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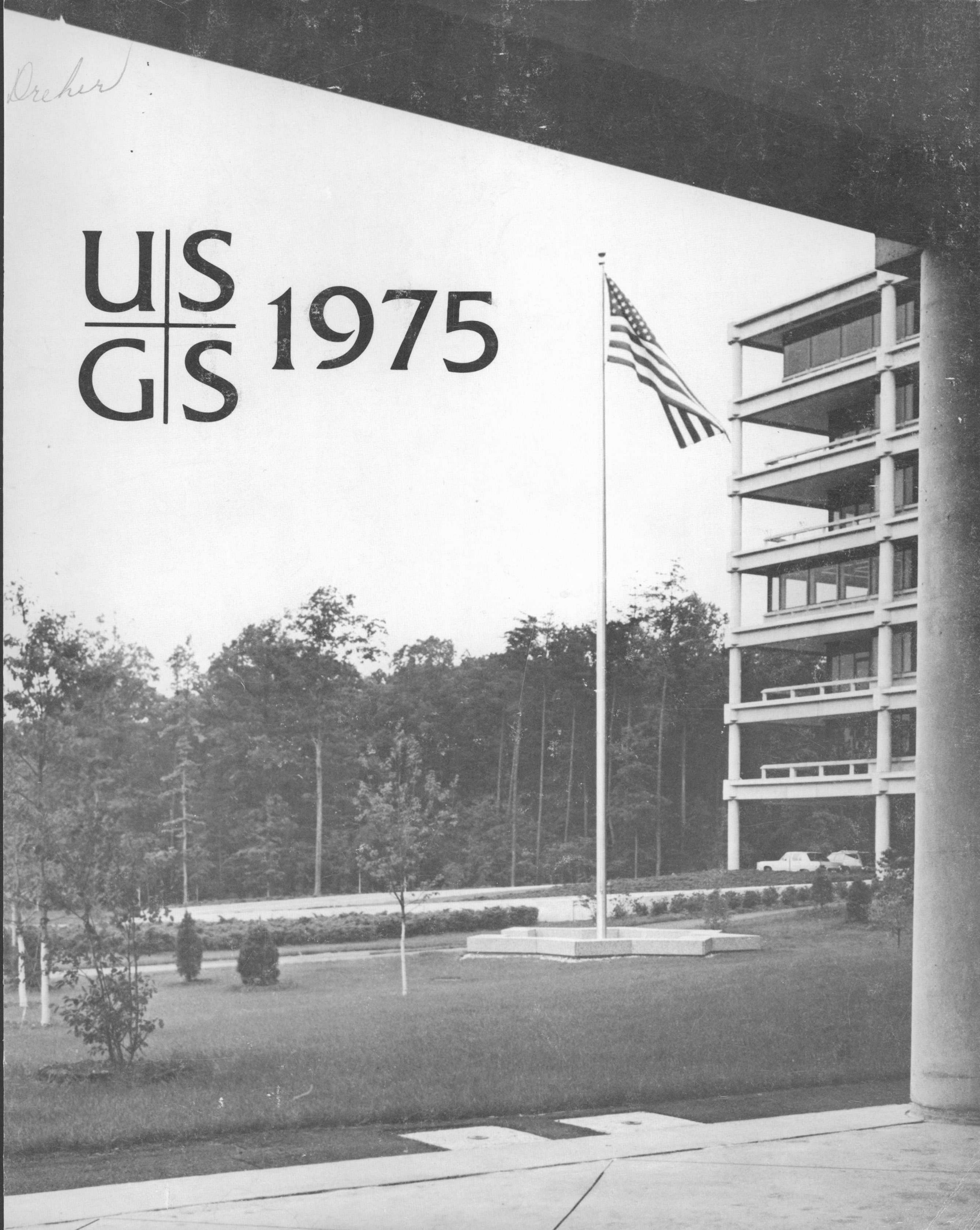

United States Geological Survey Annual Report, Fiscal Year 1975

UNITED STATES DEPARTMENT OF THE INTERIOR

Thomas S. Kleppe, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

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Preface

In 1880, Director Clarence King submitted the *First Annual Report of the United States Geological Survey* to the Secretary of the Interior for transmittal to the Congress. The Geological Survey continued to publish an annual report through 1932, after which time the Survey's report was included as part of the *Annual Report of the Secretary of the Interior.* The format of the latter was changed to the current *U.S. Department of the Interior Conservation Yearbook* series in 1965. The last *Annual Report of the Director, Geological Survey, to the Secretary of the Interior* was for fiscal year 1963.

With the publication of *United States Geological Survey Annual Report, Fiscal Year 1975,* the Survey resumes the practice of annually summarizing the progress it has made in identifying the Nation's land, water, energy, and mineral resources, classifying federally owned mineral lands and waterpower sites, and in supervising the exploration and development of energy and mineral resources on Federal and Indian lands. The Annual Report for 1975 consists of five parts:

- The Year in Review—a review of the issues and events which affected Survey programs and highlights of program accomplishments.
- Perspectives—several short papers which address major resource issues and summarize recent advances in the earth sciences.
- A description of the Survey's budget, programs, and accomplishments.
- A set of statistical tables and related information which documents program trends, workloads, and accomplishments.
- A compendium of Survey publications and information services available to the public.

One purpose of this report is to increase public awareness and understanding of the Geological Survey's programs and, more generally, of the role of earth sciences information in helping to resolve many of the natural resource conflicts that face our society now and in the years ahead. To be useful, however, information must be available and readily accessible to those responsible for natural resource policy at the time that the decisions are made. This report emphasizes the types of information products and services provided by the Survey and tells how to obtain additional information.

Supplemented by Professional Paper 975, *Geological Survey Research 1975,* the latest in a series of annual reviews of technical results of the Geological Survey's research programs, the Annual Report provides a comprehensive description of the activities of the Federal Government's largest earth science agency.

The Geological Survey welcomes comments and suggestions for improving the content and format of this report.


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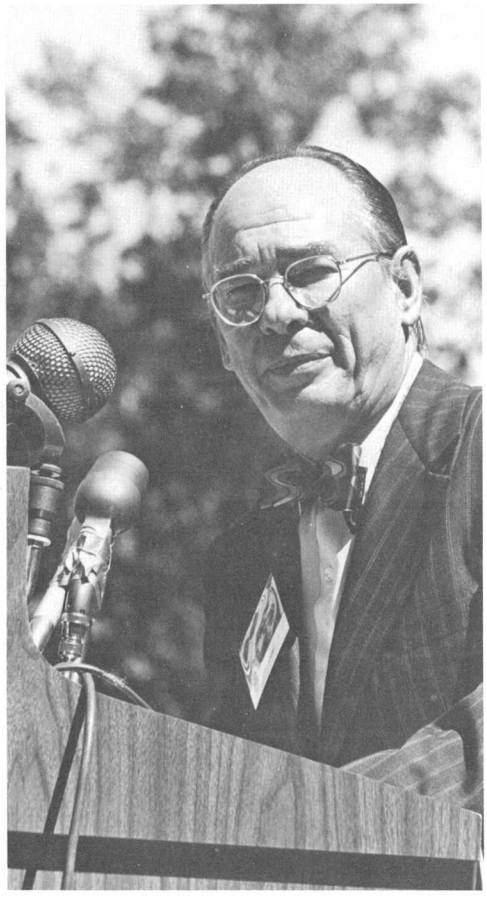


Dedication of the John Wesley Powell Federal Building on July 12, 1974. This building, located in Reston, Virginia, houses the Geological Survey's National headquarters. Participating in the dedication ceremonies (bottom row from left to right): Interior Secretary Rogers C. B. Morton; Director V. E. McKelvey; and Associate Director W. A. Radlinski.

The Year in Review

During fiscal year 1975, programs of the U.S. Geological Survey continued to grow in response to the increasingly complex demands for scientific information of a Nation faced with current and potential shortages of energy and minerals, conflicts between competing users of land and water resources, well-founded public concern about the environmental consequences of resource development, and the needs of a population growing in both numbers and in expectations for an improved standard of living and a better quality of life.

Perhaps at no other time in the Geological Survey's 96-year history have national interest and concern about natural resources been as great and intense as they have been during the past several years. This interest and concern affected virtually every activity and program and placed the Geological Survey in the unaccustomed spotlight of public attention. During fiscal year 1975, for example, the Geological Survey answered nearly a quarter of a million public inquiries about its programs, and Survey witnesses participated in some 30 Congressional hearings on subjects such as oil and gas reserve estimates, Federal coal leasing policy, Outer Continental Shelf oil and gas activities, and strip-mining legislation.

Historically, the Geological Survey has had two missions: to provide information about the Earth and its physical resources, and to regulate the activities of lessees engaged in extracting minerals from the public lands. In practical terms the discharge of these responsibilities has required extensive and continuing investigations of the location, character, and extent of the Nation's mineral, land, and water resources; a continuing program of topographic mapping; and the classification of the mineral and water potential of Federal lands to assure that private parties developing mineral leases meet appropriate standards of safety, environmental protection, and resource conservation, and that the public receives a fair return from the development of its resources.

The budget of the Geological Survey for fiscal year 1975 reflects the strong influence that current resource problems have had on the Survey's traditional missions. Major emphasis has been placed on developing a full range of mineral and energy resource assessments, defining the actual and potential environmental impacts of energy development, and strengthening capabilities to supervise the exploration and development activities implicit in a substantially enlarged oil and gas leasing program for the Outer Continental Shelf. Other programs selected for emphasis are aimed at improving identification of natural hazards, including earthquakes, floods, and volcanic activity, and developing land resource planning tools such as orthophotoquads and land use maps. Especially significant has been the effort to

make the products of the Geological Survey more meaningful to decisionmakers and to the public by collecting, interpreting, and displaying land resource information in forms that are easily understandable to a wide range of users. Public access to map and water-resources information was further enhanced by the establishment of information centers to serve as focal points for users who wish to obtain specific and timely data. These and other highlights of fiscal year 1975 are described below.

ENERGY

No demand for resource assessment is currently more compelling than that for oil and gas, not only as a guide to policy decisions such as timing, location, and extent of offshore lease sales, but also for what the assessments may disclose about the potential location and size of critically needed domestic oil and gas supplies. In fiscal year 1975 the Geological Survey launched a major effort, at the request of the Federal Energy Administration, to estimate the undiscovered recoverable petroleum resources of the United States. The talents of 70 petroleum specialists were used to develop estimates for 102 different petroleum provinces in the United States and its Continental Shelf to a water depth of about 200 metres (660 feet). Their findings, based on the assumption that technology, prices, and other economic conditions prevailing in 1974 remain unchanged, indicated that undiscovered recoverable resources range between 50 and 127 billion barrels of oil; 9.12 and 18.6 trillion cubic metres (322 and 655 trillion cubic feet) of natural gas; and 11 to 22 billion barrels of natural gas liquids. The significance of these estimates and their relation to other estimates are described in "Estimates of Undiscovered Petroleum Resources—A Perspective" in the next chapter.

The accelerated Outer Continental Shelf Leasing Program—a major action program in the Nation's effort to reduce its dependence upon foreign oil—placed heavy strains upon the Geological Survey as the amount of Outer Continental Shelf land offered in lease sales during calendar year 1974 increased by 230 percent over the amount offered in 1973. This was followed by another increase of 45 percent in calendar year 1975. More than 1,370 lease tracts covering 29,330 square kilometres (11,325 square miles) were evaluated in connection with offshore lease sales conducted during calendar year 1975. The amount of land under the Survey's supervision also increased during calendar years 1974 and 1975 by 29 and 15 percent, respectively. In preparation for future lease sales in Outer Continental Shelf frontier areas, geologists refined the 1975 resource estimates for 1.4 million square kilometres (540,000 square miles) located in 17 Continental Shelf areas.

With new petroleum resources increasingly difficult to find, coal has become a very attractive alternative energy source. During fiscal year 1975, geologists mapped 1,900 square kilometres (733 square miles) of coal-bearing lands in Wyoming, Montana, West Virginia, Kentucky, and Pennsylvania to locate coal deposits in these areas. The results of this work, much of it done on Federal lands, will assist planners in both the public and private sectors to determine what areas are most promising for future leasing when resumed.

Geological mapping was also completed on 4,800 square kilometres (1,850 square miles) of oil shale lands to support the Survey's land classification and tract evaluation activities and to provide the basis for appraising the engineering and environmental problems associated with oil shale mining. During 1975, four companies submitted their initial exploration plans under the Department of the Interior's Prototype Oil Shale Leasing program. Since little is known about the environmental effects of commercial oil shale mining and processing technology, the Bureau of Land Management, the Geological Survey, and the lessees are carefully monitoring air and water quality and collecting baseline environmental data upon which to base guidelines for future operations.

During the year, the first national assessment of geothermal resources was prepared in cooperation with the Energy Research and Development Administration. The assessment concluded that geothermal energy could be a very significant factor in the regional energy supply of those areas where it occurs. By the end of calendar year 1975, 552 leases had been awarded. Although none of these are yet in a producing status, the first commercially producible geothermal well on Federal lands was completed in May 1975, near the Castle Rock Springs area in California, and a potentially producible well was completed in June 1975, at Roosevelt Hot Springs in Utah.

Assessing the environmental aspects of energy development is also an important part of the Geological Survey's energy program. The extraction and use of energy resources and the planning, siting, and construction of energy conversion and distribution facilities lead to many environmental problems. Survey activities are directed towards providing geologic, hydrologic, geophysical, and geochemical data that will be of use in the analysis and solution of these problems.

Work continued during the year on national environmental overview maps which show the extent and frequency of occurrence of geologic processes and events which may pose constraints to land use and to energy and mineral resource development.

During fiscal year 1975, 90,000 square kilometres (34,750 square miles) in the Rocky Mountains and the northern Great Plains were thus mapped. Activities also included the collection of environmental baseline data, studies of landslide incidence and susceptibility in the Appalachian bituminous coal region, and studies of erosion and weathering rates.

The drive to develop the Nation's energy resources, particularly in the arid West, also focused attention on the availability of water required to mine, transport, and convert energy resources, and, of equal importance, the effects of such use upon regional water sources, water quality, and upon present users. During 1975, efforts were started in 22 States to answer such questions. Most of the initial effort concentrated on establishing data collection sites to determine baseline conditions prior to development, arranging for exploratory drilling, and making aquifer tests.

Environmental investigations on the Outer Continental Shelf were directed towards identifying faults, slumps, sand waves, and other bottom features which might pose a hazard to offshore energy development.

MINERALS

The need for comprehensive resource assessments of minerals continues. Not only is the Nation's dependence upon foreign sources increasing, but millions of hectares of public lands remain to be classified as to mineral potential. Work completed in the Nabesna quadrangle in Alaska identified significant potential for copper, molybdenum, gold, silver, and several nonmetallic commodities. Studies of 12 additional Alaskan quadrangles are in progress or scheduled. Commodity studies are also in progress for critical minerals and for minerals required to develop, produce, and distribute energy.

Geologic and geophysical mapping to support future mineral resource appraisal work was conducted in many parts of the country during the year and included aeromagnetic surveys of 117,000 square kilometres (45,170 square miles).

During the year, 11 wilderness area appraisals were published. Parts of five of the areas were found to contain significant mineral resources resulting in modification of the wilderness area boundaries. Equally important, the mineral potential of the other six areas studied appears to be insignificant and will not prejudice their consideration for withdrawal as wilderness areas.

GEOLOGIC HAZARDS

In addition to programs concerned with the environmental impacts of energy development, the Geological Survey is engaged in major efforts to delineate the hazards associated with earthquakes, volcanic eruptions, landslides and mudflows, ground subsidence, and floods.

Encouraging progress was made during the year in earthquake prediction. The Thanksgiving Day 1974 earthquake near Hollister, Calif., was anticipated from marked changes in deformation of the Earth's surface and local changes in the Earth's magnetic field which occurred during the weeks preceding the earthquake. During 1974, 12 other earthquakes in California were preceded by significant changes in the tilt of the Earth's surface. Those observations suggest that some earthquakes can be predicted by presently available geophysical instrumentation and analytical techniques. Before prediction systems can be deployed to provide warnings to urban areas, however, additional research on a wide variety of earthquake precursors is required. During fiscal year 1975, 35 earthquake hazards maps were published. These maps are designed to minimize future hazards and damages by providing information useful for land use zoning measures.

Two events of 1975 heightened interest in premonitory volcanic activity and the possibility of predicting volcanic eruptions. Mauna Loa in Hawaii was carefully monitored as it inflated and then erupted on July 5–6, 1975, for the first time in 25 years. Increased thermal activity on Mount Baker in Washington raised the possibility that accelerated melting of ice and snow on the volcano's flanks might lead to a large mudflow.

Survey geologists also studied the mechanisms of mudflows and landslides and the physical properties of rocks and soils that affect urban development and land use. A method was developed during the year to show the tendency of unconsolidated sediments to liquefy when shaken by an earthquake.

In its work for the Department of Housing and Urban Development's Flood Insurance Administration, the Geological Survey published 1,140 flood-prone area maps (including 202 maps prepared for publication by the Soil Conservation Service). Each map shows the boundaries of areas that would be under water from a major flood. These maps are designed to provide a basis for minimizing future flood hazards and damages through land use planning, improvements in structural design, and insurance.

WATER RESOURCES

The National Water Data System has the objective of appraising the Nation's water resources and providing water data and information needed to develop and manage surface and underground water. Water-data collection is the first step in determining how

much and what kind of water is available. Water data are commonly used to evaluate the adequacy of water supplies, to design culverts, bridges, dams, and other public works, and to prevent or lessen the impacts of floods and droughts. During 1975, the Geological Survey collected continuous stream-discharge records at 7,700 sites, measured water quality at 5,000 sites, and made water-level observations and water-quality analyses of 8,000 wells.

The National Stream Quality Accounting Network, which measures chemical, physical, and biological characteristics of the Nation's surface waters, was expanded by the addition of 245 stations. About 60 percent of the planned network to provide baseline water-quality information for national and regional water-quality evaluation and management is now in place.

Regional ground-water appraisals were completed during the year for 3 river basins out of a total of 21, and progress was made in 10 of the other basin studies. These assessments describe the quantity and quality of ground-water resources, including availability, and the existing and potential problems associated with ground-water development. In many parts of the country, ground water is a large, important, and manageable resource that can play a significant role in regional water supply and warrants full consideration as an alternative or supplemental source of water.

The first of several pilot studies of intensive river-quality assessment—the Willamette River basin in Oregon—was nearly completed during the year, and two others were begun near the end of the year—the Chattahoochee River basin in Georgia and the Yampa River basin in Colorado and Wyoming. The objective of these studies is to develop and demonstrate a technical methodology for analyzing river-quality problems and management alternatives.

In 1975, the Survey published the first 14 maps in the new series of Hydrologic Unit Maps of States. The new four-color maps use the Survey's State base map series at a scale of 1:500,000 to show hydrologic boundaries with numerical codes identifying each subdivision and counties or county equivalents. The maps, developed in cooperation with water-oriented Federal and State agencies, including the U.S. Water Resources Council, are designed for use in planning activities and in organizing and disseminating data on both a civil-unit and a hydrologic-unit basis.

SURVEYING AND MAPPING

The topographic mapping program has become a classic example of productivity growth through careful management and the introduction of new technology. More maps were produced by fewer people than ever before as productivity continued to improve at an average rate of almost 6 percent per year.

A major highlight of the year was the formal adoption of the National Mapping program (a modification of the National Topographic Mapping program) that provides for gathering, processing, and distributing basic cartographic data in a variety of forms, including several series of multipurpose line maps, aerial photographs, photoimage maps, and digital map data.

During the year a new series of topographic base maps, the intermediate-scale map series, was designed, and production was started to support energy, land management, and soils programs. Agreements were consummated with the Bureau of Land Management (BLM) and the Soil Conservation Service (SCS) to use these new base maps as the standard map data for the BLM Minerals Management Mapping program and the SCS Prime and Unique Farmland program.

The preparation and revision of 1:24,000-scale topographic maps are being assisted by the use of high-altitude photography and the application of recent advances in mapping technology. A byproduct of this process is a new kind of map—an orthophotoquad—consisting of nearly distortion-free aerial photography in the 7.5-minute quadrangle format and with a grid and a few names added. These maps are produced in less than a year as a first step in preparing conventional standard topographic maps. In fiscal year 1975, 2,869 orthophotoquads, 2,016 standard topographic maps, about 1,000 revised standard maps, and 1,359 reprinted maps were completed. At the year's end, 64 percent of the conterminous States, Hawaii, and outlying areas was covered by 1:24,000-scale maps, and 83 percent of Alaska was covered by 1:63,360-scale maps.

PROGRAM TRENDS

A significant trend in current Geological Survey programs is the increasing use of computers to improve productivity in such diverse areas as royalty accounting, lease-tract evaluation, enhancing the quality of satellite images of the Earth, decoding water data transmitted from field sites to a central receiving station by satellite, checking chemical analyses from laboratories, and speeding the analysis of resource and scientific data. Research and development programs, which rely heavily on computer techniques to develop new exploration tools and resource assessment methods and to apply new technology, such as the Landsat satellite images, represent the foundation upon which future programs will be built.

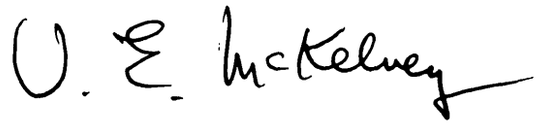
Advanced mapping technology permits cartographic data to be digitized during the map compilation process and thus avoids the necessity of a

separate operation as is now done digitizing existing maps. Since many agencies already use or plan to use digital map data in connection with geographic based data storage and retrieval systems, this development should result in substantial savings in data preparation costs to the user.

Decisions often must be made with insufficient time to allow detailed examination and analysis of available data. Data must be available in forms which can be directly used by the planner in the decision-making process. During fiscal year 1975, a program was instituted to provide orthophotoquads for all areas of the conterminous United States presently unmapped at 1:24,000 scale by 1978; a land use data and analysis program was established to collect a comprehensive national baseline set of land use and land cover data that would alleviate or remedy many of the shortcomings of various types of existing data; methods of strengthening the impact of earth sciences on land use and environmental planning decisions were tested and evaluated; and major efforts were directed toward development of energy and mineral data systems as tools in resource decisionmaking.

Still another trend found in many Geological Survey programs during fiscal year 1975 was the improvement of accessibility to information. Map users, for example, have long suffered the problem of not knowing where to go for particular maps. More than 30 Federal agencies actively collect or prepare and distribute aerial photographs, maps, and survey data in support of their missions. These agencies have spent over $1 billion on these activities during the past 10 years. To make this information readily available from a single source, the Geological Survey established the National Cartographic Information Center as a focal point for obtaining information on U.S. maps and charts, aerial photographs and space images, geodetic control data, and related cartographic data. A similar service to provide better and faster access to water data collected by Federal and State agencies, the National Water Data Exchange, was nearly ready to begin operation at the end of the fiscal year.

Fiscal year 1975 was one of change and challenge for the U.S. Geological Survey. Domestic supplies of oil and gas continued to decline, while the development of coal resources was delayed by unsolved environmental and political problems related to its extraction and conversion to energy. Attempts to open the frontier areas of the Continental Shelf to development were strongly contested, often on the grounds that not enough was known about the geology of the areas. Dependence on foreign sources for certain nonfuel minerals continued to increase. The future development of energy sources in the Western States depends upon the availability of land and water resources. None of these issues had been resolved by the end of fiscal year 1975, and they remain high priority areas of study for 1976.



V. E. McKelvey,

Director, U.S. Geological Survey

Perspectives

The Future of Earthquake Prediction

By ROBERT M. HAMILTON

The scientists first concluded in 1970 from anomalies in the earthquake pattern that an earthquake might be coming. In June 1974, observations of further changes in the earthquake pattern, tilting of the land surface, changes in water level in wells, changes in electric current in the ground, and strange animal behavior confirmed this conclusion. More seismographs and tiltmeters were moved into the area. On December 20, 1974, local government was warned to expect a large earthquake soon, and, in mid-January 1975, warning was given that the quake was imminent. On January 28, villages were warned to be prepared. Extra seismographs were set up.

Observations in the threatened area continued until February 1, when indications of an impending earthquake began to mount. A minor tremor was detected in an area that had not recently experienced one. The next day, there were seven more. On February 3, the minor tremors increased further, and more shocks were felt.

These events led the scientists to call an emergency conference at 7 p.m. on February 3 to report to authorities their prediction that a strong earthquake would probably occur in the very near future. By the afternoon of February 4, the seismic activity had leveled off, but this was judged to be the calm before the storm. At 2 p.m., people were told to expect a major quake within 2 days. Shops were shut, and general evacuation of buildings was ordered in two counties. At 6 p.m. that night in one village, the people were warned," A strong earthquake will probably occur tonight. We insist that all people leave their homes and all animals leave their stables. The people from the cinema team will show four feature films outside for us tonight."

One and one-half hours later, the earthquake, measured at 7.3 on the Richter scale, struck.

The scenario in the prologue sounds like a science-fiction writer's fantasy. Yet the events reportedly preceded an earthquake that struck Liaoning Province in the People's Republic of China on February 4, 1975. Extensive damage resulted from the shock, but loss of life was relatively light owing to the warning. This apparently successful prediction, with its life-saving benefit, represents a milestone in studies to predict the time of earthquake occurrence.

Earthquake prediction has long been a lively topic of after-dinner conversation, a proclaimed but unsubstantiated capability of mystics and soothsayers, and a controversial and elusive goal of scientists. The fascination with earthquakes derives mainly from their mysterious nature and awesome power and their capability of striking without warning to wreak disaster.

Earthquakes threaten the United States with a potential average annual loss estimated at about $630 million. True, the losses to date have not been at this rate, but the potential for disasters is rapidly increasing with the growth of population and development in earthquake-prone areas.

Historical accounts are rich with reports of strange events before earthquakes: dogs howling, strange lights in the night sky, wierd sounds, withdrawal of the sea from a harbor, and so on. In hindsight, the significance of strange animal behavior has generally been discounted, and the reports of lights and sounds have been difficult to document. But many of the other observed phenomena have been sufficiently impressive to hold out the hope to scientists that earthquakes can be predicted (see, for example, Kisslinger, 1974, and Press, 1975).

Many of the reports of earthquake precursors have come from Japan. A particularly impressive anomaly was observed for the magnitude 7.5 earthquake that caused heavy damage in the city of Niigata in 1964, when level surveys and a tide-gage station revealed anomalous land uplift beginning 10 years before the shock. Reports such as this one proved sufficiently encouraging to lead Japan in 1965 to establish a formal program to predict earthquakes. In recent years, however, that effort has been crippled by a strike of technicians at the Earthquake Research Institute in Tokyo.

