geological Survey (n,w);
Maryland State Highway Administration (w);
Maryland Water Resources Administration (w);
Montgomery County—
Department of Environmental Protection, Division of Environmental Planning and Monitoring (w),
Storm Water Management (w);
Poolesville, Town of (w);
St. Marys County Commissioners (w);
Upper Potomac River Commission, Waste Treatment Facilities (w);
Washington Suburban Sanitary Commission (w).

Massachusetts

Barnstable County Commissioners (w);
Cape Cod Commission (w);
Executive Office of Environmental Affairs (n);
Mashpee Water Distribution (w);
Massachusetts Department of—
Environmental Management, Division of Water Resources (w),
Environmental Pollution—
Division of Water Pollution Control (w),
Division of Water Supply (w),
Fisheries, Wildlife, and Environmental Law Enforcement, Division of Fisheries and Wildlife (w),
Public Works (w);
Massachusetts Water Resources Authority (g);
Metropolitan District Commission—
Parks, Engineering and Construction Division (w),
Watershed Management Division (w);
New England Interstate Water Pollution Control Commission (w);
Woods Hole Oceanographic Institute (g).

Michigan

Ann Arbor, City of, Wastewater Treatment Plant (w);
Battle Creek, City of, Public Utilities Department (w);
Cadillac, City of, Wastewater Treatment Plant (w);
Clare, City of (w);
Coldwater, City of, Board of Public Utilities (w);
Elsie, Village of, Department of Public Works (w);
Flint, City of, Department of Public Works and Utilities (w);
Genesee County Drain Commission, Division of Water and Waste Services (w);
Huron-Clinton Metropolitan Authority (w);
Huron, County of (w);
Imlay, City of (w);
Kalamazoo, City of, Department of Public Utilities (w);
Lansing, City of, Board of Water and Light, Water and Stream Division (w);
Macomb, County of (w);

Mason, City of (w);
Michigan Department of—
Natural Resources (w),
Transportation (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);
Wayne, County of, Division of Environmental Health (w);
Wayne State University (g);
Ypsilanti, City of (w).

Minnesota

Beltrami County SWCD (w);
Elm Creek Conservation Commission (w);
Fond Du Lac Reservation Business Committee (w);
Hennepin County Conservation District (w);
Leech Lake Reservation Business Committee, Division of Resources Management (w);
Lower Red River Watershed Management District (w);
Metropolitan Waste Control Commission (w);
Mille Lacs Reservation Business Committee (w);
Minneapolis Water Works (w);
Minnesota Department of—
Natural Resources (g), Division of Waters (w),
Transportation (w);
Minnesota Pollution Control Agency (w);
Northwest Minnesota Ground Water (w);
Red Lake Reservation Business Committee (w);
Rochester Public Utilities (w);
St. Paul, City of, Water Utility (w);
University of Minnesota, Department of Soil Science (w);
Vadnais Lake Area Watershed Management Organization (w);
White Earth Reservation Business Commission (w).

Mississippi

Harrison, County of—
Board of Supervisors (w),
Development Commission (w);
Jackson, City of (w);
Jackson, County of—
Board of Supervisors (w),
Port Authority (w);
Mississippi Department of—
Environmental Quality—
Bureau of Geology (w),
Bureau of Land and Water Resources (w),
Bureau of Pollution Control (w),
Highways (w);
Pat Harrison Waterway District (w);
Pearl River Basin Development District (w);
Pearl River Valley Water Supply District (w).

Missouri

Branson, City of (w);
Cape Girardeau, City of (w);
Little River Drainage District (w);
Metropolitan St. Louis Sewer District (w);
Missouri Department of—
Conservation (w),
Health (w),
Natural Resources—
Division of Environmental Quality (w),
Division of Geology and Land Survey (n,w),
Land Reclamation Commission (w);
Missouri Highway and Transportation Commission (n,w);
Springfield, City of, City Utilities (w);
St. Francis County Environmental Corporation (w);
Watershed Commission of the Ozarks (w);
University of Missouri-Columbia, Department of Geology (w).