A serious attempt to predict earthquakes has also been underway for some time in the Soviet Union. Near the village of Garm in the seismically active Republic of Tadzhikistan, scientists have been working for over 25 years. The fruits of these labors were revealed in the late 1960's, when Soviet scientists reported that, prior to some earthquakes, the speed with which vibrations or waves travel through rocks deep in the Earth shows a distinctive, troughlike variation. Up to then, seismic-wave velocity had been regarded as constant. This startling discovery opened a new realm of scientific investigation.

Soviet scientists also reported a variety of other phenomena as earthquake precursors. Radon gas in well water increased anomalously before the earthquake at Tashkent in 1966. The electrical resistivity of the Earth behaved unusually before earthquakes near Garm and in Kamchatka. Migration of centers of seismic activity and reorientation of earthquake-causing rock stress were also observed. Taken together, these findings presented an impressive case that earthquakes indeed have precursors.

These observations have an explanation. Earthquakes are caused by a gradual buildup of stress in rock to the point at which the rock can no longer withstand the forces and fails suddenly along a preexisting zone of weakness, or fault. This failure, of course, takes place on a large scale in the Earth, the larger earthquakes affecting areas of hundreds of square kilometres. The stresses are created when large plates of the Earth's crust scrape past each other; this process is variously termed continental drift, sea-floor spreading, or plate tectonics.

The failure process can be simulated in the laboratory by squeezing a rock specimen only centimetres across. As the stress builds up and the rock nears fracture, tiny cracks develop that actually cause the rock to expand in volume—a phenomenon called dilatancy. Laboratory measurements show variations in seismic-wave velocity, electrical resistivity, and other properties of a rock experiencing dilatancy that are similar to the anomalies observed before earthquakes. American scientists have played a key role in establishing this association.

A serious effort to predict earthquakes in the United States got underway in the aftermath of the great Alaskan earthquake of 1964, which, at magnitude 8.5, is the largest U.S. shock ever observed. The magnitude 6.5 earthquake at San Fernando, Calif., in 1971 further drew attention to the prediction challenge. Soon following the shock, the Geological Survey's Earthquake Hazards program, which supports most of the American research on earthquake prediction, was expanded.

American scientists have reported earthquake precursors similar to those reported by foreign scientists. In hindsight, it appears that the magnitude 6.5 earthquake near San Fernando in 1971 was preceded by a

velocity anomaly (Whitcomb and others, 1973), as was a smaller shock of magnitude 5.0 in central California in 1972 (Robinson and others, 1974). In the Adirondak Mountains region of New York State, a small earthquake was successfully forecast on this basis in 1973 (Aggarwal and others, 1973). The size of the velocity anomalies, however, has not been much above background variations in velocity, and some earthquakes in well-instrumented regions have shown *no* anomalies.

Anomalies in other phenomena have proved more encouraging. A resistivity anomaly was observed before a magnitude 3.9 earthquake in central California in 1973 (Mazzella and Morrison, 1973). The most exciting new results, however, came in November 1974, when a magnitude 5.2 earthquake struck near Hollister, Calif., in an area where the Geological Survey operates a dense network of instrumentation as part of an experimental earthquake prediction system. Strong precursors to the shock were observed in the Earth's magnetic field, the first such anomaly recorded anywhere, and in the tilting of the land surface (Johnston and Mortenson, 1974). Weak anomalies were also observed in the length of survey lines. Such a variety of precursory phenomena had not been previously observed to be associated with a single earthquake.

Thus, by 1974, the Soviet Union, Japan, and the United States had taken on earthquake prediction as a national goal and had found evidence that earthquakes have precursors. At that time, the Chinese effort in earthquake prediction was virtually unknown in other countries. The troubles of the Cultural Revolution made it difficult to follow Chinese science, but, as the turmoil began to wind down, word reached the West that a major prediction program was underway. The opportunity to learn of it came when former President Nixon's visit to China led to an exchange of earthquake specialists. The Chinese came to the United States in the spring of 1974, and, although they gave little substantive information on their program, they dropped enough hints to alert American scientists that they had some surprises in store when the U.S. delegation visited China in October of 1974.

What the delegation found was a well-organized, large-scale research effort specifically aimed at earthquake prediction. This program began soon after two very destructive earthquakes hit China's Hopeh Province in 1966. China's leaders, including Premier Chou en-lai, visited the stricken area and launched a serious effort to reduce the dreadful impact that earthquakes have had on the Chinese people. Over 800,000 people were killed in 1556 by a shock near Sian in central China, and about 180,000 were killed in 1920 near Kansu.

The cessation of publication and the lack of outside contact with Chinese scientists during the Cultural Revolution obscured from outside view the progress of the new program. The surprise awaiting the American delegation was that roughly 10,000 people, including several hundred scientists, are working to predict earthquakes by means of a wide variety of instrument systems, including some of the best in use anywhere in the world today. These specialists are joined by uncounted thousands of amateur workers who contribute to the prediction effort. Almost every technique that has ever been suggested as a basis for prediction is being studied to some degree. Numerous precursors have been observed, ranging from reports of unusual animal behavior to well-documented geophysical anomalies. About 10 earthquakes have been successfully predicted, and warnings have been issued. It is readily acknowledged that many predictions have not been followed by earthquakes.

The Chinese success in saving lives during the Liaoning earthquake signals that the age of earthquake prediction is upon us. Laboratory studies show that earthquake precursors should exist, and numerous field observations seem to confirm that they are observable. But we confront two important scientific questions. Do all earthquakes have precursors? And are precursors sufficiently regular or uniform in nature to be reliable? These questions can be answered only through careful observations and continued research.

As is the case with most new technological developments, progress can be a mixed blessing. There is no doubt that earthquake predictions can save lives, as has already been demonstrated in China. But, in the finely balanced socioeconomic structure of the United States, a prediction can also cause serious problems (Panel on the Public Policy Implications of Earthquake Prediction, 1975). One can imagine that prediction of a shock near a major city could lead to, among other things, a drop in tourism, nonrenewal of earthquake insurance policies, fleeing of the area by the panic stricken, and convergence on the area by the thrill seekers. Failure of the earthquake to occur could result in recriminations, law suits, and loss of faith in the scientists who made the prediction. Convincing people they had just experienced a near miss with an earthquake would not be as simple as convincing them that they had barely avoided a hurricane that had veered offshore.

It is nearly certain that some incorrect predictions will be made while scientists gain experience. With adequate preparation, however, adverse public response can be minimized. The time span over which predictions are most susceptible to error could be reduced by intensifying research efforts.

Damage to Lower Van Norman Reservoir caused by the February 9, 1971, San Fernando Valley earthquake.

Handled in the proper way, predictions can provide enormous benefits. Tens of thousands of lives were saved in 1971 because the level of the Lower Van Norman Reservoir had been lowered before the earthquake that struck at San Fernando, Calif., caused near collapse of the dam. Although the action was based on general concern for the dam rather than on an earthquake prediction, the lesson is clear. Many critical facilities are of necessity located in regions that will experience strong earthquakes. A warning could avert serious consequences resulting from damage to pipelines, storage tanks, and nuclear reactors. Many substandard buildings in use today would have a good chance of collapsing in an earthquake; these could be converted for warehouse use, reinforced, or evacuated.

Evacuation of cities, though often mentioned as a response to a prediction, would not be a necessary or wise course in the United States under almost any circumstances. In California, where prediction may first become a reality, most residences are of wooden-frame construction and stand up well in earthquakes. Therefore, most people would be relatively safe in their homes during a tremor. Certain hazardous buildings should be evacuated, but these could be specifically identified. Thus, the vision of a mass of people streaming out of an earthquake-threatened city need not become a reality. Dissemination of information and advice to the populace can avert panic situations.

Much remains to be accomplished before a solid basis for earthquake prediction can be established and before such prediction becomes as useful as weather forecasting. Instruments are deployed in only a few areas, the consistency of precursors has not been established, and a physical model to explain precursors remains to be confirmed. The transition to a reliable prediction capability will not be sudden. Even in the areas that are now under study, the development phase may stretch over the next decade. In the meantime, we can expect to see numerous scientific predictions based on fragmentary data. Procedures have been established to assure that these data receive thoughtful and responsible consideration.

In the quest for earthquake prediction, scientists are learning much about the nature of earthquake generation. The success with which earthquakes can be predicted remains to be determined, and many problems in the use of predictions remain to be solved. Progress toward prediction has been rapid in recent years, and the future is bright.

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Estimates of Undiscovered Petroleum Resources—A Perspective

By RICHARD P. SHELDON

Present and impending energy shortages clearly call for reliable estimates of the magnitude of the Nation's petroleum resources. Planners and policymakers must have an idea of petroleum production potential in terms of magnitude, life, and cost in order to define the actions needed to achieve this potential and also those required for the timely development of alternative sources of energy supply.

One part of the Nation's petroleum resources is the oil and gas remaining in fields that have been discovered and tested and partially produced. Estimates of the magnitude of the remaining producible oil and gas in these fields can be made with some assurance, even though they may be subject to some dispute on both engineering and economic grounds. These oil and gas field estimates can be added up to give an inventory of the amount of petroleum reserves available to the country.

The other part of the Nation's petroleum resources consists of the oil and gas that has yet to be discovered. This presents a different problem. How can the magnitude of undiscovered oil and gas fields be estimated? Perhaps it is better to ask: Can their magnitude be estimated at all when it is not even certain that they exist in the first place? Several approaches to this problem have been devised, but all have one thing in common. They are predictions or projections into the future, based on one theory or another, using a number of assumptions and some set of data. About the only thing that any estimator can say with certainty about his estimate is that it is wrong. There is simply too much uncertainty in all the approaches to allow the kind of accuracy of estimation that can be achieved for the already discovered petroleum resources.

Perhaps the next question to be asked is: Should such unpredictable resources be predicted? The answer clearly is yes, because essential national planning depends on our ideas about our future resources. The Nation at its inception had an expansionist policy based on faith in resource abundance, because not too much financial investment was at stake. The Louisiana Purchase cost only $15 million, and Alaska cost only $7.2 million. Now we must decide on multibillion-dollar investments in energy research and development to achieve national expansion. The stakes are too high to proceed on faith alone, and so an objective assessment of national resources is necessary. The assessments must be as reliable as we can reasonably make them.

How reliable are the present estimates of undiscovered petroleum resources? The different approaches or methodologies give different numbers. Is one more reliable than the others? The central controversy so far has begun with this question. This point of departure is valid only if the methodologies yield different estimates of the oil and gas that will be available to the Nation in the future. The contention of this paper is that this point of departure is not valid, because the estimates from the different methodologies are different partly, if not largely, because they are not all estimating the amount of oil and gas that will be available in the future. One method yields estimates of the amount of petroleum resources that there is to look for. Another yields estimates of the amount that there is to look for, as in the first case, but reduces the estimate by the amount that would be left in the ground if it were produced by using only the recovery technology available today. Both of these estimates are of the geologic availability and do not try to take into account the even more difficult problem of economic availability, which is what the national planner or policymaker is really interested in. The last method estimates economic availability in a limited way by analyzing the past results of our petroleum supply system with all of its economic, technologic, and political complexity and, using historic trends of discovery and production, by projecting into the future. This estimate would be equal to the first estimate of undiscovered resources only if our petroleum supply system were effective enough to find and recover what geologists think is there to find and what petroleum engineers think can be recovered in the long run. In fact, this estimate is lower, which indicates one of two things: Either the geologists and engineers are too optimistic and their estimates are too high, or our petroleum supply system has room for improvement in the future, given the proper economic stimulus, government policy, and scientific and technologic research.

If this line of reasoning is followed, the three estimates may not be incompatible but reinforcing. This does not put aside the question of how close one or all are to the unknowable "truth." That remains to be studied and is the substance of the question of reliability. The difference between estimates, then, includes both the substantial differences of reliability and the insubstantial differences of terminology. This perspective is presented in this paper.

DIMENSIONS OF PETROLEUM RESOURCE ESTIMATES

Petroleum resource estimates have many dimensions. To begin with, there are the several commodities: crude oil, natural gas liquids (NGL), and natural gas. Crude oil and NGL are commonly combined and reported as petroleum liquids. Additional potential sources of hydrocarbons that are usually not included in conventional resource estimates of petroleum are synthetic oils and gases from tar sands, oil shale and black shale, and natural gas in tight reservoirs, occluded in coal beds, and dissolved in geopressured subsurface water. Petroleum occurs in many provinces, some maturely explored, some virgin, some partly explored, some onshore, some in deep water offshore, and some in shallow water offshore. Resources within these provinces include the presently known deposits as well as the deposits that will be discovered in the future by using present exploration techniques. They also include the petroleum that will remain undiscovered by using present techniques but that could be found if better techniques were developed. Petroleum resources also include the petroleum that is left in the ground by past and present extraction technology and prices but that could be produced at higher prices or by technology yet to be developed.

If two petroleum estimates are to be compared, it is necessary to make sure that the estimates cover the same things. The dimensions of the estimates must be the same in relation to:

1. Commodity (crude oil, NGL, natural gas).
2. Time of the estimate relative to the stage of technology and economics as well as to the data source.
3. Coverage of petroleum provinces.
4. Resource category (identified, undiscovered, economic, subeconomic).

The first three dimensions are relatively easy to deal with theoretically, even though in practice the complexities that they introduce make it difficult to keep estimates consistently comparable. The fourth dimension, resource category, is more difficult to deal with theoretically because of a lack of a generally accepted resource terminology.

RESOURCE TERMINOLOGY

"As Mark Twain is reported to have remarked, most disputes arise because people use the same word to refer to different things or different terms to refer to the same thing. The report that follows is an attempt to help confine disputes over the size of resources and reserves of energy resources to substance," wrote Hans Landsberg in the foreword to J. J. Schanz's outstanding review of mineral resource terminology ("Resource terminology: An examination of concepts and terms and recommendations for improvement," unpublished report to Electric Power Research Institute, 1975). Uniform resource terminology is critical to lucid discussion and analysis of petroleum resource problems.

Petroleum accumulations in the ground are both known and unknown and range in size from a trace to billions of barrels of oil or to trillions of cubic feet of natural gas. These accumulations occur at various depths beneath the surface from a few hundred feet to as much as about 30,000 feet and in various parts of the country from the flat midcontinent area, to the mountainous regions of both the East and the West, to the continental margins offshore, and to the remote and hostile regions of Alaska. Many of the accumulations are too remote, too deep in the Earth or too far underwater, too obscure, or too small to make them worthwhile to search out, or to produce if discovered, and are not classed as resources.

The total petroleum resources of the country consist of that part of the petroleum in the ground that has been or can be discovered and can be recovered either now at present prices and technology or in the future at whatever prices and technology then exist.

McKelvey (1972) classified resources according to the geologic certainty of occurrence and the economic feasibility of recovery (fig. 1). This classification is described in other places and need not be redescribed here except to say that the "reserves" category in the upper left corner of the diagram includes petroleum that has been found and is now economic to produce, whereas the remainder of the resource field includes petroleum that has not yet been found or has been found but is not economic to recover at present prices and technology. Undiscovered resources were divided into hypothetical and speculative resource categories by Brobst and Pratt (1973) and defined as follows: "*Hypothetical resources* here are defined as undiscovered resources that we may still reasonably expect to find *in known districts; speculative resources* are defined as undiscovered resources that may exist elsewhere—either conventional types of deposits in broad geologic terrains in which as yet there are no discoveries, or else unconventional types of resources that have only recently been recognized (or are yet to be recognized) as having some potential."

These categories were created to allow the resource specialist the opportunity to separate undiscovered resources, which he feels fairly sure could be predicted by using well-established geologic theory in areas where known deposits exist, from undiscovered resources, which he feels might not exist at all and

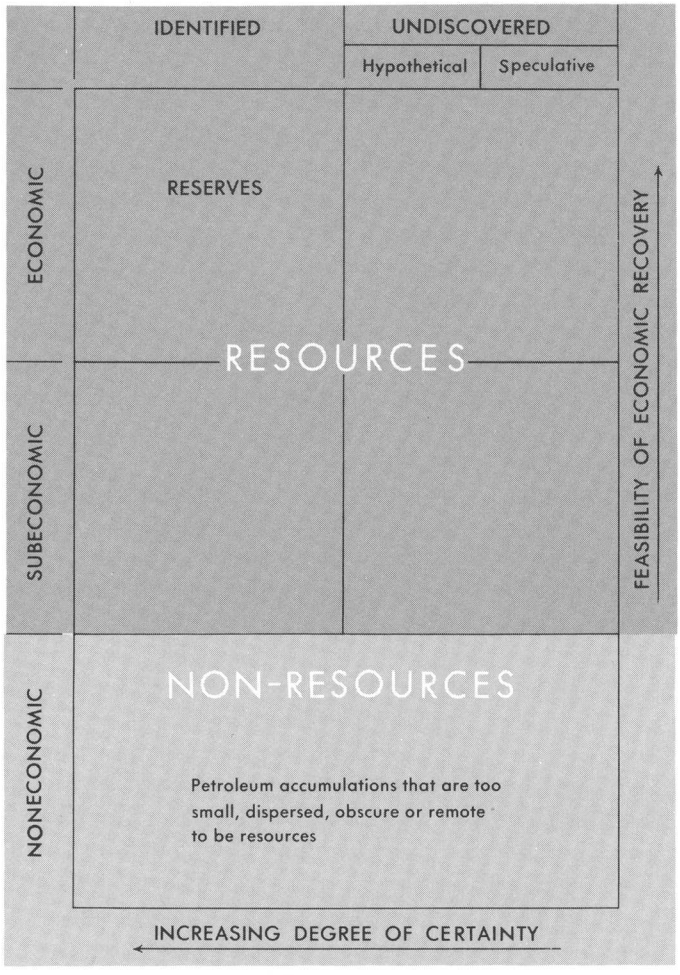

FIGURE 1.—General classification of petroleum resources (McKelvey, 1972).

whose magnitudes, if they did exist, could be estimated only very crudely within several orders of magnitude. The problem does not really stop there, because every resource geologist recognizes that resources probably exist that he has no basis to speculate on and that he would not include even in his speculative resource estimates. These resources could be set up as a category, but it would be mere sophistry. It is worthwhile to remember, however, that estimates of undiscovered resources tend to grow as knowledge increases.

It has been difficult to fit undiscovered resource estimates of petroleum into these hypothetical and speculative categories, and so far the categories have not been used by Geological Survey petroleum specialists. Most recently, the concept of probability of occurrence has been used (Miller and others, 1975). One can report these estimates in the McKelvey classification in one of two ways. The estimates can simply be shown as a range and placed in the undiscovered economic category (Miller and others, 1975, fig. 13), or the probability definitions can be adopted as part of the terminology and substituted for the hypothetical and speculative categories (fig. 2). Perhaps an acceptable correlation between the two systems would be to equate hypothetical resources with the mean estimates of resources, and speculative resources with the higher estimates at lower probabilities. In the rest of this paper, this procedure is adopted.

It is important to realize that the estimation of these resources does not imply that they will, in fact, be found or will, in fact, be produced. It is implied, however, that material classified as a resource has some chance of existing, being found, and being used in the future and is a target for exploration and technologic development.

DYNAMICS OF PETROLEUM SUPPLY SYSTEM

The movement of petroleum resources from one category to another over time transforms the McKelvey diagram from a simple static report of resources at one time into a dynamic model of the petroleum

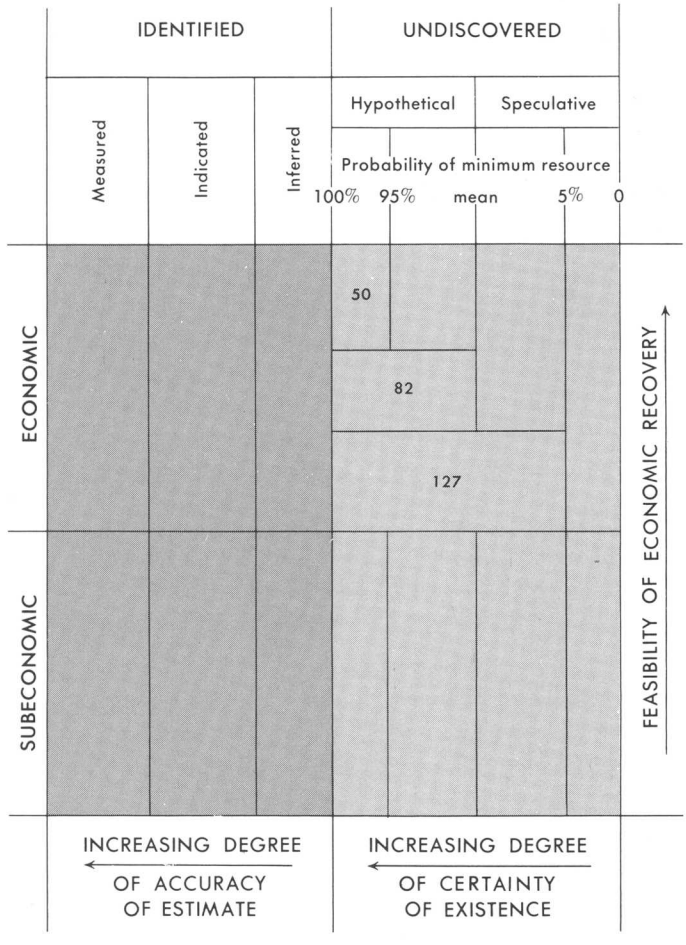

FIGURE 2.—Resource Appraisal Group (RAG) estimates of undiscovered recoverable crude-oil resources (in billions of barrels) as categorized for this discussion.

supply system if production is added as an outlet from the reserve box (fig. 3). The movement of material is to the left in the McKelvey diagram as deposits are identified through exploration and upward as more costly or lower grade deposits are developed with higher price-cost ratios or technologic advances.

A more sophisticated model of the dynamics of the complete petroleum supply system has been conceived and is being developed by Allen Clark and Lawrence Drew of the Geological Survey (fig. 4). Their

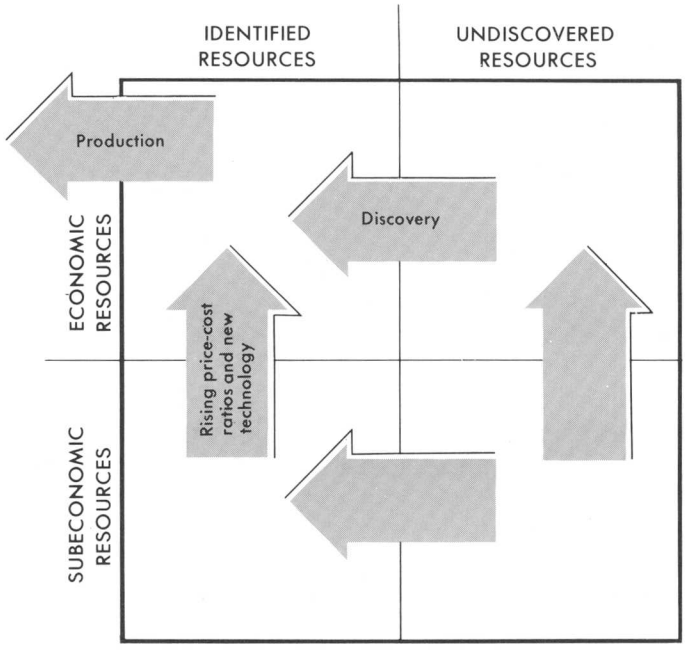

FIGURE 3.—Simplified model of petroleum supply system.

model includes three basic parts: (1) An occurrence model, (2) a search model, and (3) a production model, which describe, respectively, (1) the field size distribution of total resources, (2) the field size distribution of deposits discoverable at different levels of cost and technology, and (3) the production curves over time using various socioeconomic assumptions. Thus, when the occurrence model is operational, it would give estimates of economic and subeconomic undiscovered resources of the McKelvey classification, and the search model, using current prices and technology, would give estimates of the undiscovered economically producible resources.

CRUDE-OIL RESOURCE ESTIMATES

These concepts of classification can be applied to the many crude-oil resource estimates that have been made by scientists of various organizations, which will be discussed later, and a summary (table 1) shows the classificatory relationship of most of the modern estimates from various sources. This paper, however, will focus on the crude-oil resource estimates made recently by members of the Geological Survey to illustrate the principal effects of confusion of terminology.

Three series of estimates of undiscovered crude-oil resources have been initiated by Survey scientists. The discovery-production trend series of six estimates was begun by Hubbert (1956, 1962, 1966, 1967, 1969, 1974) while he was employed by Shell Oil Company but was extended when he joined the Geological Survey in 1964 as a senior scientist. The volumetric series of five genetically related estimates was made by a number of authors, including Duncan and McKelvey (1963, table 9), Hendricks (1965), T. A. Hendricks and S. P. Schweinfurth (written commun., 1966), Schweinfurth in works by McKelvey and others (1973), and Theobald and others (1972) and the U.S. Geological Survey (1974), using the basic estimation technique developed by A. D. Zapp and T. A. Hendricks. The geologic estimates published in Circular 725 by Miller and others (1975) are the first of the Resource Appraisal Group (RAG) to use a different, more sophisticated approach. Each of these series is an estimate of a different level of the petroleum supply system (fig. 5).

The volumetric series is a geologically controlled subjective volumetric estimate of the portion of oil in the ground that is discoverable and recoverable over the long term. The estimation, the technique of which is described in detail by Hendricks (1965), is made in the following way. The area of the United States that is favorable for the occurrence of petroleum is estimated on the basis of geologic concepts. The success of past exploration is used as a yardstick to predict the success of future exploration in the unexplored area. A number of assumptions are involved: (1) the number of wells required to totally explore an area, (2) the average depth of an exhaustive exploratory well, (3) the thickness of the petroleum-bearing rocks, (4) the comparative incidence of petroleum in the unexplored area relative to that in the explored area, (5) the extent of the unexplored area that probably will be explored, and (6) the percentage of the oil found that will be recovered.

The volumetric series of estimates has never been broken down, but it covers both the hypothetical and the speculative parts of the undiscovered economic resource field of the McKelvey diagram (fig. 6), because the analog methodology used assumes that past exploration has discovered accumulations from both the hypothetical and the speculative resource categories and thus should serve as an estimation device for both categories in the unexplored areas. The speculative resources may have been underestimated, however, because most wildcat wells have been drilled on hypothetical resource targets. It is impossible for any analog methodology to estimate the spec-

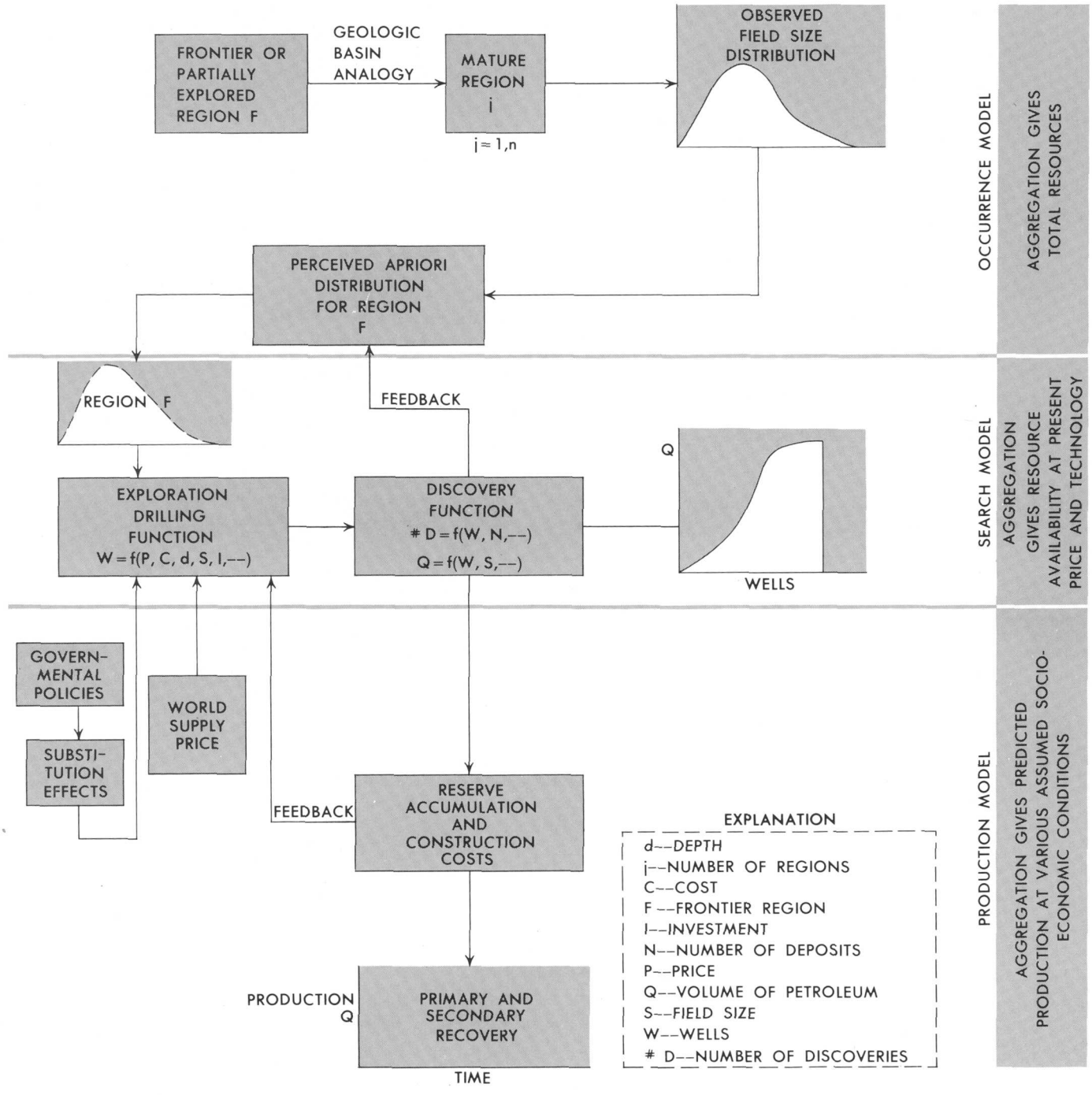

FIGURE 4.—Clark-Drew conceptual model of petroleum supply system.

ulative resources that are not analogous to known resources, since these fall into what might be termed an unconceived category, or resources that the estimator will not speculate about. Thus, the volumetric series covers as much of the undiscovered economic field as it is possible to cover. The Geological Survey volumetric estimates cover, in addition, the portion of the undiscovered subeconomic resource field that lies between the historical average of 32-percent recovery and the recovery rate of 40 percent assumed in the estimates.

The geologic estimates are of an entirely different character than those in the volumetric series. The first major difference is the magnitude of scientific effort going into the estimate. The volumetric estimates used about one scientist-year of effort and relied for their validity on the experienced judgment of the estimator, who used relatively small amounts of geologic data. The geologic estimates, on the other hand, used tens of scientist-years of effort from 70 areal-geology specialists and 8 experienced petroleum resource geologists, who used large amounts of geologic data. The

methodology is described in detail in Circular 725 (Miller and others, 1975) and consists of making estimates by assuming then-present technologic and pre-1974 economic conditions of the occurrence of undiscovered economic petroleum resources at several subjective probability levels for over 100 different petroleum provinces by means of several appraisal techniques. These geologically controlled results were then aggregated according to statistical theory. The results are explicitly reported at the 95-percent and the 5-percent probability levels of occurrence, with the idea that a 19-in-20 chance of the occurrence of a given quantity of oil is a fairly sure estimate, and a 1-in-20 chance of the occurrence of a larger quantity of oil is as unsure an estimate of the occurrence of additional petroleum as it is prudent to make. However, the technique estimates additional undiscovered recoverable oil at still lower probabilities, even though these estimates are reported only graphically. The 95- and 5-percent probability estimates do not cover all the undiscovered economic field of the McKelvey diagram. What is lacking is undiscovered economic resource estimates from the 5-percent level down to very small probability levels. The reported RAG estimates, when they are arrayed in vertical columns as they are in figure 2, therefore cover a smaller part of the undiscovered economic field than the volumetric series, particularly the later ones. Because the geologic estimates of undiscovered economic resources use the presently economic recovery factors most appropriate to the potential reservoir rocks in the basins being appraised, they did not incorrectly include any sub-

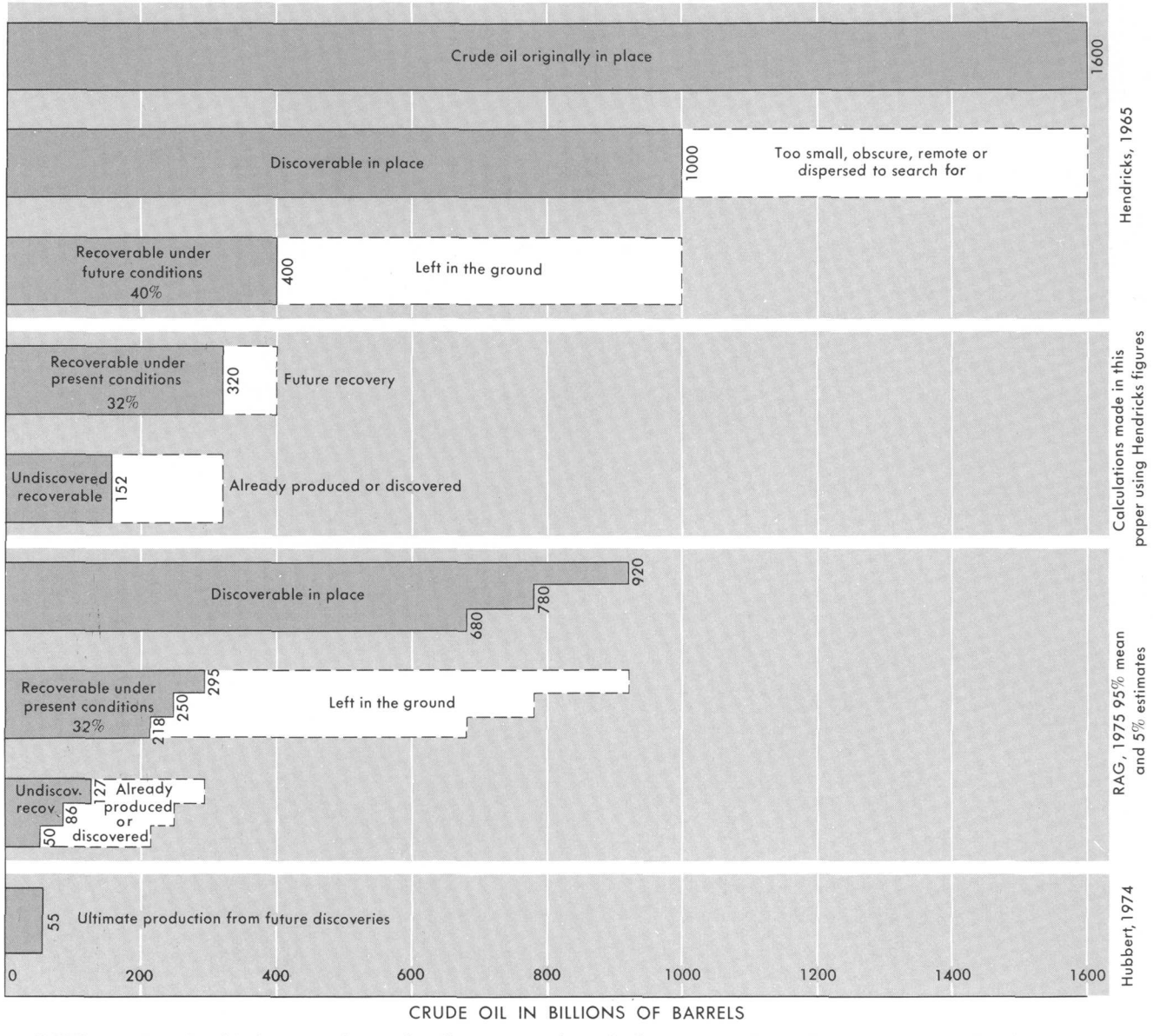

FIGURE 5.—Relationship between the crude-oil estimates of Hendricks (1965), Miller and others (1975), and Hubbert (1974).

TABLE 1.—*Comparison of crude-oil resource estimates (in billions of barrels) for the entire United States onshore and offshore to 200-metre water depth*

[If an original estimate was revised for this paper in order to express it in comparable dimensions and if the change involved implicit assumptions, the revised estimate is preceded by ca]

Estimator	Original estimate	Undiscovered economic and subeconomic crude-oil resources (60-percent recovery)	Undiscovered economic crude-oil resources (using present technology)	Ultimate crude-oil production from future discoveries	Original crude-oil resources (60-percent recovery of discovered and undiscovered crude oil in place)
Hendricks (1965)	400 [1]	285 [2]	ca 152 [3]	----	600
Theobald and others (1972)	459 [4]	ca 585 [5,6]	ca 312 [3]	----	ca 900 [5,7]
U.S. Geological Survey (1974)	200–400 [4]	ca 255–510 [5,6]	ca 136–272 [3]	----	570–825
National Petroleum Council (1970)	107	199	107 [3]	----	514
Resource Appraisal Group (Miller and others, 1975)	50–127 (82 mean)	≧94 to ≦238 [8]	50–127 (82 mean)	----	408–553 (468 mean)
Oil Co. A (Weeks, 1960)	----	----	ca 62 [9]	----	----
Oil Co. D (National Academy of Sciences, 1975)	89	----	76 [6]	----	----
Oil Co. E (National Academy of Sciences 1975)	90	----	77 [6]	----	----
Shell Oil Co. (R. H. Nanz, oral commun., 1975).[10]	65–155	----	65–155	----	----
M. K. Hubbert (1974)	----	----	----	55 [11]	----
C. L. Moore (written commun., 1975)	----	----	----	ca 156 [11,12]	452

[1] Includes past production and identified resources.

[2] Corrected for past production and all categories of reserves at 60-percent recovery. Hendricks gives 1,000 billion barrels of discoverable in-place crude oil.

[3] 32-percent recovery.

[4] Includes NGL.

[5] The original estimate includes NGL and is here reduced by 15-percent in order to subtract NGL.

[6] Estimate was classified as an undiscovered economic resource at the time of release and is reclassified here as an undiscovered resource.

[7] Estimates of crude oil on continental slope is subtracted from original estimate.

[8] The 95- and 5-percent probability levels of estimates of economic and subeconomic resources are not arithmetically additive. The proper aggregated 95- and 5-percent probability estimates would be greater than or equal to the sum of the 95-percent estimates and less than or equal to the sum of the 5-percent estimates. Estimates at 60-percent recovery.

[9] Weeks (1960) reported a figure of 270 billion barrels of ultimate resources of crude oil and NGL for the United States. This figure is adjusted by assuming crude oil is 85 percent of this and subtracting past production and all categories of reserves as of the end of 1974.

[10] Nanz, R. H., 1975, The offshore imperative—the need for a potential of offshore exploration: talk presented at colloquium on Conventional Energy Sources and the Environment, University of Delaware.

[11] Assumes continuation of pre-1974 socioeconomic conditions.

[12] Calculated by subtracting from C. L. Moore's 471 billion barrels ultimate recovery the 168 billion barrels of past production and present reserves plus an additional 147 billion barrels from identified resources at a 60-percent recovery.

economic resources and thus did not lap into the subeconomic field at all (fig. 6).

The discovery-production trend series of resource estimates is of still a different character. Hubbert analyzed the yearly trends of production and the additions to reserves through exploration by year and by exploratory drilling footage. He pointed out the dependence of the former on the latter and then projected their historic trends into the future by using logistics or growth curves. These estimates are predictions of ultimate discovery and ultimate production assuming no significant changes of exploration incentive or access to prospective land or no significant change in the rate of technological development.

RELATIONSHIP BETWEEN ESTIMATE SERIES

It was contended at the outset of this paper that part of the disagreement about estimating resources stems from using the same words for different things. This contention applies to the differences between the volumetric series and the geologic series. Both the 1972 volumetric estimate (Theobald and others, 1972, fig. 5) and the geologic estimates (Miller and others, 1975, fig. 13) are shown filling diagrammatically the complete undiscovered economic resource field (fig. 6). But, as discussed above, the volumetric series, particularly the later estimates, fills more than the undiscovered economic resource field, whereas the geologic estimate fills less, so that each series uses the term undiscovered economic resource in a different way. The true relationship between the two series, using the estimates of Hendricks (1965) and Miller and others (1975), are shown in figures 5 and 6.

The validity of the idea that differences between undiscovered economic estimates are partly due to a difference in assumptions of recoverability rates can be tested by comparing the estimated original crude-oil resources—that is, 60-percent recovery of original oil in place, estimated by each series (table 1). Hendricks' (1965) estimate at a 60-percent recovery would be 600 billion barrels, and the RAG 5-percent probability estimate is 553 billion barrels. Thus, both Hendricks and Miller and others were estimating similar amounts of undiscovered crude oil but drew different

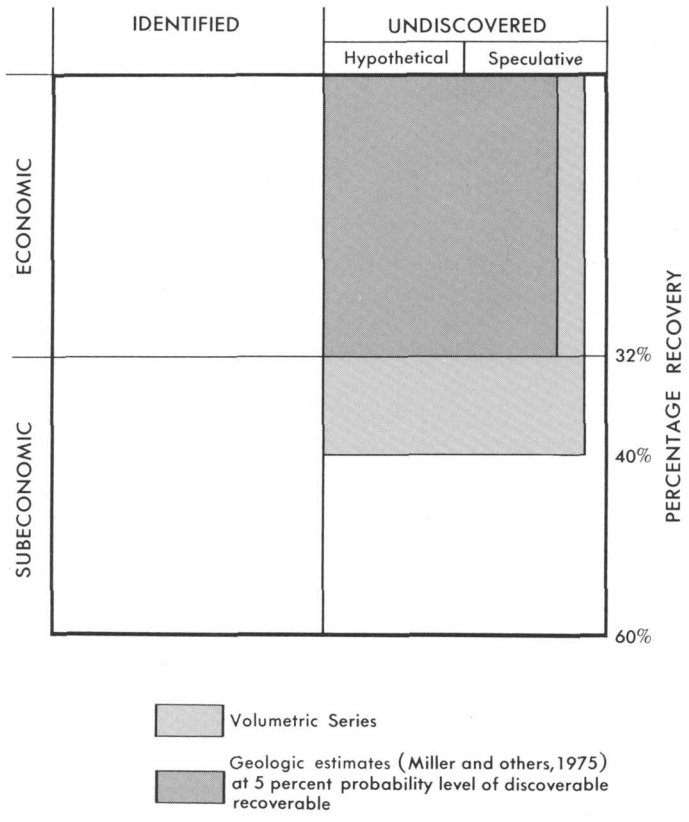

FIGURE 6.—Comparison of crude-oil resource estimates of the volumetric series with those of the geologic series.

boundaries between economic and subeconomic resources. On the other hand, Schweinfurth's (Theobald and others, 1972) estimate is about 900 billion barrels, almost twice the RAG 5-percent probability estimate. It can be assumed that the additional amount would be classed as speculative undiscovered and should be compared with the additional amount of crude oil estimated by RAG to occur at less than 5-percent probabilities, in both the economic and the subeconomic categories.

McKelvey developed and published his classification in 1972, after the first volumetric estimates had been made. However, the volumetric estimates of 1972 and 1974 were categorized as undiscovered economic resources rather than undiscovered resources. In hindsight, the assumptions of the volumetric methodology should have been adjusted to better fit the McKelvey classification. The geologic estimates, on the other hand, have followed the McKelvey classification as closely as possible. This difference has been a major source of confusion and controversy.

How do these estimates relate to the petroleum supply system model of Clark and Drew (fig. 4)? As a first approximation, the volumetric series is analogous to the resource estimates of the occurrence model. The geologic estimates are most closely analogous to the resource availability estimates produced by the search model. The discovery-production trend estimates are most similar to a production model prediction based on the assumption that the socioeconomic conditions prevailing over the last several decades will continue.

Thus, one can compare the estimates by saying that the volumetric estimates are the total undiscovered resource (to a 40-percent recovery level) and the geologic estimates are that part of the volumetric estimate that could be discovered and recovered under pre-1974 economic and technologic conditions, whereas the discovery-production trend estimates are that part of the geologic estimates that would be discovered and produced under the socioeconomic conditions of the last several decades.

UNCERTAINTY OF ESTIMATES

The above analysis asserts the relationship between these three petroleum resource estimates but does not deal with the uncertainty inherent in the estimates. The relationship requires that the volumetric estimates must be larger than the geologic estimates, which in turn must be larger than Hubbert's discovery-production trend estimates. But are the existing differences larger or smaller than they should be? Or, stated another way, is the accuracy of the estimates satisfactory?

The degree of certainty of the existence of resources decreases to the right of the McKelvey diagram. The feasibility of economic recovery decreases downward and implies a decreasing certainty of technological development and increasing economic incentive necessary to recover the resources. Thus, the volumetric estimates, which include resources that are either less well known or subeconomic, are by their nature less certain than the resources that were associated with the 5-percent probability estimated in the geologic estimates. Each series used a different technique to handle its inherent uncertainty.

Hendricks (1965, p. 3) gave a single resource figure but stated that "The statistical data from drilling in the United States are utilized to estimate the minimum total quantities originally underlying the United States and its adjoining continental shelves. As will be seen, none of the factors that enter into such a computation can be actually determined; many are purely matters of opinion. However, the analysis is given in such a manner that any reader who disagrees with any of the values assigned, or assumptions made, may substitute other values or other assumptions and derive his own estimates." In effect, he said: Here are my judgments; if you disagree, I've given you a formula into which you can substitute your own judgments. This caveat also applied to the 1966, 1969, and 1972 estimates of

the series, in which other judgments were made with the purpose of estimating not the "minimum" but the more likely (in the minds of the estimators) larger quantities of crude oil underlying the United States. As a result, estimates increased to finally the largest estimate of about 390 billion barrels of crude oil in 1972. Thus, the inherent uncertainty of the estimates was not dealt with directly until 1974 (U.S. Geological Survey, 1974) when a range of estimates was introduced that almost covered the span of estimates from 1965 through 1972. It is likely that, if additional petroleum geologists would make petroleum resource estimates by means of the Hendricks technique, the range of estimates would increase still more. For example, a number of petroleum geologists, including Halbouty (1975, p. 10), past president of the American Association of Petroleum Geologists (AAPG) and a leading analyst of petroleum resources as well as a highly successful explorationist, feel that the volumetric series estimate of 1974 is reasonable and acceptable and, if anything (Michel Halbouty, oral commun., 1975), is too low. The Panel on the Estimation of Mineral Reserves and Resources of the Committee on Mineral Resources and the Environment of the National Academy of Sciences (1975, p. 90), which included John Moody, the incoming president of AAPG and retired Senior Vice President for Exploration and Production for Mobil Oil Company, felt that even the lowest of the volumetric series estimates is too high. It is likely that some of this difference of opinion reflects a misunderstanding of what is being estimated, but, even so, it is probable that the full range of uncertainty inherent in the Hendricks estimation technique has not been established.

The uncertainty of the RAG estimates, as discussed above, was handled by presenting the estimates at several probability levels and by showing the probability of any estimate by a curve. It is possible that broadening the number of resource specialists beyond the eight in the Resource Appraisal Group would increase the range of resources estimated at the 95- and 5-percent probability levels, because it is unlikely that the RAG specialists represent the full possible range of experienced resource judgments. In addition to this, although the Resource Appraisal Group was concerned about the effect on the estimates of using a group discussion to arrive at a consensus estimate for each province, the members felt that the benefits of group discussion to the quality of the estimate outweighed any possible bias introduced. It has been suggested that the effect of group behavior might tend to reduce the range of estimates, and the generalization pointed out by Myers and Lamm (1975, p. 297)—that "group discussion tends to enhance the average pregroup inclination of the group members"—supports this suggestion. An alternative procedure for avoiding this pitfall would be to have the resource specialists make their province estimates independently and then aggregate them for each province according to statistical theory. It appears then that, even though the full range of uncertainty inherent in the geologic estimates has not been established, it is certainly better established than the range of the volumetric estimates, because probabilities were dealt with directly, more views were represented in its preparation, and statistical theory rather than intuition was used to aggregate probabilities of the occurrence of oil by province.

The inherent uncertainty of the discovery-production trend estimates is more difficult to assess. The internal precision of the projection technique—that is, the goodness of fit of the points to the curve—has been estimated by Hubbert (1975) at about ±20 percent. However, the effect of significant changes in the socioeconomic factors which would influence Hubbert's prediction of ultimate production have not been analyzed. For example, if the OPEC cartel were to break up and the world oil price return to a level more closely related to the cost of finding and producing petroleum, the effect on the American domestic petroleum industry, which has already lost the depletion allowance, would be extremely depressing, and it is possible that Hubbert's predicted ultimate production would be too large, at least within the time range of his projections. Similar effects in the opposite direction are conceivable. Thus, it is apparent that a part of the uncertainty of Hubbert's estimate is inherently tied to the uncertainties of future political events. Also, if other types of curves are adopted, the same data give widely different results. Hubbert uses a symmetrical curve to predict 170 billion barrels of ultimate crude-oil production,[1] whereas C. L. Moore (written commun., 1975), using an asymmetrical curve with the same data plus Alaskan data, predicts an ultimate crude-oil production of 471 billion barrels. I can see no evidence produced by either Hubbert or Moore that makes one curve or one manner of curve fitting preferable to the other, much less requires the use of one curve or the other. Furthermore, these particular curves are useful, mainly because they are mathematically simple. This simplicity facilitates the analysis of the data, but does it mean that other mathematically more complex curves, which would give still different results, are more or less valid? Finally, it is difficult to say, even though past frontiers are included in the historic discovery and production data, whether future frontier petroleum provinces are

[1] He adds an additional 43 billion barrels derived from a geologic estimate to account for Alaska, giving an ultimate U.S. production of 213 billion barrels.

adequately handled in the projections, and, thus, additional uncertainly is introduced into the estimates. Thus, there is a large amount of inherent uncertainty introduced into Hubbert's estimates from these three sources—that is, (1) uncertainty of future socioeconomic events, (2) choice of alternative curves and method of fitting used for prediction, and (3) the geographic extent of the prediction. However, it must be recognized that Hubbert's predictions, made 13 years ago, accurately predicted the peaking of domestic production in 1972, a significant achievement.

To repeat the question asked at the outset of this section, are the existing differences between series estimates larger or smaller than they should be? The question cannot be answered now because the full range of uncertainties inherent in the production, search, and occurrence models has not been assessed. It is too early to judge.

Other recent estimates

A number of other estimates of undiscovered petroleum resources have been made. Some of these have been described and analyzed by Theobald and others (1972), McCulloh (1973), and Miller and others (1975), and six of them are shown in table 1 along with estimates of Geological Survey scientists. One difficulty in comparing these estimates is caused by the combination of their aggregated nature and their dimensional differences.

The industry estimates given in the report of the Committee on Mineral Resources and the Environment of the National Research Council of the National Academy of Sciences (1975, p. 89) and the Shell Oil estimate apparently are estimates of undiscovered recoverable resources under pre-1974 economic conditions and technology. The estimates of the National Petroleum Council and the AAPG are very difficult to categorize owing to the varying methodologies and resource terminologies used by scientists for different regions. Still, we can be confident that the overall methodology of deriving these estimates was similar to that used by RAG. The resource is reported as undiscovered oil in the ground, and several recovery factors are reported. The resulting estimates are comparable in magnitude at a 32-percent recovery factor with the RAG estimate. The ultimate production estimates of C. L. Moore (written commun., 1975) are analogous to Hubbert's estimates as discussed earlier.

All these estimates are listed in table 1 according to the resource categories that correspond to the crude-oil supply model as proposed by Clark and Drew—that is, undiscovered crude oil (equaling the occurrence model estimates), undiscovered economic crude oil (equaling the search model estimates), and production from future discoveries (equaling part of the production model estimates). These non-Survey estimates fall within the ranges of Survey estimates, except for Moore's estimate, which is more than twice that of Hubbert's.

SUMMARY AND CONCLUSIONS

A full analysis of the Nation's petroleum supply system requires knowledge of (1) the total petroleum resources discoverable and recoverable under future technologic and economic conditions, (2) the portions of those resources that are discoverable and recoverable under present technologic and economic conditions, and (3) the ultimate production possible under a range of socioeconomic conditions. As an approximate characterization, the volumetric series of estimates was an attempt to estimate the first category, the first geologic estimate was an attempt to estimate the second category, and the discovery-production trend series of estimates was an attempt at the third category, but only under the assumption of continuing socioeconomic conditions prevailing over the last several decades. Thus, even though these estimates have inherent uncertainties that can and should be narrowed with additional work and even though they are only first approximations of their categories, they are not necessarily incompatible with one another.

It is important for policymakers to recognize these relationships so they can address substantive resource problems.

Agreement exists on all sides on the magnitude of the fairly well assured undiscovered economic resources under pre-1974 technologic and economic conditions, that is, the geologic estimates. The estimates should be improved, but little change in their magnitude is expected until substantial exploration is carried out in the frontier areas. Better estimates of undiscovered resources—that is, the occurrence model estimates—are badly needed, because the present volumetric estimates are too uncertain and too general to allow full development of the search model estimates or, in turn, the production model estimates. Finally, although the discovery-production trend estimate is valuable for the assessment of the petroleum supply system operating in 1973, the effects of a range of differing socioeconomic factors on ultimate production badly need to be evaluated in order to demonstrate the options available for policy considerations.