Montana

Blackfeet Nation (w);
Fort Belknap Indian Community (w);
Fort Peck Tribes (w);
Helena, City of (w);
Lewis and Clark City-County Health Department (w);
Montana Bureau of Mines and Geology (w);
Montana Department of—
Fish, Wildlife, and Parks (w),
Health and Environmental Sciences (w),
Highways (w),
Natural Resources and Conservation (w),
State Lands (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 Loup Natural Resources District (w);
Lower Platte South Natural Resources District (w);
Lower Republican Natural Resources District (w);
Middle Niobrara Natural Resources District (w);
Middle Republican Natural Resources District (w);
Nebraska Department of—
Environmental Control (w),
Water Resources (w);
Nebraska Natural Resources Commission (w);
Nemaha Natural Resources District (w);
North Platte Natural Resources District (w);
South Platte Natural Resources District (w);
Twin Platte Natural Resources District (w);
University of Nebraska, Conservation and Survey Division (w);
Upper Elkhorn Natural Resources District (w);
Upper Loup Natural Resources District (w);
Upper Niobrara White Natural Resources District (w);
Upper Republican Natural Resources District (w).

Nevada

Carson City Department of Public Works (w);
Clark County Regional Flood Control District (w);
Clark County Sanitation District (w);
Douglas, County of (w);
Elko, County of (w);
Las Vegas, City of (w);
Las Vegas Valley Water District (g);
Nevada Bureau of Mines and Geology (g,w);
Nevada Department of—
Conservation and Natural Resources—
Division of Environmental Protection (w),
Division of Water Resources (w),
Human Resources, Division of Health, Consumer Health Protection Service (w),
Transportation (w);
Regional Water Planning and Advisory Board of Washoe County (w);
South Lake Tahoe Public Utility District (w);
Summit Lake Paiute Indian Tribe (w);
Tahoe Regional Planning Agency (w);
University of Nevada (g).

New Hampshire

New Hampshire Department of—
Environmental Services (w),
Transportation (n).

New Jersey

Bergen County Department of Public Works (w);
Brick Township Municipal Utilities Authority (w);
Cape May, City of (w);
Gloucester County Planning Commission (w);
Lower, Township of, Municipal Utilities Authority (w);
Morris City Municipal Utilities Authority (w);
New Brunswick, City of (w);
New Jersey Department of—
Agriculture (w),
Environmental Protection (n), Division of Water Resources (w);
North Jersey District Water Supply Commission (w);
Passaic Valley Water Commission (w);
Pinelands Commission (w);
Somerset County Board of Chosen Freeholders (w);
Washington Township Municipal Utilities Authority (w);
West Windsor, Township of (w);
Wildwood, City of (w);
Woodstown Sewerage Authority (w).

New Mexico

Alamogordo, City of (w);
Albuquerque, City of (w);
Albuquerque Metropolitan Arroyo Flood Control Authority (w);
Bernalillo, County of (w);
Canadian River Municipal Water Authority (w);
Costilla Creek Compact Commission (w);
Elephant Butte Irrigation District (w);
Gallup, City of (w);
Highlands University, School of Science and Technology (w);
Las Cruces, City of (w);
Las Vegas, City of (w);
Los Alamos, County of (w);
Navajo Indian Nation (w);
New Mexico Bureau of Mines and Mineral Resources, Division of Mining and Technology (w);
New Mexico Environmental Improvement Division (w);
New Mexico Department of Highways (w);
New Mexico Institute of Mining and Technology (g);
New Mexico State University Agricultural Experiment Station (w);
Office of the State Engineer (w);
Pecos River Commission (w);
Pueblo of Acoma (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 Fe Metropolitan Water Board (w);
Santa Rosa, City of (w).