PLANS FOR FURTHER RESOURCE STUDIES

The Geological Survey has the responsibility to continue to improve resource estimates. The critical needs have been discussed in this paper, and plans to meet

some of these needs have been made and partially implemented.

Occurrence modeling

The Resource Appraisal Group and the Office of Resource Analysis of the Geological Survey are developing the computerized analytical techniques required for occurrence modeling. This process involves the development of field size distributions in the petroleum provinces of the country and the application of mature geologic basin analogs to each of the frontier basins and the partially explored basins. The data required to implement these studies are being developed cooperatively by the Geological Survey, various State geological surveys, the AAPG, the International Oil Scouts Association, the U.S. Bureau of Mines, and the University of Oklahoma or are being purchased through Petroleum Information, Inc.

A novel geophysical technique for helping to estimate petroleum resource potential is being developed by T. H. McCulloh of the Geological Survey. It consists of applying to the partially explored or frontier basins the relationship between the average lightness of a petroleum basin (that is, the average difference between the gravity of the rocks in the basin and the gravity of the surrounding area) and the average petroleum richness of the basin that McCulloh established for the well-developed basins. This technique shows promise in sharpening the analog methodology for appraising the total petroleum resources of the Nation, both onshore and offshore, thus providing the improved reliability of resource estimates necessary for the search model.

Search modeling

The Office of Resource Analysis is developing the techniques for a computerized analytical search model to generate the field size distributions, by basin, of petroleum discoverable and recoverable under present as well as alternative economic and technologic conditions. The geologic information necessary to implement this modeling is being generated by the Resource Appraisal Group and the Oil and Gas Resources Branch of the Geological Survey. This estimate will be the next in the RAG series.

In 1975, the AAPG was asked by Acting Secretary of the Interior Kent Frizzell, with the strong endorsement of the Director of the Geological Survey, to undertake a petroleum resource appraisal of the country. This effort will allow a major input to petroleum resource estimation by the petroleum explorers of the Nation.

The Resource Appraisal Group, in addition to providing input to the above modeling, will continue its ongoing resource studies on a province-by-province basis for the entire Nation. This effort will include the updating and revision of earlier appraisals, the development and improvement of appraisal methodology, Outer Continental Shelf area evaluations, wilderness area appraisals, finding-rate studies, and a series of maps showing the petroleum basins of the world.

Production modeling

The Geological Survey does not normally engage in production modeling, which gives long-range supply curves. Occurrence and search modeling are, however, necessary inputs to production modeling, and the Survey is undertaking research in the application of its occurrence and search models to production modeling in order to facilitate cooperation with these organizations that are engaging in production modeling.

These plans constitute the next steps in appraising the Nation's petroleum resources. When these steps have been taken and when an appropriate organization undertakes production modeling studies, a resource information system will have been set up to allow for continuing monitoring and assessment of the Nation's petroleum resources. Only then will a firm base have been laid for making energy policy in relation to petroleum resources. Such steps will, however, require several years to complete. In the meantime, necessary policy decisions on offshore leasing, petroleum pricing, and alternate energy source development must be made on the basis of the incomplete and uncertain petroleum resource estimates that we now have.

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Fundamental to an increasing global population is the expansion of food production, which requires preservation of good agricultural land. (Photograph courtesy of Wine Institute, San Francisco, Calif.)

Earth Sciences and the Urban Environment

By DONALD R. NICHOLS

Cities have been built and have either prospered or declined and died because of the natural attributes of their locations. Only recently has there been much awareness of the role that earth sciences can play in defining the urban environment and in offering alternatives for its development and enjoyment.

Commerce traditionally has been regarded as the basis of urbanization. Commerce itself, however, is governed by the availability of resources, such as construction materials, land, water, and minerals, and by the ease of transportation, which in turn is governed by energy, topography, or the presence of navigable waterways. Where these resources have combined favorably to support large populations, cities have prospered and grown; where they have not, cities have gradually declined or even been obliterated overnight by the forces of nature. For example, the depletion of mineral resources created many ghost towns in the West; many ancient and even some relatively modern cities have disappeared because of catastrophes such as drought, duststorms, earthquakes, and volcanic eruptions.

Modern technology can overcome some resource problems by transporting water, by transmitting energy and fuel, and by moving minerals to factories, but the direct and indirect costs to the Nation's economy and environment are skyrocketing; also, opposition is growing in many areas to the export of critical resources. In addition, byproducts of modern technology produce air and water pollution that make many cities ugly, uncomfortable, and even hazardous to the health and life of their inhabitants.

NATURAL RESOURCES

Natural resources are the basis for urbanization. Without construction materials, cities could not be built; without minerals, industry could not develop and expand and most urban jobs would not exist; without fuel, factories would close and houses would be cold and unlit; without a potable water supply, society could not function; without prime agricultural land, vast concentrations of people could not be fed. Because these resources are severely limited in many areas, it is important that they be identified and judiciously developed if urban amenities are to be preserved.

Construction materials are essential to urban growth. Sand, gravel, and crushed stone are rapidly becoming scarce commodities in some urban areas because nearby sources are exhausted or are being built over or because their development is opposed as a nuisance. Such materials have a low unit value; thus, transporting them is a major factor in their cost, which roughly doubles for every 32 kilometres (20 miles) of transport.

Although the development of most mineral commodities does not conflict with urbanization, some jurisdictions have recognized the need to divert urbanization from potential resource areas. For example, Pima County in Arizona has adopted an ordinance prohibiting surface development over potentially mineable copper deposits. The ubiquitous oil-well pumps in commercial, industrial, and even residential districts of Los Angeles, Calif., and Oklahoma City, Okla., are striking testimony to the priority that society has placed on fuel resources.

As oil and gas become more scarce, other sources of fossil fuels become more important. It remains to be seen, however, whether the development of coal and oil shale, where it conflicts with urbanization and the quest for environmental quality, will be pursued. In any event, the rapid depletion of fossil fuels requires development of alternative energy sources if our present form of society is to be maintained. Even more fundamental to an increasing global population

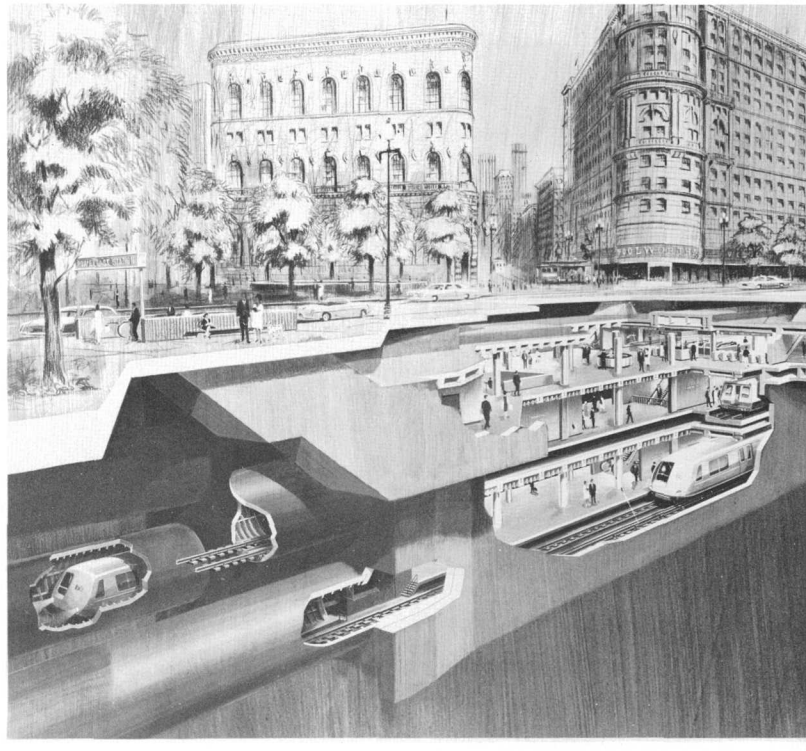
Sand and gravel are becoming scarce because many sources are being exhausted or built over or because their development is opposed as a nuisance. (Photograph courtesy of Los Angeles City Department of Building and Safety.)

is the expansion of food production, which requires preservation of good agricultural land and water supplies and the production of fertilizers. These prerequisites are being threatened, however. For example, prime agricultural land is being converted to housing tracts, and the mining of phosphate, a critical fertilizer ingredient, is in conflict with other land use values in some areas.

Although water is usually not considered a depletable commodity, as are minerals and fuels, adequate good-quality water supplies are of special concern in most urban areas. This concern arises from the increasing demands placed on locally limited water supplies and the effects of urbanization on water quality. Urban areas compete for existing surface-water supplies from streams and reservoirs; suitable reservoir sites are few and often are in conflict with other land uses. Only by regional or, in some cases, statewide or interstate water-resource planning can serious shortages be averted.

Continuous heavy withdrawal of ground water, coupled with urbanization that paves recharge areas and that greatly increases storm runoff, has severely depleted supplies in many areas. Additionally, industrial and residential wastes have polluted both surface- and ground-water sources. In the case of ground water, the effects of existing waste-disposal practices (for example, poorly designed landfills, leaky sewer systems, and septic tank systems) may not become evident for decades; where serious ground-water pollution has occurred, as it has in some areas of acid mine-water drainage, water supplies may not become potable for tens of years, if ever. It is essential, therefore, that critical ground-water supplies be identified and wisely managed.

Just as conflicts over the use of the land surface grow, so has competition for the use of the subsurface. The shallow subsurface has long been used to store and filter effluents from septic tank systems and industrial and urban wastes. In recent decades, deeper zones have been used to store industrial wastes and toxic fluids. Existing underground openings in mines and new, specially designed excavations are used increasingly, particularly in urban areas; stormwater runoff is stored temporarily in tunnels in the Chicago, Ill., area; natural gas is stored for peak urban use in manmade caverns in many areas; factories and warehouses occupy excavations beneath Kansas City, Mo.; tunnels are being designed, built, or expanded for utilities and rapid transit systems in many larger cities. Development of all underground resources requires extensive and detailed subsurface geologic and hydrologic data to determine their capacity for development.



Development of all underground space requires extensive and detailed subsurface geologic and hydrologic data. (Photograph courtesy of San Francisco Bay Area Rapid Transit District.)

HAZARDS

Natural hazards are taking an increasing toll of life and property. Catastrophic landslides that have claimed large numbers of lives include earthquake-generated avalanches that killed 30,000 Peruvians in 1970 and 830,000 Chinese in 1556. Not all destructive landslides are triggered by earthquakes, however. Almost 3,000 people were killed in 1963 when a large earth mass, lubricated by a rising water table, slid into the Vaiont Reservoir in Italy. The resulting overflow destroyed several towns (fig. 7). We court similar disasters in the United States by building reservoirs in valleys underlain by active faults or on the flanks of volcanoes that have produced debris avalanches.

Aside from such infrequent catastrophic events, thousands of landslides occur annually throughout the United States, especially in urban areas where residential development, seeking new ground for expansion, has moved into "view" sites on hillslopes, many of which are already unstable. Cutting into these slopes, adding water to lawns, concentrating runoff from roofs and streets, and other acts of man cause landslides estimated to cost over $200 million annually. Typical damage during a single winter has been documented for only a few areas; damages of more than $25 million occurred in the nine-county San Francisco Bay region (Taylor and Brabb, 1972),

$6.25 million in the Los Angeles area (Yelverton, 1971), and $250,000 in the vicinity of Seattle, Wash. (Tubbs, 1974).

Most losses from flooding and erosion are predictable and can be avoided. Despite that, flooding is the most widespread natural hazard in the United States and accounts for the largest average annual property losses (White and Haas, 1975, p. 255). Nearly all cities were founded beside rivers and along coasts to be close to both the water supply and a convenient means of transportation and to enjoy the scenic views. When man encroaches on river flood plains or coastal plains, he is subject to havoc from rapid runoff of melting snow, intense rainfall, hurricanes, tsunamis—tidal surges caused by submarine landslides—and accelerated erosion and sedimentation (table 2). Erosion along shorelines of rivers, along Lakes Michigan and Erie, in coastal California, along the Gulf Coast, and along the Atlantic is both costly and hazardous to owners of waterfront property. Major engineering works to prevent flooding and erosion in many cases succeeded only in postponing the hazard or in diverting it and intensifying it in another area.

Earthquakes pose the greatest potential hazard to many urban areas of the United States. A great earthquake today in Los Angeles or San Francisco, Calif., or a repeat of the Charleston, S.C., earthquake of 1886 would probably result in the loss of tens of thousands of lives and many billions of dollars in property damage. Most of these losses would be caused by building collapse owing to vibration or to failures in the ground beneath them (landslides and liquefaction). Losses also would result from surface ruptures along active faults that underlie many urban towns along the Pacific coast and in other parts of the West.

Subsidence of the land surface owing to groundwater withdrawal occurs in many densely populated areas in Alabama, Florida, Missouri, Texas, Louisiana, Arizona, and California. Individual houses and even entire cities have suffered major property damage; losses are likely to continue for several years, even after the causes are identified and eliminated. Land subsidence of as much as 2.5 metres (8 feet) in the Houston-Galveston area of Texas has been estimated to cost $110 million. Even greater amounts of subsidence have occurred in San Jose (4 metres, 13 feet) and Long Beach (8 metres, 26 feet), Calif., the latter being due to oil withdrawal. The Baldwin Hills Reservoir failure in Los Angeles that killed five people in 1954 is generally attributed to subsidence resulting from oil-well operations. Subsidence also occurs in other States over formerly mined areas, natural cavities and caverns, and heavily pumped oilfields.

Volcanic activity during historic time in the United States fortunately has been infrequent and restricted to remote areas. Elsewhere, however, the complete burial of Pompeii, Italy, in 79 A.D. and of St. Pierre on the island of Martinique in 1902 and the rapid growth to a height of 366 metres (1,200 feet) of the Parícutin Volcano on farmland in Mexico in the mid-1940's serve

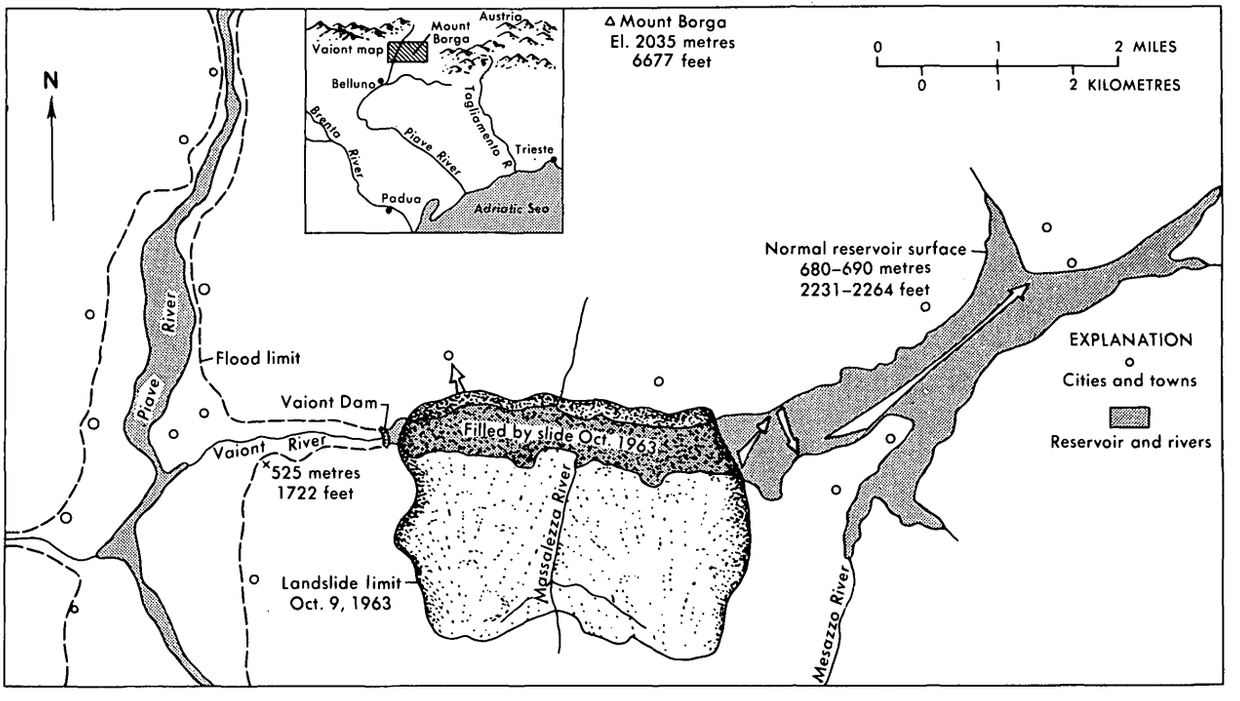


FIGURE 7.—Sketch map of Vaiont Reservoir in Italy showing the 1963 landslide which created waves that overtopped the dam and caused flooding and destruction over large areas downstream (modified from Kiersch, 1964, fig. 1).

A great earthquake today in Los Angeles or San Francisco would probably result in the loss of tens of thousands of lives and many billions of dollars in property damage.

as reminders that we live on a dynamic planet. Large areas in the Western United States, including many urban areas (Hilo, Hawaii; Portland, Oreg.; and Seattle, Wash.) are adjacent to major volcanic eruptive centers. A residential subdivision near Hilo is located on a series of lava flows, the most recent of which erupted from Kilauea in 1955. The renewal of volcanic activity in 1975 on Mount Baker, east of Bellingham, Wash., is a cause for concern in the Puget Sound area. The location and frequency of future volcanic activity are unknown, but the consequences are predictable in some areas.

The safe disposal of wastes is closely interrelated with geologic and hydrologic phenomena and conditions. Certainly, a better understanding of geologic processes and environments, combined with the application of established engineering practices, could have averted the Buffalo Creek, W. Va., disaster, where failure of coal-mine waste piles claimed 118 lives in 1972. The potential hazards from nuclear waste disposal; many types of industrial and mining operations; overconcentrations of fertilizers, herbicides, and insecticides; livestock feedlots; and municipal sewage and trash disposal have long been recognized. For example, a recent newspaper article (*Washington Post,* September 29, 1975) cited authorities in Tampa, Fla., as saying "High levels of radiation, which could double the chances of lung cancer, have been found in houses built on reclaimed phosphate mining lands in southwest Florida." Similar accounts have come from Colorado, Missouri, and other States.

TABLE 2.—*Examples of catastrophic losses to property and lives from single hydrologic events affecting low-lying land*

Event	Property losses (millions of dollars)	Fatalities
Rapid runoff from melting snow (Vanport, Oreg., flood, 1948)--	$103	51
Intense rainfall (Rapid City, S. Dak., 1972) ---	128	238
Hurricane Agnes (1972) --------	3,100	117
Hurricane Camille (1969) -------	1,400	258
Tsunami (Hawaii, 1946) ----------	25	159
Tsunami (Crescent City, Calif., 1964) ---	11	10
Submarine landslides (Valdez and Seward, Alaska, 1964) ----------	27	42

CONSTRAINTS AND OPPORTUNITIES IN LAND USE MANAGEMENT AFFORDED BY EARTH SCIENCES

Man has lived with and surmounted natural hazard and finite resource problems without much serious consequence throughout his history. Why should there suddenly be such strong concern for earth-science problems? Some reasons are obvious. The total dependency of urbanization and technology on natural resources and on a stable and conducive urban environment was no problem as long as (1) resources were plentiful, (2) population growth did not exceed the capability of the land and water to absorb the resultant wastes, and (3) complex economic and industrial centers did not concentrate in hazard areas. Recognition of the constraints that the Earth places on its exploitation is a first step in developing opportunities for continued growth through effective land and water management.

Natural resources can be harvested in such a way that the land surface and subsurface can still be put to other vital uses. Planning and development to take advantage of these uses, however, rest upon (1) recognition of resource areas, (2) definition of geologic and hydrologic controls, (3) ultimate potential uses of the land, (4) environmental consequences of development, (5) imaginative management, and (6) an enlightened public that has the will and patience to conserve resources and guide sequential use of the land.

After resource extraction, open-pit mines can be used for recreational lakes, for flood storage and desilting basins, for buried underground structures, and for disposal of solid wastes and subsequent reclamation and development of the surface. Ground-water recharge areas can be used for nonintensive agriculture and grazing or as parkland. Treated sewage can

be injected into aquifers to form barriers against saltwater intrusion. Underground mines sometimes can be reclaimed for solid-waste disposal, storage, or even for industrial sites.

Future development can minimize natural hazards by avoiding high risk areas and, at the same time, provide for such environmental amenities as open-space and recreational areas. Applying earth-science information can avert most hazard losses in new construction and reduce them in existing structures. Where hazards to structures cannot be mitigated, alternative land uses are possible. Golf courses, nurseries, agriculture, parks, and many other land uses are compatible with active faulting, landsliding, flooding, and volcanic hazards. Existing mechanisms that can be used to encourage future development and redevelopment in low-risk areas include public education, land use planning, zoning, public acquisition, and tax incentives, when they are properly based on a knowledge of natural conditions and processes.

Less catastrophic but equally or more costly problems, such as subsidence, swelling soils, erosion, and weak foundation conditions, can be overcome by knowing where and why they occur, how severe they are, and how to engineer for them. For example, corrective construction design and practice, stimulated by building codes, allow development on swelling or compressible soils without serious consequences.

Individual houses and even entire cities have suffered major property damage owing to subsidence.

STATUS OF EARTH SCIENCES IN THE URBAN ENVIRONMENT

The U.S. Geological Survey, its sister State surveys, and the earth-science professions have a long and proud history of service to society. Geologists, hydrologists, and topographers, through nationwide mapping programs that have identified mineral, water, and energy resources, have provided the basis for current urban and technological development.

Today, earth scientists are becoming more active in relating their work directly to urban problems. More scientists, at all levels of government and in the private sector, are working in urban areas, making their studies more easily understandable to nonscientists, and participating in public forums. Consequently, many people now have a much greater awareness of the role that the earth sciences play in governing the quality of life in the urban environment.

This awareness is reflected in recent legislation such as the National Environmental Policy Act (Public Law 90–190) of 1969, the Flood Insurance Program of 1968, which was amended in 1973 to include mudslide insurance, and the Federal Water Pollution Control Act (Public Law 92–500) of 1972, and the act establishing the Environmental Protection Agency. In addition, several Federal agencies are actively seeking a greater application of earth science in their programs. For example, the Department of Housing and Urban Development joined with the Geological Survey in sponsoring a program to develop and apply earth-science information in support of land use planning and decisionmaking in the San Francisco Bay region. Similarly, the Department of Transportation and the Appalachian Regional Commission have provided funds for the Geological Survey to conduct geologic, geographic, hydrologic, and topographic studies in urban areas and to relate them to urban and regional planning needs. Leading this effort was a new program initiated by the Survey in 1971 to conduct a series of interdisciplinary earth-science studies in representative urban areas across the country. Many new and innovative products and techniques are outgrowths of the program, including regional topographic maps at scales of 1:100,000 and 1:125,000; orthophoto quadrangles at a variety of scales and with overprinted contours; slope maps; maps delineating potential hazards such as floods, active faults, landslides, and mine subsidence; maps delineating the availability of ground water, the potential for copper deposits, and other mineral and construction resource maps; and land capability studies.

At the same time, many States have undertaken earth-science studies in urban areas and have adopted legislation for their application to land use problems.

A plant nursery, undeveloped open space, a freeway, and a cemetery are land uses most compatible with the hazards posed by this active fault. Other uses might include a drive-in theater, a golf course, a riding stable, and other recreational activities.

Alabama, California, Florida, Illinois, and Texas are among the States that have provided leadership in collecting, interpreting, and applying geologic, hydrologic, and soils data to urban decisionmaking. Two noteworthy examples of a State's concern for geologic hazards are California Senate Bills 351 (1971) and 520 (1972). Senate Bill 351 requires that all community general plans include a seismic safety element which assesses hazards from earthquake faulting, ground shaking, ground failure, and seismic sea waves. Senate Bill 520 initially prohibited the construction of any structure intended for human occupancy on the trace of an active fault but was later amended to exclude single-family residences.

Many local governments have independently faced up to their responsibilities to minimize hazards and conserve resources in urban areas. As early as 1952, both the City and the County of Los Angeles, Calif., required geologic studies to be made before construction was allowed in hazard areas. Since 1972,

four counties and a major city in the San Francisco area have employed geologists on their staffs to review development plans, assist in general planning, and guide public-works construction. Geologists are now similarly employed in Tucson, Ariz., Boulder and Lakewood, Colo., King County in Washington, and other areas. Long Island, N.Y., Orange County in California, and Houston, Tex., are among the many urban areas that have adopted controls to limit the withdrawal and degradation of ground-water resources.

Private industry, which had employed geologists, hydrologists, and geotechnical engineers largely to correct costly foundation failures, now is employing an increasing number of private consultants in advance of site selection and development. Earth scientists contribute not only to the siting and construction of major urban-related structures such as dams, powerplants, highways, and office and apartment buildings, but also to the planning and designing of new communities.

THE FUTURE

As people continue to concentrate in cities, earth science becomes increasingly important in maintaining an acceptable environment. Urbanization, already so dependent on limited mineral, water, energy, and agricultural resources, will stagnate and wither unless critical resources are conserved, new resources are found, and the effects of potential catastrophic natural disasters are minimized. The future also affords many new opportunities to correct past mistakes and avoid new ones. As cities age, redevelopment should not concentrate populations in previously developed areas of potential hazards and costly foundation conditions. In the past, development generally proceeded first in areas of flat ground having good foundation conditions, but often on flood plains, sand and gravel deposits, ground-water recharge areas, and prime agricultural land, and avoided land more costly to develop (often unstable hillslopes and other hazard areas). When land was plentiful and cheap, earth science was not critical to development. More recently, development has tended to "fill in" the still open hazard areas. With less land available, increasing development costs, and major potential hazards, earth science becomes more critical in guiding urban development.

As the use of earth science grows, so will the ability of the science to devise means of collecting and applying knowledge. Computer-assisted mapping and display techniques are evolving that combine a variety of earth-science and related data and will allow legislators to rapidly assess planning solutions and the consequences of alternative courses of actions (Stewart and Van Driel, in press). Opportunities also are in sight to use Landsat and other Earth satellites more fully in monitoring environmental and land use changes. New geophysical techniques, remote sensing tools, and the data collection and relay capacities of satellites can greatly reduce the cost of data collection and the speed with which data can be interpreted and synthesized.

Earth-science information is useless, however, without effective communication and application. Earth, natural, and social scientists must work diligently to communicate with one another, with decisionmakers, and with the public. Where earth-science expertise exists in support of the planning process, opportunities are enhanced for partnerships between local, State, and Federal agencies to effectively address urban problems. A start has been made under the Geological Survey's pilot Urban Area Studies program. However, a much greater effort is necessary if the earth sciences are to assume their full responsibilities in helping to guide future urbanization.