New York

Amherst, Town of, Engineering Department (w);
Auburn, City of (w);
Brookhaven, Town of (w);
Chautauqua, County of, Department of Planning and Development (w);
Cheektowaga, Town of (w);
Chenango, County of (w);
Cornell University—
Department of Natural Resources (w),
Department of Utilities (w);
Cortland County Planning Department (w);
Dutchess, County of, Environmental Management (w);
Essex, County of, Planning Department (w);
Hamilton College (g);
Hudson-Black River Regulating District (w);
Kiryas Joel, Village of (w);
Long Island Regional Planning Board (w);
Monroe, County of, Department of Health (w);
Nassau, County of—
Department of Health (w),
Department of Public Works (w);

New York City Department of Environmental Protection, Air and Water Resources-Energy (w);
New York State Department of—
- Environmental Conservation—
  - Division of Fish and Wildlife (w),
  - Division of Water (w),
- Transportation, Bridge and Construction Bureau (w);

New York State Power Authority (w);
Nyack, Village of, Board of Water Commissioners (w);
Onondaga, County of—
- Department of Drainage (w),
- Water Authority (w);

Orange County Water Authority (w);
Putnam, County of, Department of Planning (w);
Seneca County Soil Conservation District (w);
Suffolk, County of—
- Department of Health Services (w),
- Water Authority (w);

Tompkins, County of, Department of Planning (w);
Ulster, County of, County Legislators (w);
Vermont Department of Environmental Conservation (w).

North Carolina

Asheville, City of (w);
Bethel, Town of (w);
Brevard, City of (w);
Chapel Hill, Town of (w);
Charlotte, City of (w);
Durham, City of, Department of Water Resources (w);
Fayetteville, City of (w);
Forsyth, County of (w);
Greensboro, City of (w);
Guilford County S.W.C.D. (w);
Lexington, City of (w);
Mecklenburg, County of (w);
North Carolina State Department of—
- Environment, Health, and Natural Resources (g,w),
- Natural Resources and Community Development (n),
- Transportation, Division of Highways (w);

Raleigh, City of (w);
Rocky Mount, City of (w);
Triangle Area Water Supply Monitoring, Project Steering Committee (w).

North Dakota

Dickinson, City of (w);
Lower Heart River Water Resources District (w);
Minot, City of, Public Works Department (w);
North Dakota Department of—
- Game and Fish (w),
- Health (w),
- Parks and Recreation (w),
- Transportation (w);

North Dakota Geological Survey (w);
Oliver County Board of Commissioners (w);
Public Service Commission (w);
State Water Commission (w);
Three Affiliated Tribes Natural Resources Department (w).

Ohio

Akron, City of (w);
Canton, City of, Water Department (w);
Columbus, City of (w);
Eastgate Development and Transportation Agency (w);
Fremont, City of (w);
Lima, City of (w);
Miami Conservancy District (w);
Oberlin College (g);
Ohio Department of—
- Natural Areas and Preserves (w);
- Natural Resources—
  - Division of Water (w),
  - Division of Reclamation (w),
- Transportation (n,w);

Ohio State University (g,w);
Ross, County of (w);
Seneca Soil and Water District (w);
Sumit, County of (w);
Toledo Metropolitan Area Council of Governments (w);
University of Cincinnati, Department of Geology (w);
University of Toledo (w).

Oklahoma

Ada, City of (w);
Altus, City of (w);
Association of Central Oklahoma Governments (w);
Central Oklahoma Master Conservancy District (w);
Fort Cobb Reservoir Master Conservancy District (w);
Foss Reservoir Master Conservancy District (w);
Lawton, City of (w);
Lugert-Altus Irrigation District (w);
Mountain Park Master Conservancy District (w);
Norman, City of, Public Works (w);
Oklahoma City, City of, Department of Water Resources (w);
Oklahoma Department of Transportation (n);
Oklahoma Geological Survey, University of Oklahoma (w);
Oklahoma State Health Department (w);
Oklahoma Water Resources Board (w);
Tulsa, City of—
- Water and Sewer Department (w),
- Department of Storm Water Management (w);

Wellston, City of (w).

Oregon

Clark County Intergovernmental Resources Center (w);
Confederated Tribes of Warm Springs Indian Reservation (w);
Coos Bay-North Bend Water Board (w);
Douglas County Board of Commissioners (w);
Eugene, City of, Water and Electric Board (w);
Jackson, County of (w);
Klamath Tribe (w);
McMinnville, City of, Water and Light Department (w);
Oregon Department of—
- Fish and Wildlife (w),
- Geology and Mineral Industries (n),
- Human Resources, State Health Division (w),
- Natural Resources, Analysis and Planning Management Services Division (w),
- Transportation, Highway Division (w),
- Water Resources (w);

Portland, City of—
- Bureau of—
  - Environmental Services (w),
  - Water Works (w).

Pennsylvania

Allentown, City of, Engineering Department (w);
Bryn Mawr College (g);
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);
Erie, County of, Department of Health (w);
Harrisburg, City of, Department of Public Works (w);
Joint Planning Commission of Lehigh-Northampton Counties (w);
Lehigh University (g);
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);

Susquehanna River Basin Commission (w);
University Area Joint Authority (w);
University of Delaware, Geological Survey (w);
Williamsport, City of, Bureau of Flood Control (w).

Puerto Rico

Puerto Rico Aqueduct and Sewer Authority (w);
Puerto Rico Department—
- Health (w),
- Natural Resources (w);

Puerto Rico Energy and Power Authority (w);
Puerto Rico Environmental Quality Board (w);
Puerto Rico Industrial Development Company (w);
Puerto Rico Mineral Resources Development Corporation (g);
Puerto Rico Planning Board (w);
Virgin Islands Department of Natural Resources (w);
Virgin Islands Water and Power Authority (w).

Rhode Island

Governor's Office of Housing, Energy, and Intergovernmental Relations (w);
Narragansett Bay Water Quality Commission (w);
New Shoreham, Town of (w);
Rhode Island State Department of Environmental Management, Division of Water Resources (w);
State Water Resources Board (w);
University of Rhode Island (n).

South Carolina

Beaufort-Jasper County Water Authority (w);
Charleston Commission of Public Works (w);
Cooper River Water Users Association (w);
Lee, County of (w);
Myrtle Beach, City of (w);
North Myrtle Beach, City of (w);
Oconee County Sewer Commission (w);
South Carolina State—
- Department of Health and Environmental Control (w),
- Department of Highways and Public Transportation (w),
- Geological Survey (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);
Waccamaw Regional Planning and Development Commission (w);
Western Carolina Regional Sewer Authority (w);
York, County of (w).

South Dakota

Belle Fourche Irrigation District (w);
East Dakota Water Development District (w);
Lawrence, County of (w);
Mellette/Todd County Water Quality Board (w);
Rapid City, City of (w);
Rosebud Sioux Tribe (w);
Sioux Falls, City of (w);
Sisseton-Wahpeton Sioux Tribe (w);
South Dakota Department of—
- Game, Fish and Parks (w),
  - Custer State Park Division (w),

Transportation (w).
Water and Natural Resources—
Geological Survey Division (w),
Water Resource Management Division (w),
Water Quality Division (w),
Water Rights Division (w);
South Dakota North Central Resource Conservation and Development (w);
South Dakota School of Mines and Technology (w);
South Dakota State University (w);
Watertown, City of (w);
West Dakota Water Development District (w).