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". . . the classification of the public lands,
and examination of the geological structure,
mineral resources, and products of the national
domain." --Act of March 3, 1879

Missions, Organization, and Budget

For more than 96 years, the U.S. Geological Survey has served Federal, State, and local governments and the public by collecting, analyzing, and publishing detailed information about the Nation's mineral, land, and water resources. The Geological Survey was originally created in 1879 to study the geologic structure and mineral resources of the public domain and to provide information to support development of the West. Congress and the Secretary of the Interior later expanded the Survey's responsibilities to include: topographic mapping, chemical and physical research, stream gaging and water-supply assessments, supervision of mineral exploration and development activities on Federal and Indian lands, administration of a minerals exploration program, and engineering supervision of waterpower permits.

Although the emphasis and balance of the Survey's programs have changed over the years, these programs still retain the fact-finding mission described in the brief enabling legislation of 1879. Today the Survey's broad mission is to enlarge the knowledge of the extent, distribution, character, and origins of the Nation's natural resources and of the geologic processes that affect the use of the land so that man may intelligently adjust his activities to the constraints imposed by the environment and may wisely manage the Earth's resources. The Survey's regulatory responsibilities—classifying Federal lands and supervising mineral lease development on Federal and Indian lands—are no less important. By working closely with the Bureau of Land Management and other land management agencies, the Survey seeks to identify, conserve, and supervise development of the Nation's public resources so that the public receives its fair share for leased resources and so that damage to other resource, environmental, and social values are minimized during exploration and development.

Both missions call for objective and impartial reporting of investigations, identification of natural constraints on land use and resource development, and analyses of the consequences of alternative policies or actions related to resource development, conservation, or environmental protection.

ORGANIZATION

The scientific and regulatory missions of the Geological Survey are carried on by five organizational units, each of which has responsibilities for one of the Survey's major programs or budget activities (see the organization chart and table 25 in the section "Organizational and Statistical Data."

- *The Topographic Division* produces maps delineating the physical features of land areas in the United States, its outlying areas, and Antarctica. The Division also collects and distributes information on the availability of aerial photographs and space images, maps and charts, geodetic data, and related cartographic information through its National Cartographic Information Center.
- *The Geologic Division*, through research on geologic processes and Earth history, provides information that permits intelligent adjustment to the national environment and wise use of the Earth's resources. The Geologic Division determines the composition and structure of the rocks and materials that lie at and beneath the Earth's surface, identifies potential energy and mineral resources including those of the Outer Continental Shelf, and develops and distributes knowledge about natural hazards such as earthquakes, volcanic eruptions, and land subsidence.
- *The Water Resources Division* assesses the quantity and quality of the Nation's water supply, develops the knowledge necessary to predict the environmental consequences of alternative plans for developing water resources, coordinates Federal water-data acquisition activities, collects and distributes information about the availability of water data through the National Water Data Exchange, and develops and distributes information about natural hazards such as floods and land subsidence.
- *The Conservation Division* classifies the public lands with respect to leasable minerals and waterpower sites, and supervises exploration and development authorized under leases and permits on Federal and Indian lands.
- *The Land Information and Analysis Office* coordinates and administers interrelated interdisciplinary programs of both the Department of the Interior and the Geological Survey with the objective of interpreting and displaying resource information in ways that are readily accessible and understandable to a wide range of potential users, particularly land use planners and decisionmakers.

The structure of the Geological Survey's budget closely parallels the structure of the organization. Each program division (Topographic, Geologic, Water Resources, and Conservation Divisions, and the Land Information and Analysis Office) is responsible for one of the Survey's major budget activities (tables 3 and 25). A small program, Alaska Pipeline Related Investigations, is currently administered by the Geologic Division with technical assistance from the Water Resources Division.

TABLE 3.—*Geological Survey obligations for fiscal year 1975, by activity*

Activity	Fiscal year 1975 (Dollars in millions)	Percent change relative to fiscal year 1974	
		Current dollars	Constant dollars
Total	$338.76	+36	+22
Direct program	253.60	+48	+33
Reimbursable program	85.16	+10	−1
Alaska Pipeline Related Investigations [1]	.34	−61	−65
Topographic Surveys and Mapping	52.60	+21	+9
Direct program	45.35	+22	+10
Reimbursable program	7.25	+11	+1
Geologic and Mineral Resource Surveys and Mapping	114.48	+56	+40
Direct program	89.02	+78	+61
Reimbursable program	25.46	+8	−3
Water Resources Investigations	101.44	+15	+4
Direct program	53.42	+18	+6
Reimbursable program	48.02	+12	+1
Conservation of Lands and Minerals	36.08	+98	+79
Direct program	36.03	+98	+79
Reimbursable program	.05	+22	+10
Land Information and Analysis	16.99	+31	+18
Direct program	15.46	+35	+22
Reimbursable program	1.53	−1	−10
General Administration [1]	3.67	+4	−6
Facilities [1]	10.31	+88	+70
Miscellaneous services to other accounts [2]	2.85	+3	−7

[1] Direct program.
[2] Reimbursable program.

These research, fact-finding, and regulatory programs receive executive direction from the Office of the Director and technical and administrative support from the Administrative, Computer Center, and Publications Divisions. The *General Administration and Facilities* budget activities fund the Office of the Director, the Administrative Division, and the operation of the Survey's National Center facilities located in Reston, Va. Other administrative and management services provided by the Administrative Division and technical services provided by the Computer Center and Publications Divisions are financed through as-

sessments of the program Divisions. While not a budget activity, the entry *Miscellaneous services to other accounts* represents reimbursements received from other Federal agencies for data-processing and publication services and for the sale of material from stock.

BUDGET

The total funds obligated by the Geological Survey in fiscal year 1975 amounted to $338.8 million, an increase of $89.3 million over fiscal year 1974. This one-year increase, much of which was aimed at strengthening the Survey's regulatory programs and at expanding energy-related resource assessments and environmental studies, represented 40 percent of the total increases received by the Survey during the past 10 years (fig. 8). While the budget has increased 197 percent since fiscal year 1966, rising prices have taken their toll. The purchasing power of the Survey's budget (in terms of constant 1967 dollars) has only increased 87 percent during this 10-year period.

The mix of funding sources for the Survey's programs has changed markedly during the past year because the growth rate of direct programs (funds appropriated by Congress) continued to exceed the growth rate of reimbursable programs (funds transferred to the Survey by Federal, State, and local agencies, and by miscellaneous non-Federal sources). In fiscal year 1975, about 75 percent of the total funds available to the Survey were appropriated directly to the Survey by Congress as opposed to 69 percent in fiscal year 1974 (fig. 9). While the purchasing power of the direct program increased about 33 percent, the purchasing power of the reimbursable program remained about the same as in fiscal year 1974 (table 3 and fig. 8).

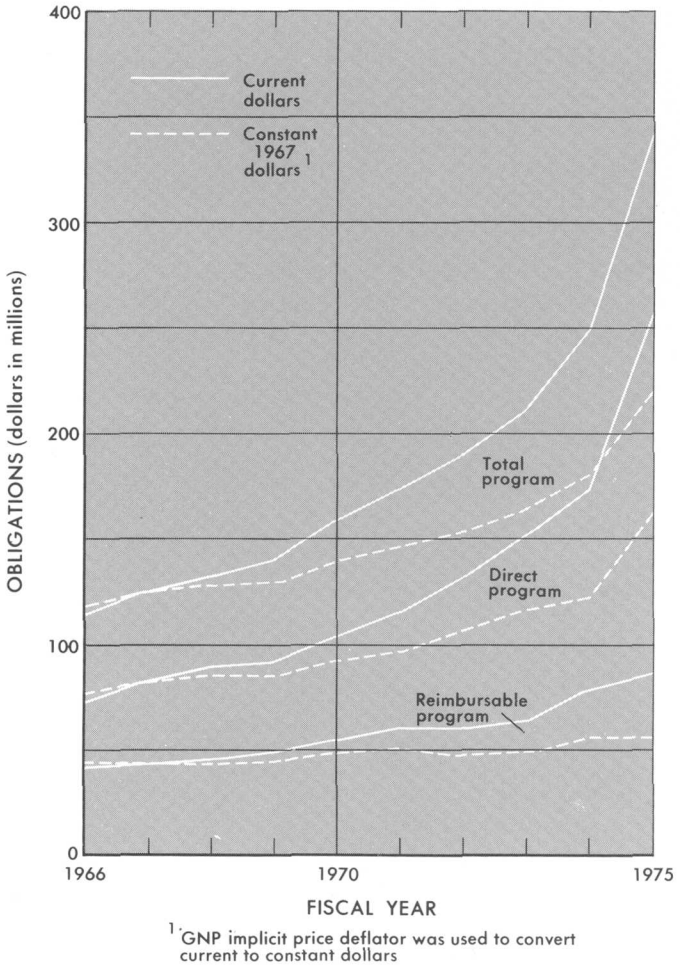


FIGURE 8.—Geological Survey budget, by source of funds, fiscal years 1966–75.

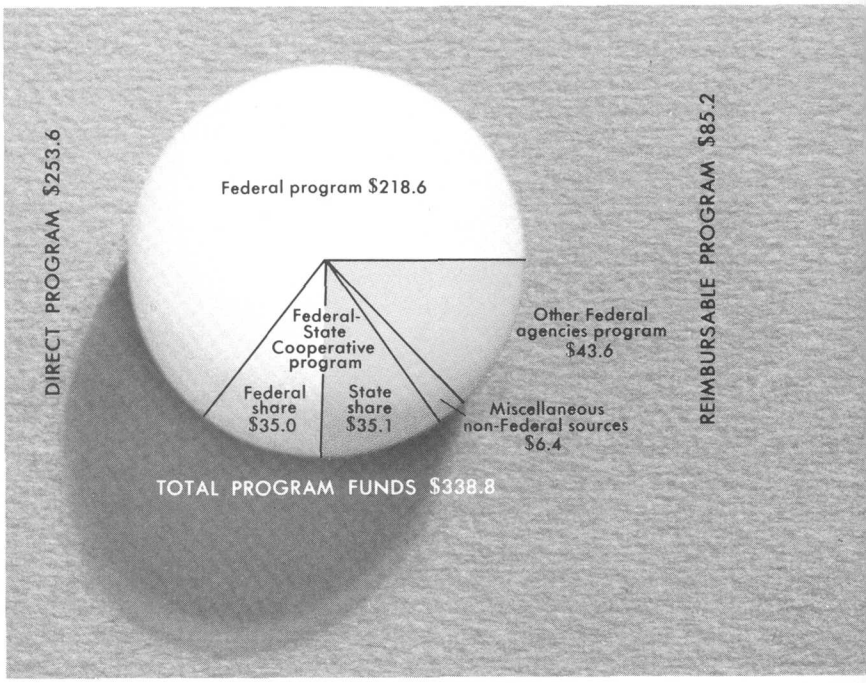
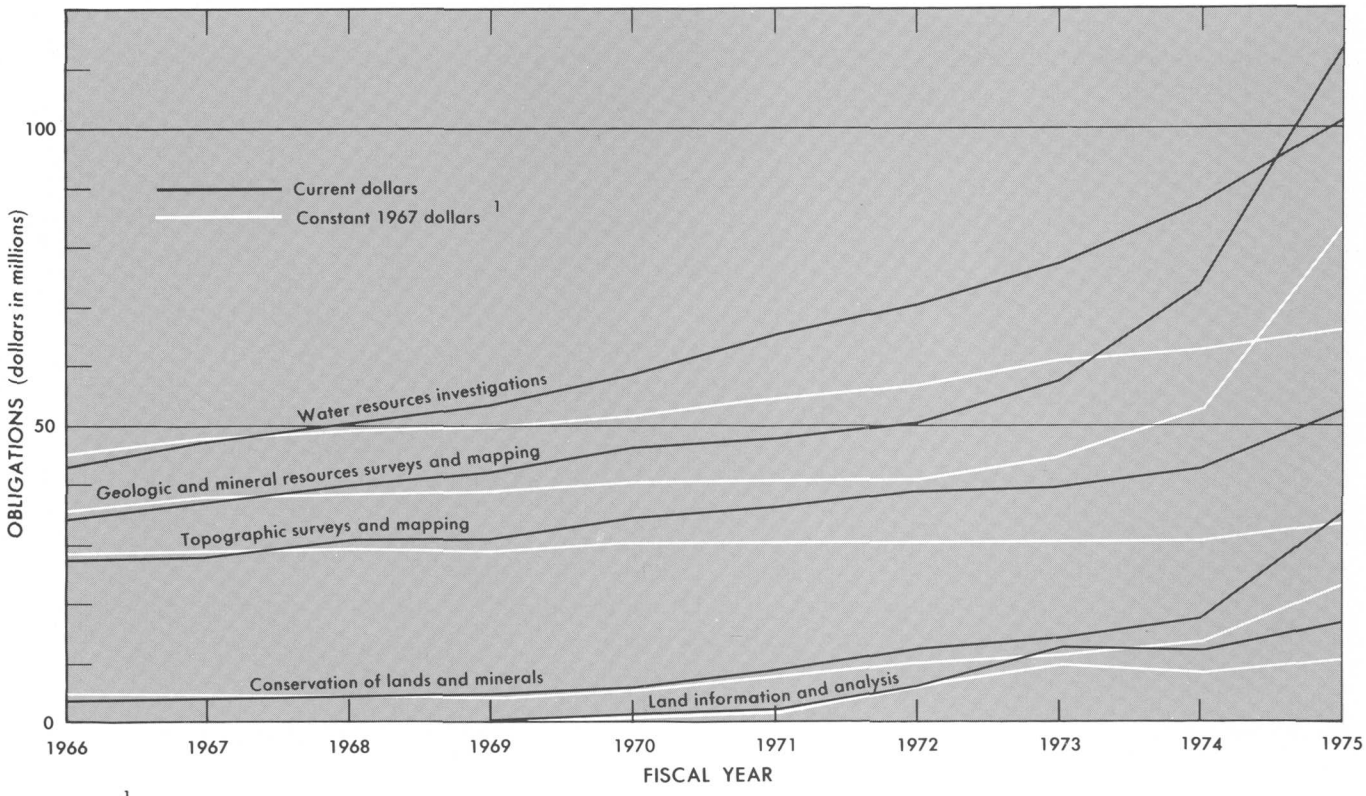


FIGURE 9.—Sources of Geological Survey funds in fiscal year 1975 (dollars in millions).

The allocation of funds to the Geological Survey's five principal budget activities (Topographic Surveys and Mapping, Geologic and Mineral Resource Surveys and Mapping, Water Resources Investigations, Conservation of Lands and Minerals, and Land Information and Analysis) has also changed rather dramatically over the last several years reflecting the increased emphasis the Survey is placing on its regulatory programs and energy-related resource appraisals and environmental studies (fig. 10). Both the Geologic and Mineral Resource Surveys and Mapping and the Conservation of Lands and Minerals budget activities underwent rapid growth in fiscal years 1974 and 1975 (fig. 10). In fiscal year 1975, the Geologic and Mineral Resource Surveys and Mapping activity comprised 34 percent and the Conservation of Lands and Minerals comprised 11 percent of the Survey's total budget (fig. 11).



[1] GNP implicit price deflator was used to convert current dollars to constant dollars

FIGURE 10.—Geological Survey budget by activity, fiscal years 1966–75.

TABLE 4.—*Participation of Survey organizational units in areas of study included in the fiscal year 1975 budget*

Area of study	Topographic Division	Geologic Division	Water Resources Division	Conservation Division	Land Information Analysis Office	Office of the Director and Administrative Division
Energy:						
OCS oil and gas	--	X	--	X	--	--
Onshore oil and gas	--	X	--	X	--	--
Oil shale	--	X	X	X	--	--
Coal	--	X	X	X	--	--
Uranium and thorium	--	X	X	X	--	--
Geothermal	--	X	X	X	--	--
Minerals:						
Metallic and nonmetallic minerals	--	X	--	X	--	--
Mineral and fuels information system	--	X	--	--	--	--
Hazards:						
Earthquakes	--	X	--	--	--	--
Volcanoes	--	X	--	--	--	--
Floods	--	--	X	--	--	--
Water quality	--	--	X	--	--	--
General hydrology	--	--	X	--	--	--
General geology	--	X	--	--	--	--
Standard topographic mapping	X	--	--	--	--	--
Products for land-resources decisions	X	--	--	--	X	--
Environmental impact statements	--	X	X	X	X	--
Earth Resources Observation System	--	--	--	--	X	--
General administration and facilities	--	--	--	--	--	X

An alternative way of looking at the Survey's budget is by area of study (fig. 12). For example, energy-related investigations include the regulatory and resource-evaluation activities of the Conservation Division, the resource assessments and related mineral research of the Geologic Division, and hydrologic investigations of the Water Resources Division (table 4). In fiscal year 1975, energy-related investigations constituted 27 percent of the Survey's budget; mineral investigations, 8 percent; natural hazards, 15 percent; and general hydrology, general geology, and standard quadrangle mapping, 39 percent. The remaining 11 percent involved operation of the Earth Resources Observation System programs; preparation of products to aid in making land-resources decisions, preparation of environmental impact statements, and general administration and operation of facilities.

PERSONNEL

Unlike the budget, which has increased 197 percent since 1966, the number of permanent full-time employees involved in the Survey's programs remained more or less constant through fiscal year 1973 (fig. 13

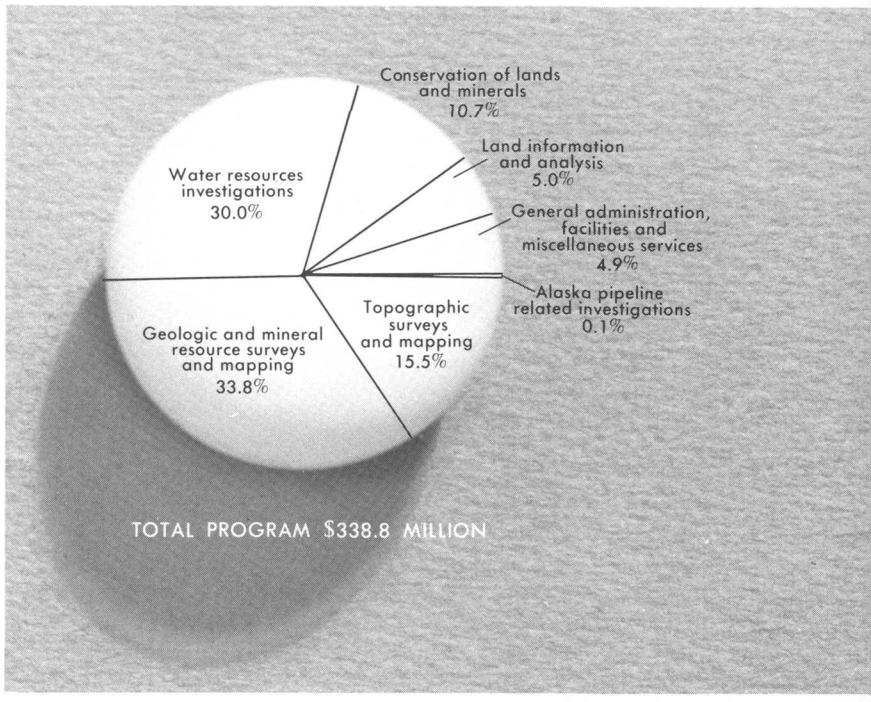


FIGURE 11.—Distribution of Geological Survey funds by budget activity in fiscal year 1975.

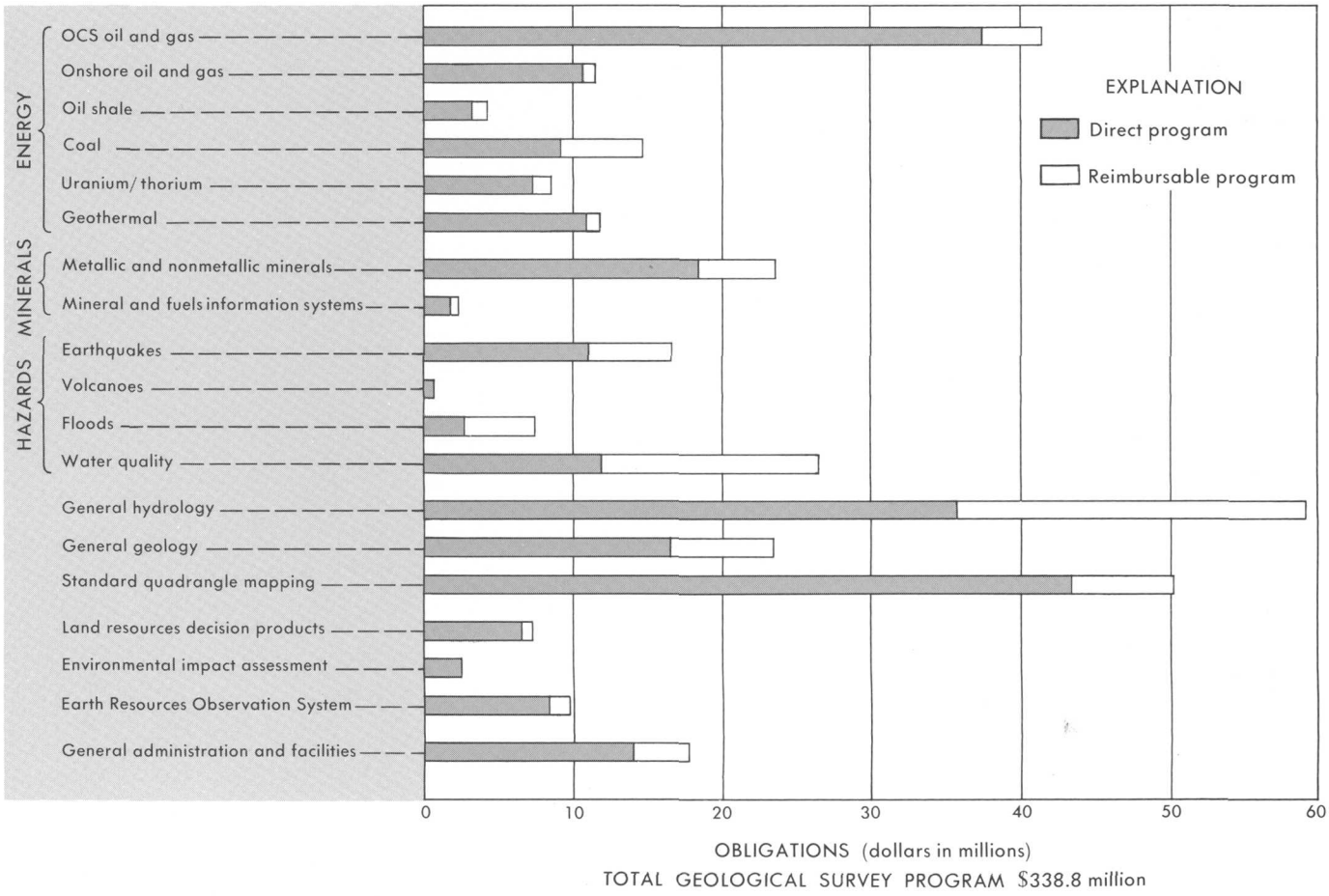
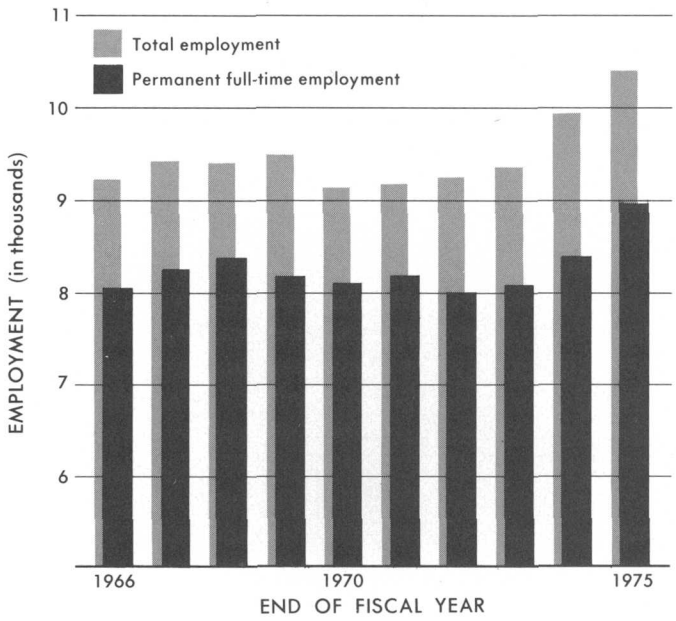


FIGURE 12.—Distribution of Geological Survey obligations for fiscal year 1975, by areas of study.

and table 44). In fiscal years 1974 and 1975, 910 additional permanent full-time positions were filled, an increase of 11 percent over fiscal year 1973. The distribution of permanent full-time employees by organizational unit is shown in figure 14. The Water Resources Division employed 33 percent of the permanent full-time employees, Geologic Division, 24 percent, Topographic Division, 19 percent, and the Conservation Division, 10 percent.

The technical nature of the Geological Survey's programs is reflected in the composition of the work force. At the end of fiscal year 1975, the Survey employed 8,999 people on a permanent full-time basis of which 76 percent held professional or technical positions (figure 15). The high level of training and diversity of specialized skills present in this work force provides the Federal Government with an important resource of scientific expertise in the earth sciences.