Tennessee
Alamo, City of (w);
Alcoa, City of (w);
Bartlett, City of (w);
Blountville, City of, Utility District (w);
Collinwood, City of (w);
Columbia, City of (w);
Dickson, City of (w);
Eastside Utility District (w);
Erwin, Town of (w);
Franklin, City of (w);
Germantown, City of (w);
Hixson Utility District (w);
Humphreys County Commissioners (w);
Jackson, City of, Utility Division (w);
Johnson City, City of (w);
Knoxville, City of (w);
Lawrenceburg, City of (w);
Lebanon, City of (w);
Lincoln, County of, Board of Public Utilities (w);
McMinnville, City of (w);
Memphis, City of, Light, Gas, and Water Division (w);
Memphis State University (w);
Metropolitan Governments, Nashville, City of, and Davidson, County of, Department of Public Works (w);
Murfreesboro, City of, Water and Sewer Department (w);
Rogersville, Town of (w);
Sevierville, City of (w);
Shelby, County of, Public Works (w);
Suck Creek Utility District (w);
Tennessee Department of—
Agriculture (w),
Health and Environment—
Construction, Grants, and Loans (w),
Office of Water Programs (w).
Transportation—
Division of Planning (w),
Division of Structures (w);
Tennessee State Planning Office (w);
Tennessee Wildlife Resources Agency (w);
Townsend, Town of (w);
University of Tennessee (w);
Upper Duck River Development Agency (w);
Wartrace, City of (w).

Texas
Abilene, City of (w);
Arlington, City of (w);
Austin, City of, Regulatory Affairs and Quality Control (w);
Bexar-Medina-Atascosa Counties, Water Improvement District No. 1 (w);
Brazos River Authority (w);
Coastal Water Authority (w);
Colorado River Municipal Water District (w);
Corpus Christi, City of (w);
Dallas, City of, Public Works Department (w);
Edwards Underground Water District (w);
El Paso, City of, Public Service Board (w);
Fort Worth, City of, Water Department, Water Pollution Control (w);
Franklin, County of, Water District (w);
Gainesville, City of (w);
Galveston, County of (w);
Garland, City of (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);
Lunar and Planetary Institute (g);
Nacogdoches, City of (w);
North Central Texas Municipal Water Authority (w);
North Texas Municipal Water District, Research and Development (w);
Northeast Texas Municipal Water District (w);
Orange, County of (w);
Pecos River Commission (w);
Red Bluff Water Power Control District (w);
Red River Authority (w);
Rice University (g);
Sabine River Authority of Texas (w);
Sabine River Compact Administration (w);
San Angelo, City of (w);
San Antonio Alamo Conservation and Reuse District (w);
San Antonio, City of—
Public Service Board (w),
Water Board (w),
Water Resources Management Division (w);
San Antonio River Authority (w);
San Jacinto River Authority (w);
Tarrant, County of, Water Control and Improvement District No. 1 (w);
Texas Water Commission (w);
Texas Water Development Board (w);
Titus, County of, Fresh Water Supply District No. 1 (w);
Trinity River Authority (w);
University of Texas (g);
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
Federated States of Micronesia—
State of Kosrae (w),
State of Ponape (w);
Northern Mariana Islands, Government of (g,w),
Commonwealth of, Utility Commission (w),
Municipality of—
Rota (w),
Tinian (w);
Republic of Palau (w);
Samoa, Government of (w).

Utah
Bear River Commission (w);
Confederated Tribes of the Goshute Reservation (g);
Five County Association (w);
Moon Lake Electric Association (w);
Ogden River Water Users (w);
Salt Lake City-County Department of Health (w);
Salt Lake, County of, Division of Flood Control (w);
Tooele, City of (w);
Tooele, County of (w);
Utah Department of—
Agriculture, Environmental Quality Section (w),
Health, Division of Environmental Health (w),
Natural Resources—
Geological and Mineral Survey (g,n,w),
Oil, Gas, and Mining Division (w),
State Lands and Forestry Division (g),
Water Resources Division (w),
Water Rights Division (w),
Wildlife Resources Division (w),
Transportation (w);
Weber Basin Water Conservancy District (w);
Weber River Water Users (w).