FIGURE 13.—Geological Survey end-of-year employment, fiscal years 1966–75.▼



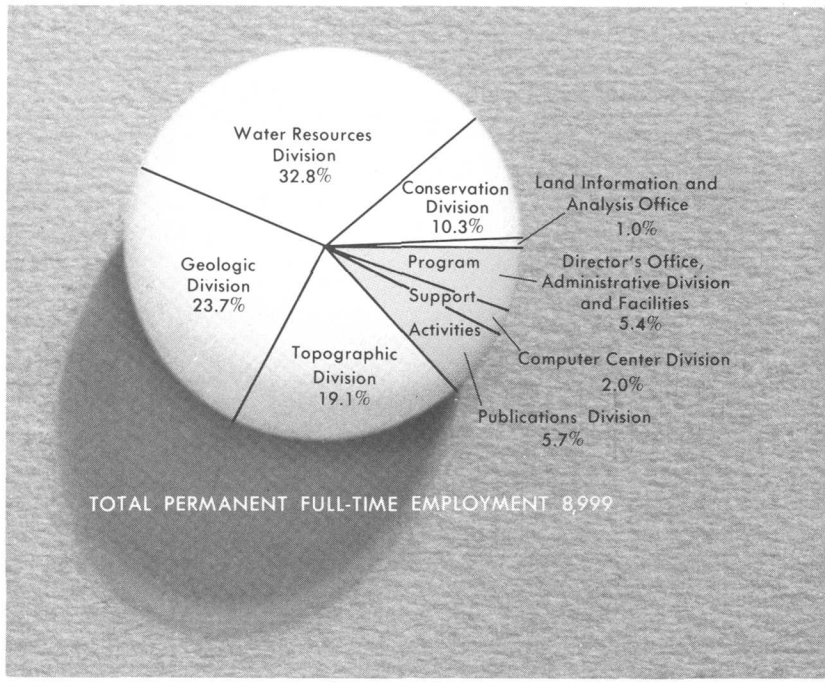


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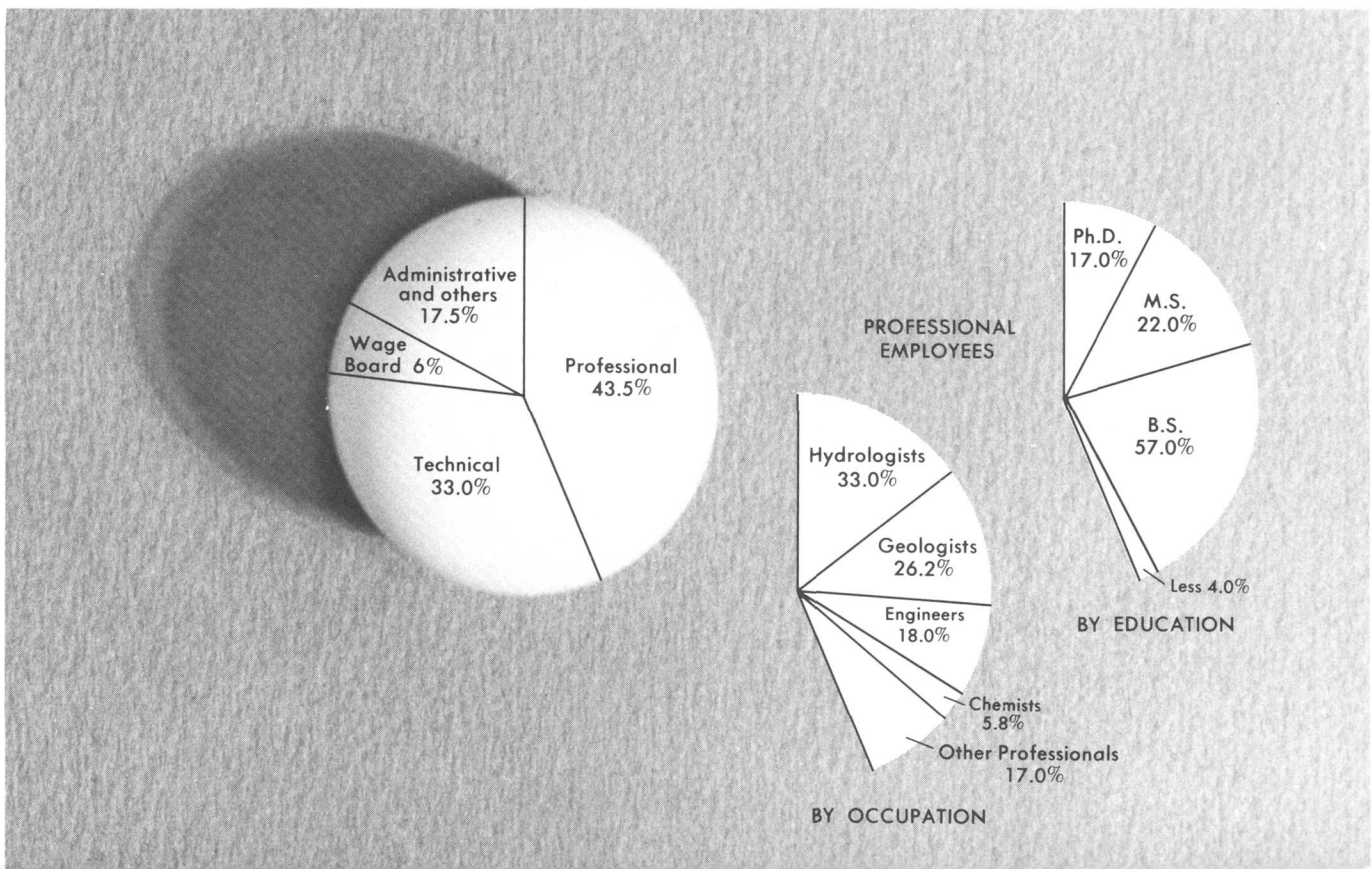
FIGURE 14.—Distribution of permanent full-time employees by organizational unit as of the end of fiscal year 1975.

FIGURE 15.—Geological Survey permanent full-time employees by type.▼



DEFINITIONS

A few of the terms used to describe the budget are defined here, as they will be frequently used throughout the next few chapters. The budget appropriation of the Geological Survey consists of a number of *budget activities* or broad functional areas such as Topographic Surveys and Mapping and Water Resources Investigations. Budget activities are further subdivided into *subactivities, programs,* and *program elements,* depending upon the size and complexity of the activity. However, the term *"program"* may refer to the entire budget, a budget activity, a subactivity, or may denote work supported by funds from a particular source.

Funds to support Geological Survey programs come from two sources: (1) an annual Congressional appropriation and (2) reimbursements from Federal and non-Federal agencies. Federal funds, appropriated by Congress under the title "Surveys, Investigations, and Research" support the Survey's *direct programs* under each budget activity. Other funds from State and local agencies, Federal agencies, permittees and licensees of the Federal Power Commission, foreign countries, and international organizations pay for various information products and services provided by the Survey's *reimbursable programs.*

Whereas direct programs are aimed at resource investigations and research on problems of nationwide concern, the reimbursable programs enable the Survey to expand earth-science support to the specific problems of Federal, State, and local agencies. The results of these investigations contribute in a very substantial way to the solution of urgent national resource problems and directly respond to the changing mutual needs of Federal, State, and local governments for earth-science information. Agencies and organizations with which the Survey had written agreements for fiscal cooperation in fiscal year 1975 are listed in the "Organizational and Statistical Data" section.

Work done for State, county, or municipal agencies may be performed on a cost-sharing basis. The funding arrangements vary depending on the type of investigation. For example, the Survey's annual appropriation bill restricts the use of Federal funds to finance not more than one-half the cost of any topographic mapping or water-resources investigation carried on in cooperation with a State or municipality. Within this general 50-percent limitation, the bill also specifies the dollar amount of Federal funds that shall be available for cooperative water-resources investigations. On the other hand, appropriated funds may be used to pay for more than 50 percent of the cost of cooperative geologic investigations. The activities jointly funded by State and local reimbursable program funds (State share) and direct program funds (Federal share) are collectively referred to as the *Federal-State Cooperative program.* Other work done by the Survey for specific Federal agencies and non-Federal organizations is usually performed on a fully reimbursable basis.

Finally, mention should be made of the use of *current dollars* and *constant dollars* in the various budget tables in this report. Financial resources are one measure of the level of program activity and are often used to show the expansion or contraction of an agency's program over a period of years. To be used in this way, however, the *current dollars* (the dollar amount received in a particular year) must be adjusted to reflect changes in the purchasing power of the dollar. The adjusted dollars, referred to as *constant dollars,* represent the purchasing power of any year's budget in terms of a base year; fiscal year 1967 is the base year in this report. In the absence of an index with which to measure the impact of rising prices on the Survey's activities, the implicit price deflator for the total gross national product has been used to convert *current dollars* to *constant dollars* following the practice of the National Science Board in analyzing trends in research and development funding (National Science Board, 1975).

To carry out its nationwide missions and programs, the Geological Survey has established over 160 offices throughout the United States (see map in "Organizational and Statistical Data" section). The Survey's National Headquarters is located in Reston, Va. Regional research and administrative centers are located at Menlo Park, Calif.; and Denver, Colo.; and Rolla, Mo. A directory of principal Survey offices appears in the section, "Organizational and Statistical Data."

REFERENCE

National Science Board, 1975, Science Indicators 1974, report of the National Science Board 1975: Washington, D.C., Natl. Sci. Found., Natl. Sci. Board, 242 p.

Topographic Surveys and Mapping

OVERVIEW

A basic mission of the Geological Survey is to produce and distribute topographic maps of the United States. While topographic mapping was begun to support the Survey's resource investigations and land-classification activities, many other Federal, State, and local agencies throughout the country have come to depend upon the topographic map for detailed and precisely referenced information about the natural and manmade features on the Earth's surface. Whether the task is coal resource assessment, land reclamation, flood and erosion control, or industrial site selection, there is a common need for accurate and up-to-date cartographic data.

Fiscal year 1975 marked the transition from the National Topographic Mapping Program to the National Mapping Program—no mere change of name. The action was largely the result of recommendations made by the Federal Mapping Task Force after a thorough examination of all Federal domestic mapping and geodesy programs (Office of Management and Budget, 1973). The mapping program has been expanded and strengthened in several important ways:

- Basic cartographic data (such as roads, structures, topography, and watercourses) will be gathered, processed, and distributed in formats tailored to users' specifications in addition to the well-known topographic map series. Cartographic data collected by other agencies may also be incorporated into the program.
- Public access to cartographic data will be simplified through the newly formed National Cartographic Information Center—a clearinghouse for the exchange of information on maps and charts, aerial photographs and satellite imagery, and geodetic data.
- Clearly defined Federal standards for urban mapping and for coastal wetlands mapping will be formulated to meet the need for common mapping methodologies affirmed by the Department of Housing and Urban Development and by States affected by the Coastal Zone Management Act of 1972.
- A digital cartographic base will be produced to aid the construction of computerized, geographic-based information systems by Federal and State agencies. Some of the developmental work on this data base will be a jointly funded interagency effort.

Programs

The National Mapping Program makes graphic or digital cartographic data and services readily available for a multiplicity of uses. Cartographic products include:

- Aerial photographs—low- to high-altitude photographs which provide basic information on the character of the land surface for mapping and other purposes.
- Geodetic data—positions, elevations, and descriptions of control points which are used in the preparation of the map base.
- Standard topographic maps in the 1:24,000, 7.5-minute quadrangle series (or in the 1:62,500, 15-minute quadrangle series until replaced)—the basic map series from which smaller scale and special maps are usually derived.
- Orthophotoquads—rectified aerial photographs in standard quadrangle format and with map information superimposed.
- Smaller scale and special maps—standard series at scales ranging from 1:50,000 to 1:1,000,000 and National Park maps and special products such as slope maps at various scales.
- Digital map data—a numerical representation of the information normally shown on multipurpose topographic maps, to be used in planning and management activities as well as in map production and revision.
- *The National Atlas.*

The National Cartographic Information Center is an important link between the cartographic data and the user. The Center collects and organizes descriptions of the form and whereabouts of data, such as maps and photographs, so that a user need only query the Center to find out what information is available to meet his cartographic needs. Other major repositories of cartographic data, such as the National Oceanic and Atmospheric Administration's National Geodetic Survey Information Center and the Survey's Earth Resources Observation System Data Center, will be linked with the National Cartographic Information Center.

The Survey provides technical assistance and training in surveying and mapping to other countries through an international activities program. The Survey is also a major participant in the U.S. Antarctic

Research Program by administering field mapping programs and supporting ongoing multidisciplinary studies with Doppler satellite observations.

Coordination of mapping with other agencies

Federal surveying and mapping activities are coordinated by the Geological Survey for the Department of the Interior. Following the procedures set forth in the Office of Management and Budget Circular A–16 (Bureau of the Budget, 1967), the Survey annually requests and assists other Federal agencies to identify their mapping requirements. In fiscal year 1975, the Survey received specific mapping requests from 26 Federal agencies and bureaus. A total of 43,519 requests for 27,630 quadrangles were received for 1:24,000-scale mapping: 32 percent of these requests were for new mapping, 48 percent for revision, and the balance for mapping already in progress. At present funding levels, about 1,800 new 7.5-minute quadrangles are started each year, only about 20 percent of the requests for new mapping.

The Survey also receives requests for mapping from State and local governments. State mapping advisory committees in 13 States (Alaska, Colorado, Idaho, Iowa, Maine, Michigan, Minnesota, Montana, Nebraska, Nevada, New Mexico, Texas, and Utah) make requests for cartographic data and in some cases guide the use of State funds to support cooperative mapping programs. Mapping needs of States, counties, and municipalities are also established and met through the medium of cooperative programs with costs being equally shared; there were cooperative programs with 38 States and the Commonwealth of Puerto Rico in fiscal year 1975 (table 31). Requests from private individuals are also considered in setting priorities for the National Mapping Program. In this manner, new areas to be mapped and revised are selected on the basis of demand insofar as practical from the standpoint of mapping operations. The Survey reports back to all concerned agencies once the selections are made and supplies details on the entire mapping program.

In addition to other agencies and individuals, the Geological Survey itself is a principal user of cartographic data, for mapping the location and determining the extent of the Nation's natural resources, for helping develop new sources of energy, and for solving a wide range of environmental problems through various technical assistance programs.

Budget

The Topographic Surveys and Mapping activity comprises three budgetary subactivities (table 5): (1) Quadrangle Mapping and Revision, (2) Small-scale and Special Mapping, and (3) the National Cartographic Information Center. Quadrangle Mapping and Revision is carried out in four regional mapping centers located in Reston, Va., Rolla, Mo., Denver, Colo., and Menlo Park, Calif. Most Small-scale and Special Mapping is the responsibility of a fifth mapping center in Reston. The National Cartographic Information Center is also located in Reston.

Obligations of the Topographic Surveys and Mapping activity in 1975 amounted to $52.6 million, an increase of 20.5 percent over fiscal year 1974 (table 5). Of this total (fig. 16), $5.0 million from 38 States and Puerto Rico was matched by Federal funds, and $2.2 million was from other Federal and non-Federal sources (table 26). Such cooperative mapping projects must benefit the national program to be accepted. Currently the largest cooperative project is a 6-year, $9-million program for complete coverage of Georgia with standard quadrangle maps (either line maps or orthophotomaps) and a variety of special maps—1:100,000-scale, slope, and land use maps—of the Greater Atlanta metropolitan area.

TABLE 5.—*Topographic Surveys and Mapping activity obligations for fiscal year 1975, by program*

Program	Fiscal year 1975 (Dollars in millions)	Percent change relative to fiscal year 1974	
		Current dollars	Constant dollars
TOTAL	$52.60	+20	+9
Direct programs [1]	45.35	+22	+10
Quadrangle Mapping and Revision	41.15	+17	+6
Small-scale and Special Mapping	2.66	+26	+14
National Cartographic Information Center	1.54	New subactivity [2]	
Reimbursable programs	7.25	+11	+1
States, counties, and municipalities	5.00	+1	−9
Miscellaneous non-Federal sources	.59	−8	−17
Other Federal agencies	1.66	+81	+63

[1] Includes $5.00 million to match reimbursable funds from States, counties, and municipalities.
[2] $1.04 million for the Center was included in Quadrangle Mapping and Revision in fiscal year 1974 (table 30).

Though total obligations for the mapping program increased from $28.7 million in 1966 to $52.6 million in 1975 (fig. 10), the increases were largely absorbed by higher operating costs. In fiscal year 1975, additional funds were approved to undertake a national orthophotoquad program and to exploit advances in mapping technology. The growth and decline of the reimbursable funds during this period resulted from the absorption of cost-sharing programs into the National Mapping Program and the replacement of completed basic mapping programs by less costly map revision.

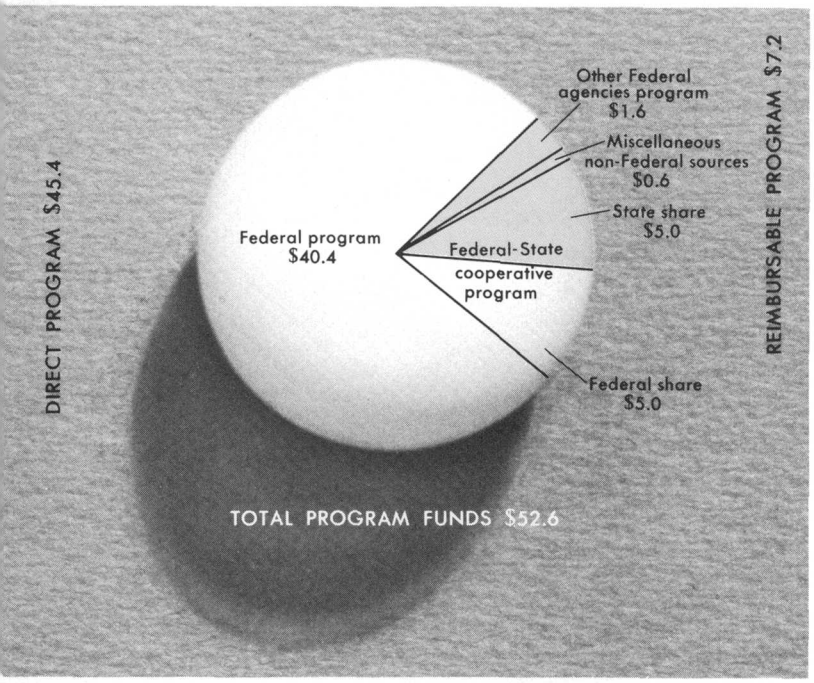


FIGURE 16.—Sources of fiscal year 1975 funds for Topographic Surveys and Mapping (dollars in millions).

Personnel and productivity

In fiscal year 1975, the National Mapping Program was carried out by 1,719 career employees—largely photographic technologists, cartographers, physical scientists, engineers, engravers, computer specialists, and clerical workers (table 44). An additional 158 temporary employees, many on work-study programs, served as aids, technicians, and professional consultants.

Despite decreasing personnel and rising costs, productivity has improved on the average about 6 percent per year (fig. 17). Although operating costs have increased 124 percent since 1966, improvements in the efficiency of operations have kept the actual unit cost of standard quadrangle mapping from increasing more than 34 percent.

Highlights

Noteworthy achievements and events of fiscal year 1975 include:

- *Establishment of the National Mapping Program* to meet the increasing demand for basic cartographic data in all forms.
- *Bureau of Land Management agreement* to provide intermediate-scale base maps of public lands, with priority given to areas of known coal and geothermal energy potential.
- *National Ocean Survey agreement* to coordinate topographic and bathymetric mapping in the coastal zone.
- *Opening of the National Cartographic Information Center* to begin building a central file that will link U.S. repositories of cartographic data.
- *Organization of Mapping Requirements Staff* to analyze nationwide map use on a continuous, full-time basis.
- *Record map production* of about 4,900 new and 923 revised standard maps to meet the goal of covering unmapped areas of the U.S. by 1978 with either standard quadrangles or orthophotoquads.
- *Design of the Digital Cartographic Data Base* to serve as the structure for future map production.

QUADRANGLE MAPPING AND REVISION

Aerial photography

Although taking aerial photographs of areas to be mapped is essential to the mapping process, there is also great demand for aerial photographs for other purposes. In fiscal year 1975, Survey contracts for precision aerial photography covered about 1.22 million square kilometres (473,000 square miles). More than half of the photographs were taken from altitudes higher than 7,900 metres (26,000 feet) for use in orthophotoquad mapping and map revision projects. Virginia and Ohio have cooperative programs with the Survey to obtain high-altitude photographs of their entire States on a 5- and 6-year cycle, respectively, as part of their map revision programs. Several other States are considering similar programs.

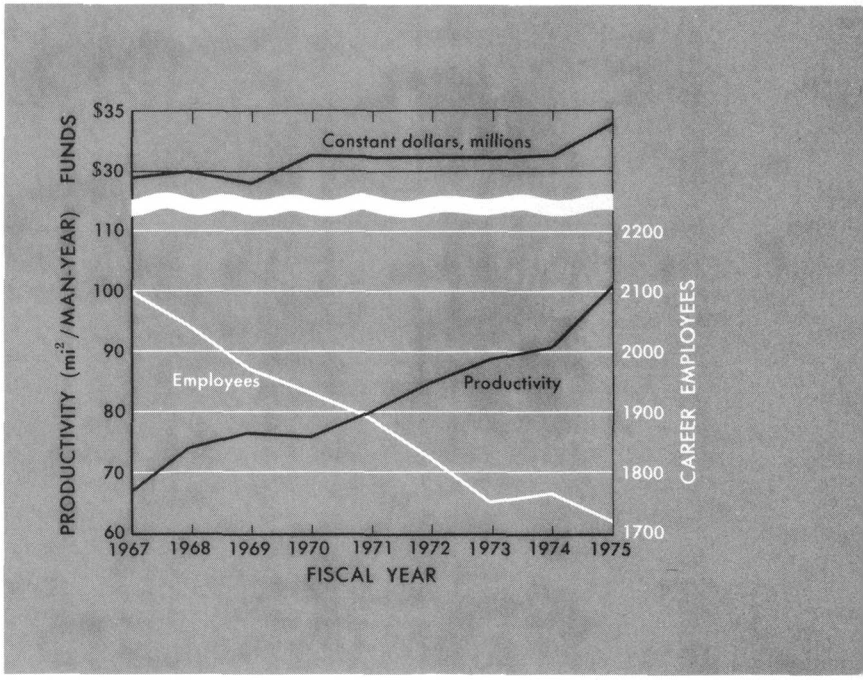


FIGURE 17.—Productivity of 1:24,000-scale mapping, fiscal years 1967–75.

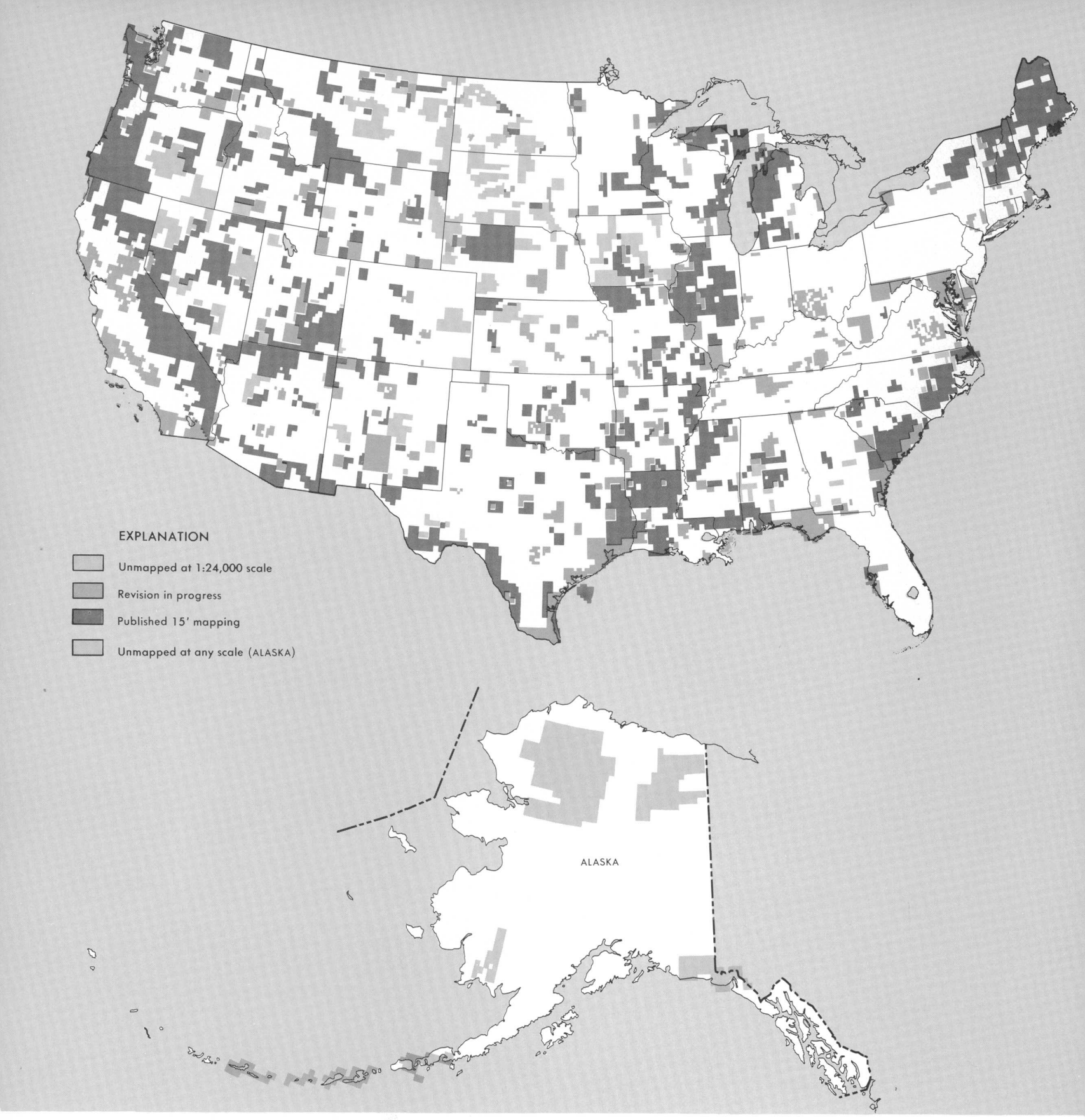


FIGURE 18.—Status of standard topographic mapping and revision.

Standard topographic maps

During 1975, the Survey topographically mapped 277,894 square kilometres (107,295 square miles) at 1:24,000 scale (equivalent to 1,870 quadrangles). As of June 30, 1975, published maps in this series were available for 64 percent of the conterminous States, Hawaii, and outlying areas; published 1:63,360-scale maps were available for 83 percent of Alaska (fig. 18).

Revision mapping

As maps become outdated, revision is necessary to show changes in terrain and manmade features, especially changes associated with the development of metropolitan areas and expansion of their suburbs. During fiscal year 1975, 1,569 7.5-minute quadrangles were checked against current photographs, and 1,044 maps were found to need revision.

More than 900 1:24,000-scale maps were revised in 1975 (table 46). The majority of these maps were updated from new aerial photographs and without a field check. Generally, photorevised maps can be produced within a year by overprinting revisions in purple on the original map. If more extensive revision is warranted, the changes are field verified, and occasionally a completely new map must be prepared.

During the year, about 1,280 quadrangle maps were reprinted to replenish shelf stocks of published maps. Nearly 10 million copies of maps were distributed.

Orthophotoquads

The Survey has introduced a new series of photomaps which can be produced quickly, economically, and accurately. The standard 1:24,000 orthophotoquad consists of a nearly distortion-free, black-and-white aerial photograph in 7.5-minute-quadrangle format with a geographic grid and a few place names added. Orthophotoquads are in demand as interim maps for unmapped areas or as up-to-date companions to published line maps. The imagery provides a wealth of detail that cannot be portrayed on a conventional line map (fig. 19).

The objective of the program is to produce orthophotoquads for all areas of the conterminous United States presently unmapped at 1:24,000 scale by 1978. In fiscal year 1975, the Survey produced 2,869 orthophotoquads (fig. 20 and table 46).