Vermont
Agency of 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);
Henrico, County of, Department of Public Utilities (w);
James City, County of (w);
James City Service Authority (w);
Loudoun, County of (g);
Maryland, Department of—
Environment (w),
State Highways (w);
Mount Rogers Planning District Commission (w);
Newport News, City of (w);
Northern Virginia Planning District Commission (w);
Prince William Health District (w);
Rappahannock-Rapidan Planning District Commission (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, Department of Public Utilities (w);
Virginia State Water Control Board (w);
Williamsburg, City of (w);
York, County of (w).

Washington
Bellevue, City of, Public Works Department (w);
Centralia, City of, Light Department (w);
Chelan, County of, Public Utility District No. 1 (w);
Confederated Tribes of the Umatilla Indian Reservation (w);
Douglas, County of, Public Utility District No. 1 (w);
Hoh Indian Tribe (w);
King, County of, Department of Public Works (w);
Kitsap, County of, Public Utility District No. 1 (w);
Lewis, County of, Public Works Department (w);
Okanogan, County of, Department of Public Works (w);
Pend Oreille, County of, Public Utility District No. 1 (w);
Pierce, County of (w);
Portland, City of, Bureau of Water Works (w);
Puget Sound Water Quality Authority (w);
Quinault Business Committee (w);
Seattle, City of, Department of Lighting (w);
Seattle-King County Department of Public Works (w);
Skagit, County of (w), Department of Public Works (w);
Snohomish, County of (w);
Swinomish Tribal Community (w);
Tacoma, City of, Department of—
Public Utilities (w),
Public Works (w);

Thurston, County of, Department of—
Health (w),
Public Works (w);
Washington Department of—
Administration, Capitol Buildings and Grounds Facilities (w),
Ecology (n,w),
Emergency Management (w),
Fisheries (w),
Natural Resources (g,n);
University of Washington (g);
Whatcom, County of, Department of Public Works (w);
Yakima Tribal Council (w).

West Virginia
Eastern Panhandle Regional Planning and Development Council (w);
Morgantown, City of, Utility Board (w);
Region VII Planning and Development Council (w);
Research Corporation, Marshall University (w);
Washington Public Service District (w);
West Virginia Department of—
Commerce (w),
Health, Office of Environmental Health Services (w),
Highways (w),
Natural Resources, Division of Water Resources (w);
West Virginia Geological and Economic Survey (w).

Wisconsin
Bad River Tribal Council (w);
Balsam Lake Protection and Rehabilitation District (w);
Beaver Dam, City of (w);
Big Muskego Lake (w);
Chippewa, County of, Land Conservation Department (w);
Dane, County of—
Department of Public Works (w),
Regional Planning Commission (w);
Delavan, Town of (w);
Delton, Town of (w);
Fond Du Lac, City of (w);
Fowler Lake Management District (w);
Green Bay Metropolitan Sewerage District (w);
Green Lake Sanitary District (w);
Hillsboro, City of (w);
Hills Lake Management District (w);
Lac Courte Oreilles Governing Board (w);
Little Muskego Lake District (w);
Madison Metropolitan Sewerage District (w);
Menominee Indian Tribe of Wisconsin (w);
Oconomowoc Lake, Village of (w);
Okauchee Lake Management District (w);
Oneida Tribe of Indians (w);
Peshtigo, City of (w);
Powers Lake, District of (w);
Red Cliff Band of Lake Superior Chippewas (w);
Rock, County of (w);
Southeastern Wisconsin Regional Planning Commission (w);
Thorp, City of (w);
University of Wisconsin, Extension, Geological and Natural History Survey (n,w);
Waukesha Water Utility (w);
Waupun, City of (w);
Wind Lake Management District (w);
Wisconsin Department of—
Justice (w),
Natural Resources (w),
Transportation, Division of Highways (w);
Wisconsin Winnebago Business Committee (w);
Wittenberg, Village of (w).

Wyoming
Attorney General (w);
Cheyenne, City of (w);
Evanston, City of (w);
Evansville, Town of (w);
Gillette, City of (w);
Laramie, County of (w);
Midvale Irrigation District (w);
Northern Arapahoe Tribe (w);
Pinedale, City of (w);
Shoshone Tribe (g,w);
Teton, County of (w);
Uinta, County of (w);
Water Development Commission (w);
Wind River Environmental Quality Commission (w);
Wind River Indian Reservation (g);
Wyoming Department of—
Agriculture (w),
Environmental Quality (w),
Game and Fish (w),
Highways (w);
Wyoming Governor's Office (w);
Wyoming State Engineer (n,w);
Wyoming Water Research Center (w).

Federal Cooperators

Central Intelligence Agency (g,n)

Department of Agriculture
Agricultural Research Service (n,w);
Agricultural Stabilization and Conservation Service (n,w);
Forest Service (g,n,w);
National Agricultural Statistics Service (n);
Soil Conservation Service (n,w).

Department of the Air Force (w)
Air Force Academy (w);
Hanscom Air Force Base (g);
Headquarters, AFTAC/AC (g);
MacDill Air Force Base (w);
Occupational and Environmental Health Laboratory (w);
Patrick Air Force Base (g);
Vandenberg Air Force Base (w).

Department of the Army (n,w)
Aberdeen Proving Ground (w);
Belvoir RD&E Center (g);
Corps of Engineers (g,n,w);
Engineer Topographic Laboratory (g,w);
Fort Carson Military Reservation (w);
Lab Command, Adelphi (g);
Picatinny Arsenal (w);
Waterways Experiment Station, Vicksburg (g);
White Sands Missile Range (w).

Department of Commerce
Bureau of the Census (n);
National Institute of Standards and Technology (g);
National Oceanic and Atmospheric Administration (g,n,w);
National Weather Service (n,w).

Department of Defense Agencies
Defense Advanced Research Projects Agency (g);
Defense Intelligence Agency (g);
Defense Logistics Agency (w);
Defense Mapping Agency (g,n);
Defense Nuclear Agency (g);
National Guard Bureau (w).

Department of Energy (g,n,w)
Bonneville Power Administration (w);
Hanford Project (w);
Health and Environmental Research (g);
Idaho Operations Office (g,w);
Los Alamos National Laboratory (g);
Nevada Operations Office (g,w);
Oak Ridge Operations Office (g,w);
Sandia National Laboratories (g,w);
Savannah River Operations Office (g,w);
Situ-Field Research, Morgantown, West Virginia (g);
Test Operations Office, Las Vegas, Nevada (g).

Department of the Interior
Bureau of Indian Affairs (g,n,w);
Bureau of Land Management (g,n,w);
Bureau of Mines (n,w);
Bureau of Reclamation (g,w);
Minerals Management Service (g);
National Park Service (g,n,w);
Office of the Secretary (g,w);
Office of Surface Mining Reclamation and Enforcement (w);
U.S. Fish and Wildlife Service (g,n,w).

Department of Justice (w)

Department of the Navy (w)
Naval Explosive Ordnance Disposal Technology Center (g);
Naval Oceanographic Office (g);
Naval Ocean Systems Center (g);
Naval Weapons Center, China Lake (g,w);
Office of Naval Research (g);
U.S. Marine Corps (w).

Department of State (g)
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Foreign and Nonforeign Governments (g);
Government of Saudi Arabia (g);
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Department of Transportation
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U.S. Coast Guard (w).

Environmental Protection Agency (g,n,w)
Corvallis Environmental Research Laboratory (w);
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Federal Emergency Management Agency (g,w)

Federal Energy Regulating Commission Licensees (w)

Library of Congress (n)

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National Science Foundation (g,n,w)

Nuclear Regulatory Commission (g)

Tennessee Valley Authority (n,w)

Veterans Administration (g,w)

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Organization of American States (w);
United Nations Development Program (n);
Unesco (w);
World Bank (g,w).

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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 promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.