Orthophotomaps

An image-enhanced version of the topographic map is called an orthophotomap. To date, 291 orthophotomaps have been produced for areas of the United States where conventional line maps cannot adequately portray relatively featureless terrain. The orthophotomap represents approximately the same production effort and cost as the line map, but the colored imagery accentuates such detail as types of vegetation, marshland limits, and the physical character of prominent geologic features. During fiscal year 1975, 66 orthophotomaps were published; about 300 are in various stages of production.

SMALL-SCALE AND SPECIAL MAPPING

Intermediate-scale maps

The new intermediate-scale mapping series includes base maps at scales of 1:50,000 in county format and 1:100,000 in quadrangle, county, or regional format. These maps are normally derivative products of standard 1:24,000 maps. The 1:100,000 30×60-minute series will be in metric units.

Intermediate-scale mapping is designed to provide, in either graphic or digital form, basic map data at various levels of detail and scales, and will enable Federal, State, regional, county, and other map users to select the combinations of content, scale, and format that will best suit their general or special needs.

During fiscal year 1975, the Geological Survey and Federal and State agencies developed technical specifications for these maps. In this developmental process, two 1:100,000 maps in 30×60-minute format and seven 1:50,000 county maps were produced. Intermediate-scale mapping scheduled for fiscal year 1976 includes 134 1:100,000 quadrangle base maps for the Bureau of Land Management, 116 1:100,000 county maps for the Soil Conservation Service, and 39 1:100,000 quadrangle maps and 68 1:50,000 county maps for State cooperators (fig. 21).

1:250,000-scale topographic maps

The conterminous States and Hawaii are completely covered by 473 topographic maps at 1:250,000 scale. Alaska is covered by 153 maps of which 141 are topographic maps and 12 are older reconnaissance maps. During fiscal year 1975, 52 maps in this series were revised (fig. 22 and table 46).

The 1:250,000-scale maps are used by the Survey as a base for the preparation of the State base map series, the International Map of the World series, various geologic maps, and special-purpose maps such as those produced for the Land Use Data and Analysis program. The series has also been designated by the Board on Geographic Names as the standard reference for geographic nomenclature in Government publications. Elevation data, digitized from the contours on the 1:250,000-scale maps, are available on magnetic tape from the National Cartographic Information Center (fig. 22).

The Geological Survey and the National Oceanic and Atmospheric Administration have agreed on a program to produce topographic-bathymetric editions of the 1:250,000-scale maps for the coastal zones of the conterminous States (including the Great Lakes), Hawaii, and Alaska. The Beaufort, N.C., quadrangle is the first topographic-bathymetric map published in this program, and five more joint editions are in production.

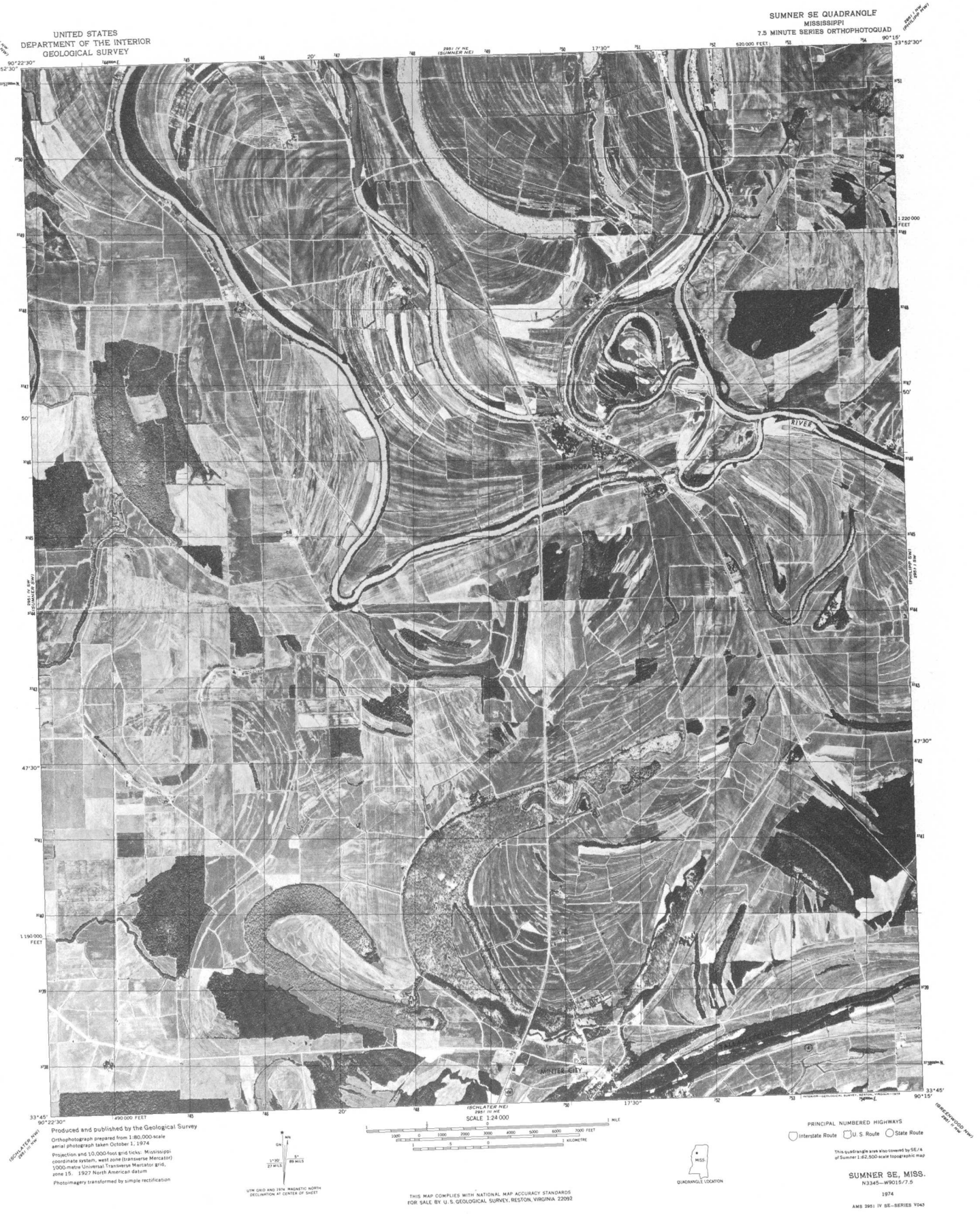


FIGURE 19.—Standard orthophotoquad: Sumner SE, Miss. (Original scale is 1:24,000.)

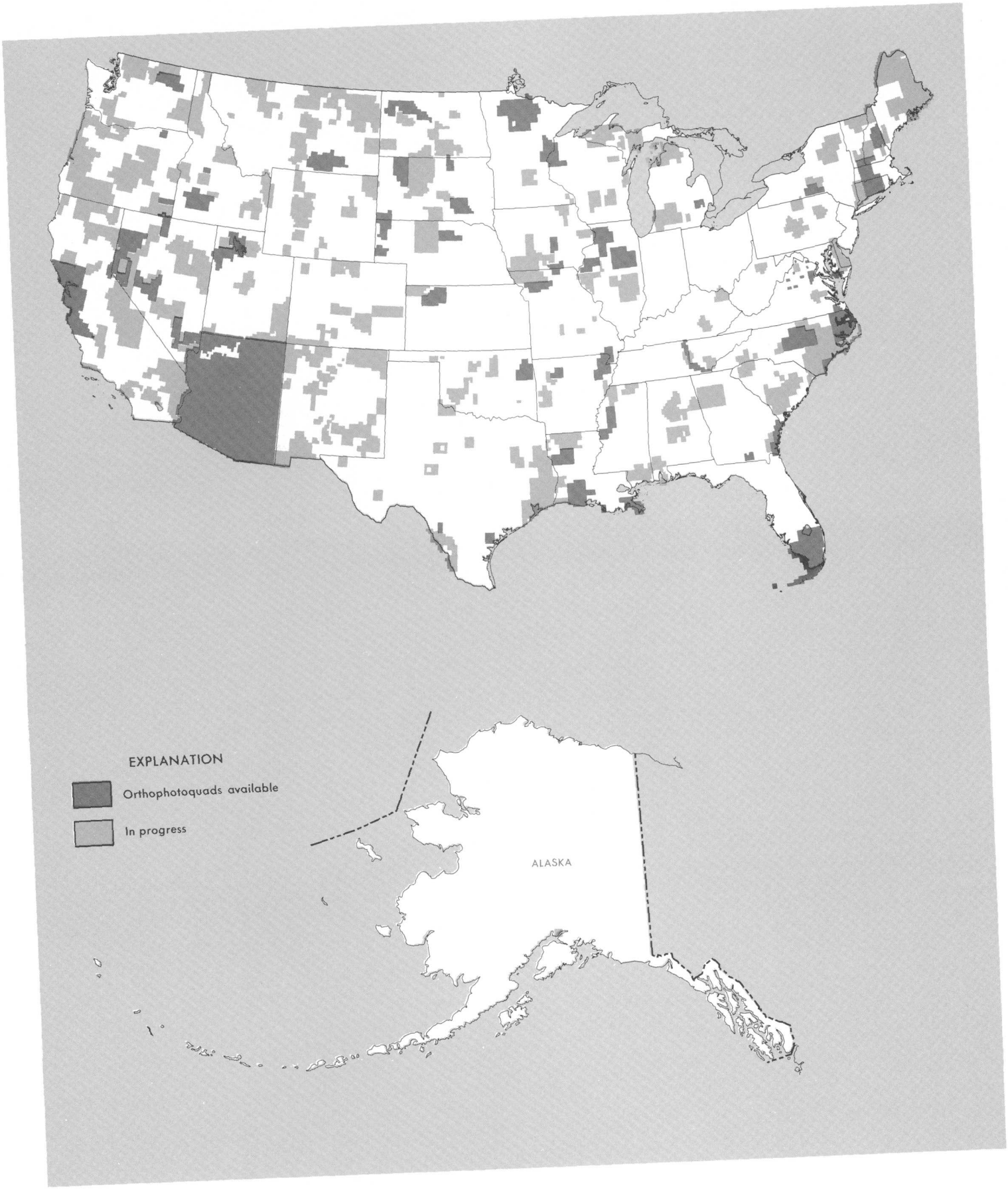


FIGURE 20.—Status of orthophotoquad production.

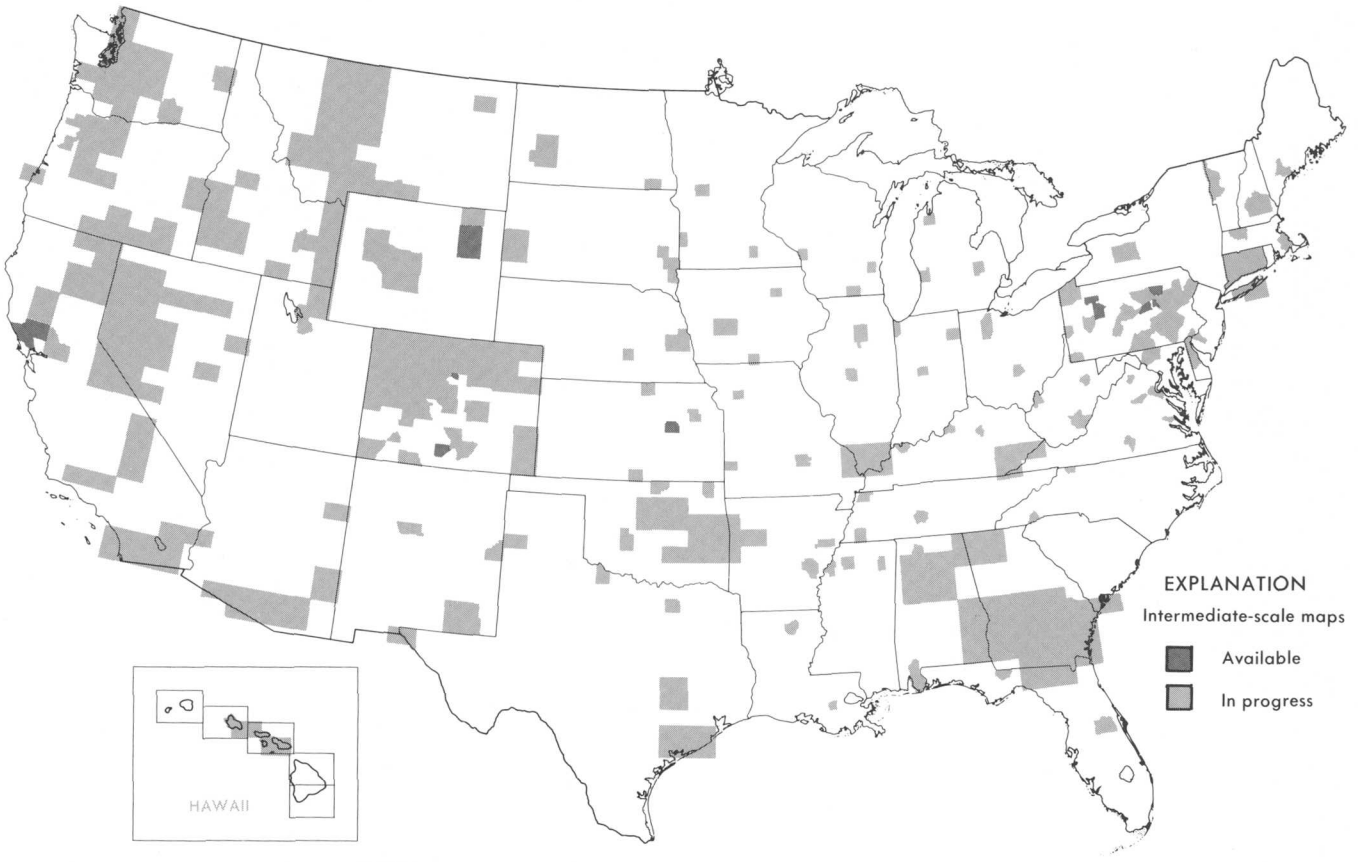


FIGURE 21.—Status of the Intermediate-scale Mapping program.

Other products

The Survey also produces:

- State base maps—planimetric, topographic, and shaded-relief editions available at a scale of 1:500,000 for all States except Alaska, for which base maps are available at scales from 1:1,584,000 to 1:12,000,000.
- International Map of the World series—part of an international program to attain worldwide coverage with maps at a scale of 1:1,000,000.
- National park maps—topographic maps combined into one or more sheets covering the area of the park; seven were published in fiscal year 1975.
- Slope maps—the result of transforming contour lines into slope zones; applications include land use and soil studies and construction planning.
- Special maps—such as the map of the 50 States in correct proportion, position, and relationship to each other; available at 1:6,000,000 and 1:10,000,000.
- *National Atlas*—first edition published in 1971; plans for a second edition are currently under study.

International mapping

The Geological Survey, supported by funds from the Agency for International Development, the United Nations, International Development Association, and the Government of Saudi Arabia, provides technical assistance on mapping programs in the host countries and on-the-job training to visiting scientists and technicians. During fiscal year 1975, the Survey assisted:

- *Indonesia,* by evaluating mapping capabilities and making recommendations for the new National Institute of Mapping.
- *Yemen,* by preparing 11 orthophotobase manuscripts to support an agricultural development project in the Tihāmah region.
- *Saudi Arabia,* by continuing to assist the Ministry of Petroleum and Mineral Resources and compiling maps for geologic investigations.
- *Mexico,* by continuing liaison with the Comisión de Estudios del Territorio Nacional for the exchange of cartographic data of the United States-Mexico border area.
- *Turkey,* by training cartographers in shaded-relief and other specialized scribing techniques.

The Survey also conducts Antarctic field mapping operations and provides other cartographic support for the U.S. Antarctic Research Program, administered and funded by the Office of Polar Programs of the National Science Foundation. Survey personnel winter over in Antarctica each year to make Doppler satellite observations that support the study of ice movement, scintillation, and polar motion, and to operate seismological equipment for the Survey's Earthquake Hazards program. The Survey publishes a variety of maps of

Antarctica—1:250,000 topographic maps, 1:500,000 sketch maps, and small-scale satellite image maps (fig. 23).

NATIONAL CARTOGRAPHIC INFORMATION CENTER

Established in July 1974, the National Cartographic Information Center provides a focal point for information on U.S. maps and charts, aerial photographs and space imagery, geodetic control, and related cartographic data. The Center serves the user of cartographic data in three ways:

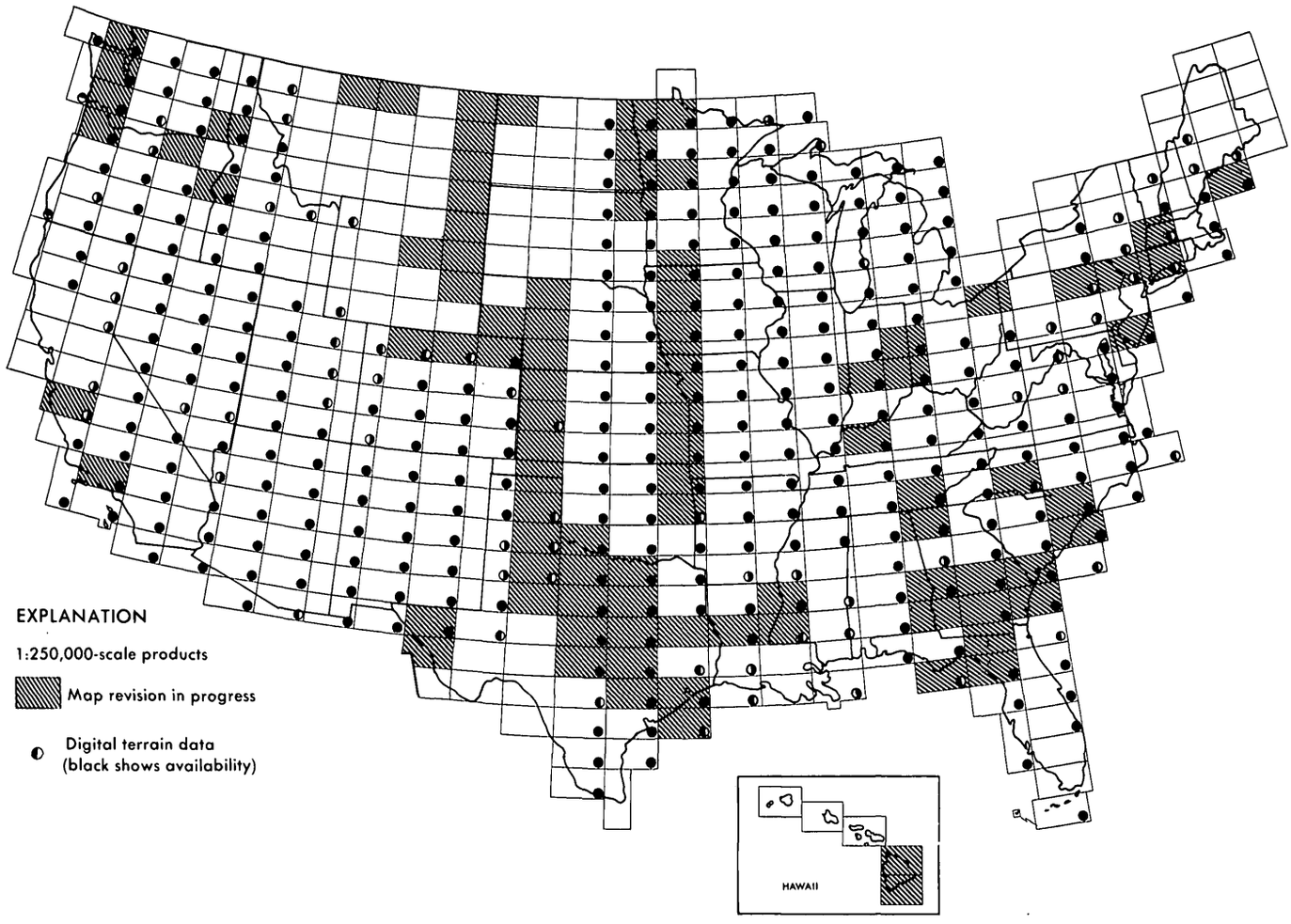
- Furnishes information on cartographic data available from Federal, State, and private organizations.
- Furnishes information on the data-collection plans of these organizations.
- Processes orders for cartographic data.

The Center does not duplicate the cartographic holdings of other agencies but collects and organizes information describing their form and location in such major repositories as the Library of Congress, the National Ocean Survey, the Department of Agriculture, and the Earth Resources Observation System Data Center. In fiscal year 1975, the Center's staff began to negotiate interagency agreements, develop information systems, and acquire information on Federal holdings of aerial photographs.

Representatives from 27 Federal organizations and 4 professional societies met in August 1974 at the invitation of the National Cartographic Information Center to discuss the coordination of the collection and distribution of cartographic data and ways in which to carry out the Center's mission. Formal management agreements were reached by the end of fiscal year 1975 with the Agricultural Stabilization and Conservation Service and the Soil Conservation Service to acquire information on their aerial photographs and soils maps and with the National Oceanic and Atmospheric Administration concerning geodetic control data.

During the year, the Defense Mapping Agency Topographic Center also began transferring digital terrain data of the conterminous States to the Center for distribution. Magnetic tapes contain a grid of elevations interpolated from the 1:250,000-scale topographic maps and are useful in computer analyses of difficult terrain and land-management problems.

FIGURE 22.—Status of 1:250,000-scale map revision and digital terrain data.



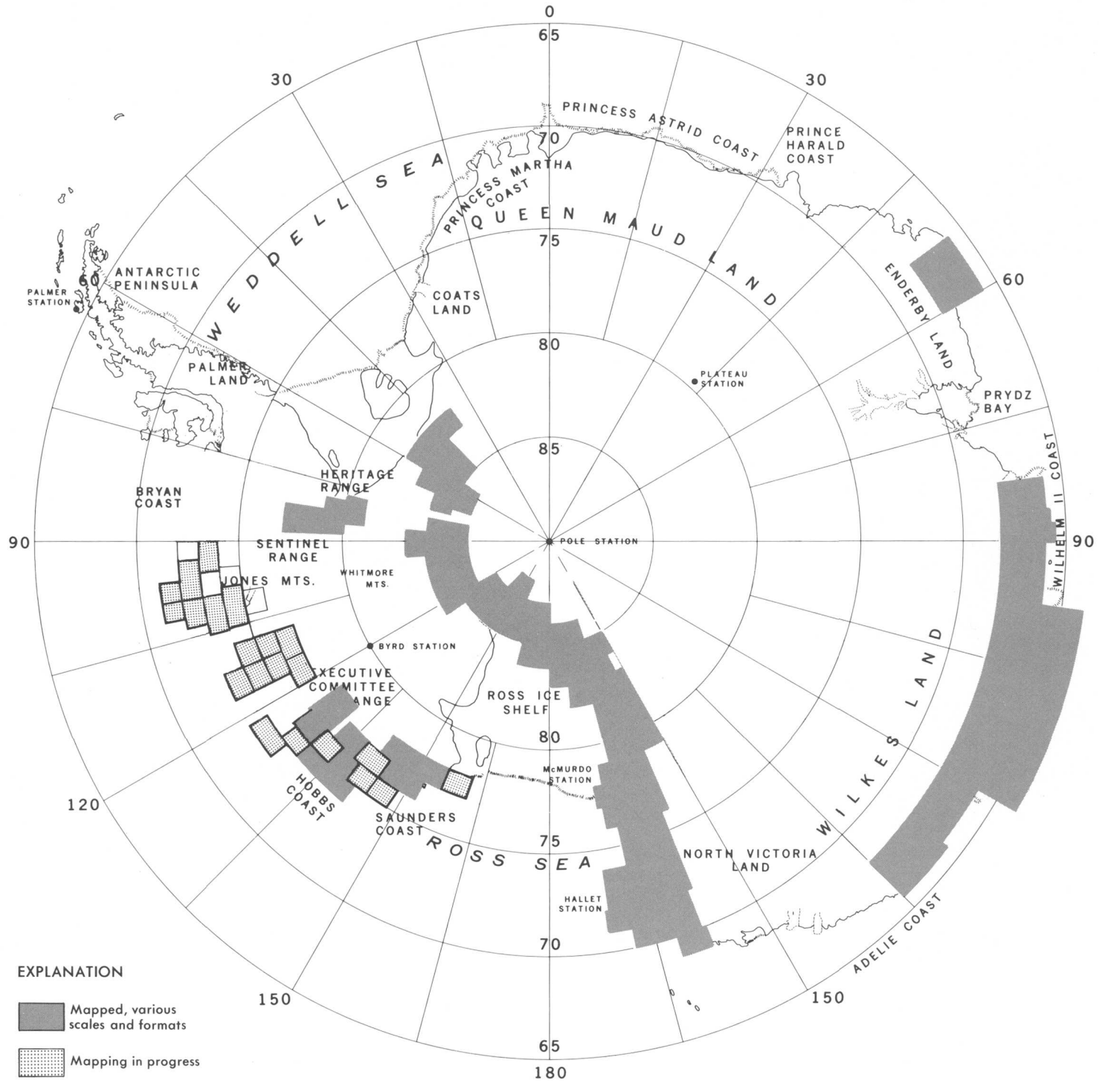


FIGURE 23.—Status of mapping in Antarctica.

The Center began developing computer information systems for cartographic data. In this period, the design of an aerial photography information system was completed; the data base contains information on the coverage and general characteristics of available collections and on plans for the acquisition of photographs. Participating agencies provide the Center with the essential data in digital form for direct input to the system. To date, the system has information on the photo collections and mapping plans of the Survey, the National Aeronautics and Space Administration, and the Defense Mapping Agency. Other Federal agencies will be involved in building this data base, as will State and private organizations.

The demand for out-of-print Survey maps and need for a more compact and convenient research file led the Center to build a microfilm map file. About 20,000 of the 100,000 current and historic topographic maps have been microfilmed on 35-mm black-and-white film to complete a New England and Mid-Atlantic States file; all maps are expected to be microfilmed by the end of 1976.

RESEARCH AND DEVELOPMENT

A primary objective of Survey cartographic research is to automate and link together as many of the mapping phases as possible. Automatic data-processing equipment is an integral part of the mapping system —automatic data acquisition, analytical aerotriangulation, computation and adjustment of geodetic control data, and automatic plotting. The Survey's library of computer programs for geodesy, photogrammetry, and cartography represents a major developmental effort and a valuable tool available to the mapping community.

Mapping systems

In the last decade, the trend in mapping techniques has been towards greater precision and speed. The mechanical and optical techniques of 1965 have given way to the computerized, digital, remote sensor, space technology techniques of 1975. The Survey's effort to advance mapping instrumentation and technology concentrates on improving productivity and the quality and diversity of cartographic products by replacing obsolete mapping equipment, procuring high-resolution orthophoto instrumentation also capable of producing digital terrain data, obtaining the hardware and software to extract digital information from stereoimages and available graphics, and developing automatic theme extraction techniques (U.S. Geological Survey, 1975). Examples of systems examined during fiscal year 1975 are described below:

- *Inertial navigation systems* were investigated for possible application as map-control surveying instruments. The Position and Azimuth Determining System, developed by the U.S. Army Engineer Topographic Laboratories, is an inertial platform mounted on a Jeep; field trials showed that map-control accuracies can be met over a distance of several kilometres, but elevation accuracy is marginal. In December 1974, the Survey and the Bureau of Land Management tested the Auto-Surveyor, a civilian helicopter-borne version of the military system. Preliminary analyses of the test data indicate an acceptable average accuracy of ±0.6 metres (2 feet) in latitude, longitude, and elevation over a 38-kilometre (24-mile) course on flat terrain. In this field test, data were obtained in 30 minutes which would normally take a field party 2 days to collect.
- The engineering analysis of the *Aerial Profiling of Terrain System* was completed by the Charles Stark Draper Laboratory (Cambridge, Mass.) under contract to the Survey. This inertial navigation system is being developed as a means of providing ground profiles and cross sections by measurement from an aircraft. When the system is applied to map-control surveys, substantial savings of field time may be realized.
- The Survey acquired *new orthophoto instrumentation* that produces higher quality orthophotos; digital coordinate data precisely control the exposure of the film to produce an accurate and esthetically pleasing orthophoto (fig. 19). In addition, a digital orthophoto system was designed that will produce digital profile data from a stereoimage, store the data on magnetic tape, and use the data off line to control the photographic unit that produces the orthophoto; construction started on prototypes of the three subsystems.
- *Analytical plotters and associated techniques* developed by the Department of Defense were adapted to standard topographic mapping in an effort to increase mapping capability and reduce production time.

Product research

Cartographic products will be tailored to the user's needs; however, an equally important objective is to promote simplicity and economy in the design and reproduction of future products, both analog and digital. For ease in digitizing and flexibility in format, data will be separated by color and by map feature.

Navajo Cartographic Facility

The ultimate in flexibility is the digital map for which most map parameters may be specified by the user before the map is automatically plotted.

During the year, considerable progress was made toward these objectives:

- *Experimental maps have been produced* that incorporate a metric format, computer-compatible symbology, feature-separation flexibility, and economy in printing. Specifications for the new intermediate-scale maps are being drawn from this research.
- Maps reproduced by *standard color printing on scale-stable clear plastic* resulted in good transparency and register. Such color printings are being considered for thematic overlays displaying land use and terrain slope.
- To *optimize use of the new Survey 5-color press,* experiments were conducted in combining map colors for printing 6-color interim-revision maps in a single press run. The 5-color scheme could save from $65 to $245 per quadrangle in printing preparation costs and could reduce printing time 2.5 times.
- *Research in analog approaches to slope mapping* resulted in the development of photomechanical techniques and equipment for semiautomatically deriving slope zones from map contours. A patent is pending for the Survey's orbital-lens slope mapping device.
- A research contract for the production of *maps for the visually handicapped* was awarded to the University of Washington. The maps will cover the Capitol Mall area in the District of Columbia and will be ready for the Bicentennial.
- The core of future cartographic production will be the *Digital Cartographic Data Base.* A data-base structure was proposed and is being evaluated that would enable users to interactively extract data from the base and produce the desired graphic, whether a television image or hard copy. In some applications, the map may not be displayed but will serve as a computer model for conducting analyses.

Automated cartography

In recent years, great strides have been made in the field of automated cartography, both in the development of hardware and software. The Survey is investigating possible applications of: (1) digital data-collection systems, from hand-operated digitizers to computer-controlled line followers; (2) interactive systems for identifying and correcting data errors; (3) output systems, especially precision automated drafting systems such as the Gerber 1232 [1] purchased by the Survey (fig. 24); and (4) cartographic software packages which offer the user an impressive array of programs.

Orthophoto applications

The widespread acceptance of the Survey's orthophoto products is reflected in their applications to forest management, soil surveys, geological studies, land use inventories, urban mapping, and coastal wetlands management. Continued orthophoto product refinement represents a major research and development effort utilizing several new technologies. A special laboratory was designed to support image technology research, and construction is scheduled to begin in 1976.

Developments in orthophotomapping during the year included:

- *Improved image quality*—Orthophotomapping projects are now subject to stringent quality controls in every phase of production, from aerial photography through generation of the orthophoto negative to lithographic printing. Masking techniques were used to alleviate the problem of scan lines showing on orthophotos, and the Survey's orthophotoscopes were modified to improve conditions during exposure of the film.
- *Large-scale urban mapping*—Four urban areas—Fort Wayne, Ind., Charleston, S.C., San Francisco, Calif., and Frederick, Md.—were mapped by contractors at large scale to determine what type of orthophoto product would be most useful to urban

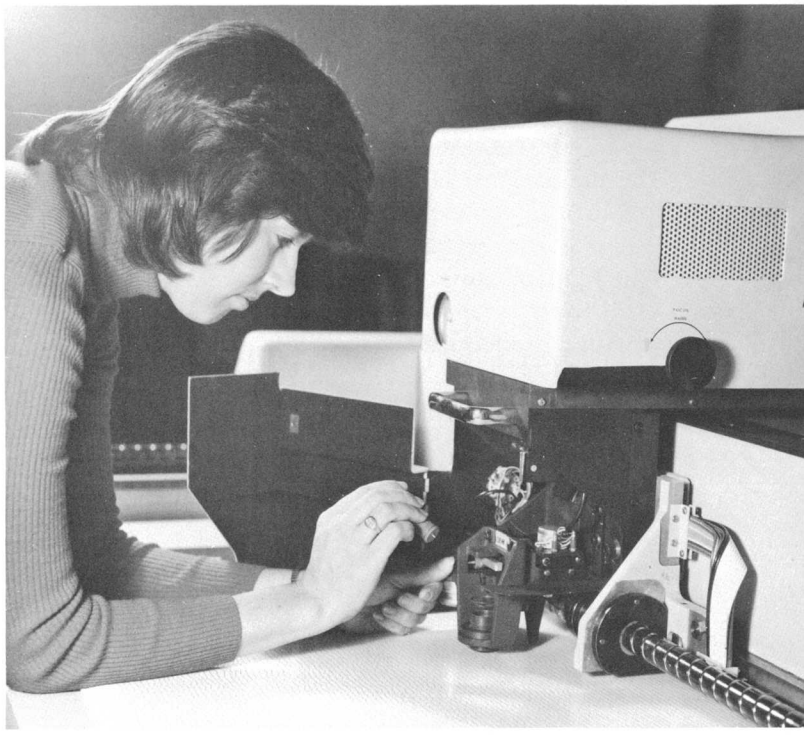


FIGURE 24.—Automated drafting system.

[1] The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

decisionmakers and to develop standards for urban mapping. To date the maps have been used by the cities to derive line maps and to digitize land use information.

- *Wetlands mapping*—The Survey prepared six 1:10,000-scale orthophotoquads of Sapelo Island, Ga., as a first step in an effort to formulate and recommend a coastal mapping policy for coastal States. At this experimental scale, major plant species could be delineated from color infrared photographs, but considerable field checking was required.

Cartographic applications of satellite imagery

With Landsat–1 and Landsat–2 in orbit and Landsat–C scheduled for launch in late 1977, mapmakers have a new source of data from which to produce small-scale image maps. Experiments have shown that several cartographic applications (Williams and Carter, 1976) are feasible from Landsat-type imagery:

- *Photomapping* at 1:250,000 and smaller scales.
- *Aeronautical charting*—line-chart revision of gross features or as an image base.
- *Mapping shallow-water areas.*
- *Extending geodetic positions* from mapped into unmapped areas.
- *Mapping selected features,* such as water areas, infrared-reflective vegetation, snow and ice, massed works of man, and spatial changes in these over time.
- *Mapping Antarctica*—revising small-scale maps, detecting and monitoring gross changes in coastal glaciological features, and discovering geographic features.

Future investigations will concentrate on the development of a variety of Landsat cartographic products and applications of various scales, waveband treatments, formats, and processing techniques in conjunction with the Earth Resources Observation System program. The continuing development and improvement of sensor and spacecraft technologies point the way toward automated mapping of the Earth.

FUTURE PROGRAM OPPORTUNITIES

New demands and uses are not only forcing a reshaping of the mapping program but suggest a redefinition of mapping. Historically, mapping activities have been directed almost exclusively to the production of maps. Today, the data gathered about the Earth's surface are analyzed and distributed in many ways, some bearing little resemblance to what has been customarily known as mapping.

The nature and scope of Federal mapping will be fundamentally affected by the actions of the Government during the next few years:

- Since gathering and processing the data are major costs in mapping and require advanced programs and technologies, the responsibilities and systems for gathering data need to be carefully planned and integrated to avoid costly duplication of programs and systems. For example, nearly every Government agency collecting cartographic data is now in the process of developing at least one digital map- or image-processing system.
- The rapid rate at which our world is changing has increased the demand for cartographic data that are accurate and current and that meet the user's format requirements. This means that more flexible and economical mapping methods need to be devised that will make the data available more quickly. Additionally, data distribution systems need to be coordinated to realize the full value of the data.
- Advances in computer technology over the past decade have made many new applications of cartographic data technically feasible, such as projecting the advance of forest fires, conducting resource inventories, predicting the effects of floods and pollution, or automating aerial-navigation warning systems. Digital cartographic data need to be structured to anticipate applications beyond mapping; this means future user requirements need to be identified as quickly as possible.

The key problem of the future is how to collect, store, and retrieve land use and resource data in a way that is accurate and understandable and within the price range of planners and decisionmakers.

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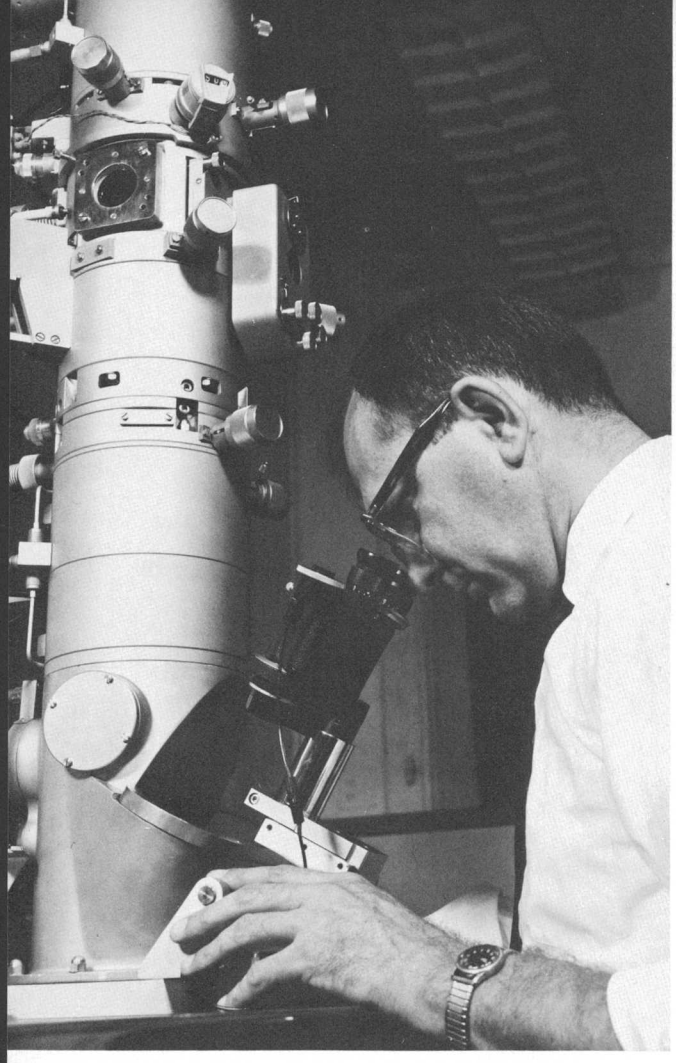
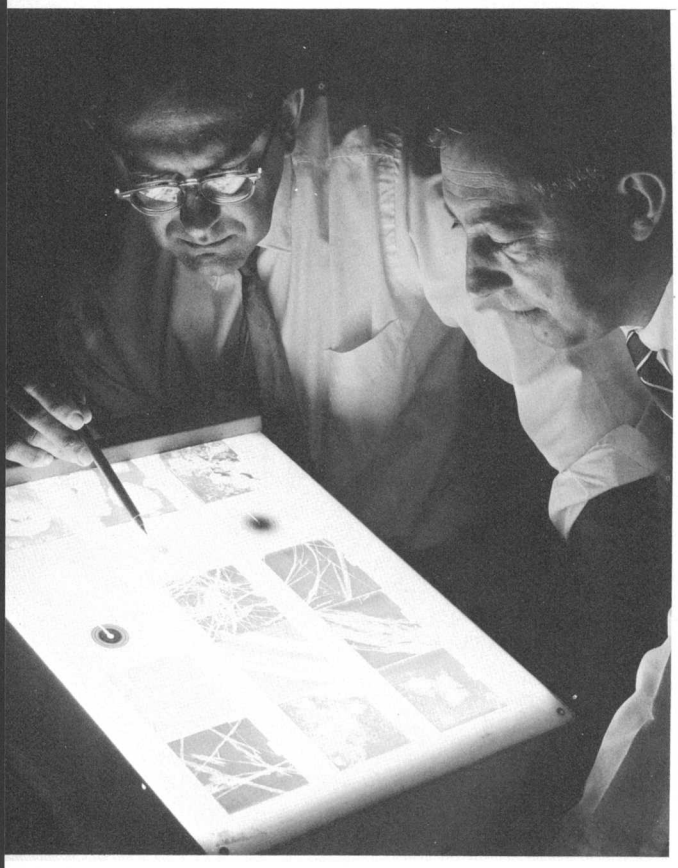




Clockwise from lower right: Geologist measures the attitude of a rock outcrop; scientists examine electron micrographs of mineral grains; a valuable research tool is the electron microscope which can magnify particles up to 120,000 times; Mt. Rainier, Washington; RV *Don J. Miller* supports mineral assessment work in Alaska.

Geologic and Mineral Resource Surveys and Mapping

OVERVIEW

Geologic processes and events that led to the composition and structure of the Earth affect every facet of our lives in one way or another by controlling the distribution and amount of energy, mineral, and land resources needed to support modern societies. Improving our understanding of the Earth, its composition, its structure, and the geologic processes that effect it, can lead to wiser, more intelligent use of our Nation's natural resources.

The basic mission of the Geologic and Mineral Resource Surveys and Mapping activity, under the direction of the Geologic Division, is to provide geologic, geochemical and geophysical information for other Governmental agencies and for the general public on land resources, on mineral and energy resources, and on geologic hazards of the Nation and its territories. The activity is divided into four subactivities: Land Resource Surveys, Mineral Resource Surveys, Energy Resource Surveys, and Offshore Geologic Surveys.

Land Resource Surveys provide the basic interpretive geological, geophysical, and geochemical maps and data that support the resource and mission-oriented activities of the Geological Survey. Other programs of this subactivity aim at identifying the effects of geologic hazards, including earthquake and volcanic hazards, the environmental aspects of developing energy resources, and investigations of the geologic processes and historical events that led to the present physical and chemical composition and structure of the Earth.

Mineral Resource Surveys provide knowledge of the availability of metallic and nonmetallic mineral resources by studying the geology of known mineral occurrences and potentially mineralized areas, developing and improving exploration techniques, and assessing the Nation's mineral resources. Mineral resource assessment work responds to the requirements of legislative actions such as the Survey's Organic Act (1879), the Strategic Raw Materials Act (1938), the Wilderness Act (1964), the Mining and Minerals Policy Act (1970), and the Alaska Native Claims Settlement Act (1971).

Energy Resources Surveys update our knowledge of the location, quantity, and quality of the Nation's energy resources through resource studies of coal, oil and gas, oil-shale, uranium and thorium, and geothermal energy.

Offshore Geologic Surveys assess the potential mineral resources on the continental margins of the United States and determine the nature of geological environmental hazards related to offshore siting of energy facilities.

Two programs—International Activities and Astrogeology—are supported primarily by outside funds and are not included within the four budget subactivities. The International Activities program provides technical assistance to other countries utilizing funds provided by other Governments or international organizations through the Department of State. The Astrogeology program, established on behalf of National Aeronautics and Space Administration, provides geological research in support of space exploration.

In addition to the Geologic and Mineral Resources Surveys and Mapping activity, this chapter also describes the Alaska Pipeline Related Investigations activity. The Alaska Pipeline Related Investigations activity monitors the construction of the Trans-Alaskan Pipeline from Prudhoe Bay to Valdez, Alaska. The hydrologic, geologic, and topographic data collected by the Survey's Water Resources, Geologic, and Topographic Divisions are used by the Alaska Pipeline Office of the Department of the Interior to establish engineering design criteria and to assure that the pipeline contractor conforms to the technical and environmental stipulations of the construction permits.

Budget and personnel

In fiscal year 1975, obligations of the Geologic and Mineral Resources Mapping and Surveys activity were $114.5 million (table 6), an increase of 56 percent over 1974. About $1.5 million came from 20 States and the Virgin Islands and $24 million came from other Federal and non-Federal sources (fig. 25 and table 26). The largest cooperative project was with the State of Kentucky for quadrangle geologic mapping at a scale of 1:24,000. Although budget obligations increased from $33.1 million in 1966 to $51.5 million in 1972 (fig. 10), the increase was largely absorbed by higher operating costs. Since fiscal year 1973, however, the

TABLE 6.—*Geologic and Mineral Resource Surveys and Mapping activity and Alaska Pipeline Related Investigations activity obligations for fiscal year 1975, by programs*

[Figures may not add to totals because of rounding]

Program	Fiscal year 1975 (dollars in millions)	Percent change relative to fiscal year 1974	
		Current dollars	Constant dollars
Total	$114.48	+56	+40
Direct programs	89.02	+79	+61
Land Resource Surveys	33.38	+45	+30
Earthquake Hazards	10.97	+21	+9
Volcano Hazards	.64	+2	−8
Environmental Aspects of Energy	5.35	New program	
Arctic Environmental Studies	.40	New program	
Engineering Geology	1.26	+5	−6
Regional Mapping and Analysis	14.76	+21	+9
Geologic Mapping Geophysical Surveys Geochemical Surveys	9.34	+24	+12
Dating and Correlation	4.32	+20	+8
Geologic Processes	1.10	+7	−3
Mineral Resource Surveys	18.02	+20	+8
Mineral Resource Appraisal	7.77	+40	+26
Wilderness Mineral Resource Appraisal	1.24	+13	+2
Alaska Mineral Resources Appraisal	2.52	+130	+108
Geologic and Geophysical Appraisal Mapping	1.67	+3	−7
Commodity programs:			
Critical Mineral Commodities	1.50	+10	−1
Minerals for Energy	.59	New program	
Minerals Discovery Loan program	.25	−24	−31
Resource Analysis and Information Systems	.96	−6	−16
Geology of Mineral Occurrence	5.14	+6	−5
Appraisal-Exploration Technology	4.14	+16	+5
Energy Resources Surveys	22.38	+234	+202
Coal	1.64	+45	+31
Oil and Gas	4.93	+285	+247
Oil Shale	1.19	+174	+147
Uranium and Thorium	4.23	+254	+220
Geothermal Energy	9.06	+240	+207
Energy Resource Data	1.33	New program	
Offshore Geologic Surveys	15.24	+197	+168
Oil and Gas Resources Appraisal	10.07	+160	+135
Environmental Investigations	3.93	New program	
Marine Geology	1.24	−2	−12
Reimbursable programs	25.46	+8	−3
States, counties, and municipalities	1.55	−8	−17
Miscellaneous non-Federal sources	3.75	+40	+26
Other Federal agencies	20.16	+4	−6
Alaska Pipeline Related Investigations[1]	.34	−61	−65

[1] Not included in totals.

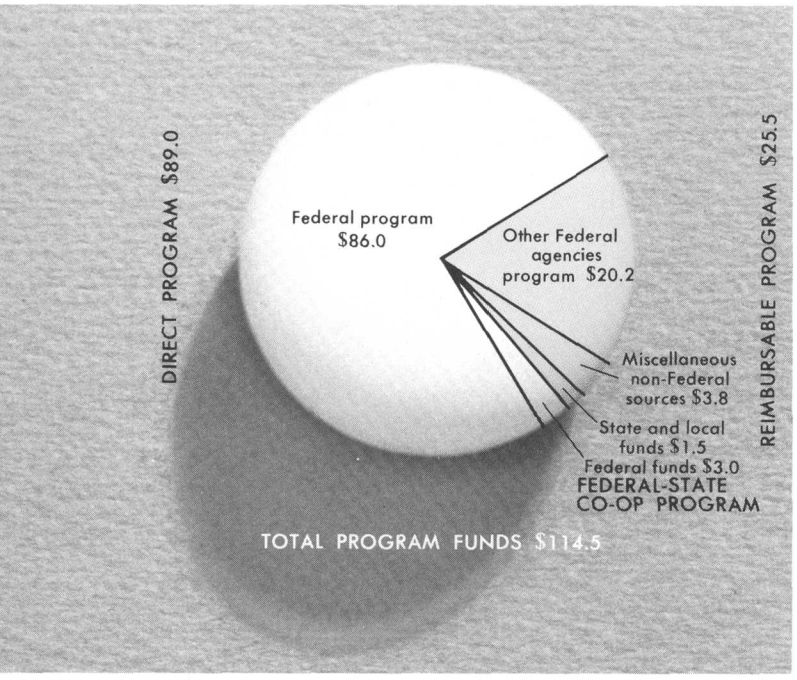


FIGURE 25.—Sources of fiscal year 1975 funds for Geologic and Mineral Resource Surveys and Mapping (dollars in millions).

activity's budget has been doubled by substantial increases in Energy Resource Surveys, Offshore Geologic Surveys, and the Earthquake Hazards and Environmental Aspects of Energy programs of Land Resources Surveys (table 33), together with large increases in support from other Federal agencies.

At the end of fiscal year 1975 the Geologic Division had 2,135 permanent fulltime employees, an increase of 13.1 percent over 1974. In addition 437 temporary employees served as scientific aides, laboratory technicians, and field assistants.

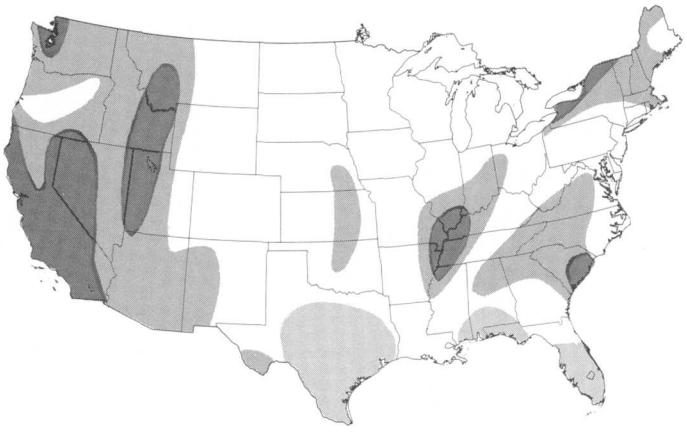
Highlights

Major highlights of 1975 included the following events and developments:

- *The Thanksgiving Day, 1974, earthquake near Hollister, Calif., was anticipated* from a variety of precursory geophysical signals. These and other observations indicate there is a possibility that some earthquakes can be predicted.
- The *July 5–6, 1975, eruption of the Hawaiian volcano Mauna Loa was predicted* from measurements of the volcano's inflation.
- *Mount Baker, Wash., was monitored* because increased thermal emissions accelerate the melting of snow and ice which could cause massive landslides.
- *Regional and detailed geologic mapping of 145,000 square kilometres (55,970 square miles) was accomplished* to support land, mineral, and energy resource assessments.
- *A new method of dating rocks 35,000 to a million years old was developed,* based on certain changes in the amino acids in fossil mollusks.
- *Environmental impact statements were prepared* for the Alaska Trans-Arctic pipeline, potassium mining in New Mexico, coal mining in Montana, Wyoming, and Colorado, phosphate mining in Idaho, copper-nickel mining in Minnesota, and recreational development in the Glen Canyon National Recreation Area, Utah.
- *Geologic studies of 11 Wilderness areas* found that portions of 5 areas contained significant mineral resources.
- *Resource appraisals in Alaska identified copper, molybdenum, gold, silver, chromium, and tin* as potential mineral occurrences.
- *Aeromagnetic mapping of 116,550 square kilometres (45,000 square miles) was completed* in parts of Alabama, Georgia, Maryland, New Mexico, New York, North Carolina, South Carolina, Washington, and West Virginia. These maps show the distribution of rocks potentially related to mineral deposits.
- *New geochemical methods were developed* to locate buried sulfur-rich and radioactive minerals by measuring the amounts of sulfur gases, carbon dioxide, mercury, and helium in soil gas.
- *Estimates of recoverable oil and gas resources of the United States were revised* (Miller and others, 1975).
- *The geothermal resources of the United States were assessed* (White and Williams, 1975).
- *Potential oil and gas resources were estimated* on 17 Outer Continental Shelf areas covering approximately 1.4 million square kilometres (540,400 square miles).

LAND RESOURCE SURVEYS

The reservoir of knowledge and expertise that the Geological Survey develops in the land resource investigations assists the Government and the general public to analyze and to solve geologic problems related to the use of the land and the protection of man's environment. It also makes possible quick and effective response to requests for geologic information and advice from other Federal agencies, and, where practical and appropriate, from State and local agencies. The research carried out under the Land Resource Surveys subactivity consists of six major programs: Earthquake Hazards, Volcano Hazards, Environmental Aspects of Energy, Arctic Environmental Studies, Engineering Geology, and Regional Mapping and Analysis.



EXPLANATION

RISK ZONE		U.S. POPULATION by risk zone
Zone 0	No reasonable expectance of earthquake damage	16.7M (8%)
Zone 1	Minor earthquake damage can be expected	115.1M (57%)
Zone 2	Moderate earthquake damage can be expected	40.5M (20%)
Zone 3	Major earthquake damage can be expected	30.9M (15%)

FIGURE 26.—Earthquake risk zones in the United States.

Earthquake Hazards

All 50 States are subject to some earthquake-related hazard (fig. 26), and 39 States, which contain nearly 35 percent of the population, are in zones where moderate to major damage from earthquake shaking has occurred in the past. For example, destructive earthquakes struck Boston, Mass. in 1755, New Madrid, Mo. in 1811–12, and Charleston, S.C. in 1886. Alaska, California (fig. 27), Montana, Nevada, and Washington have experienced more recent major damaging earthquakes.

Losses from earthquakes can be greatly reduced by proper engineering design, by wise use of the land, and by emergency preparedness actions. The National Earthquake Information Service locates and rapidly evaluates important earthquakes worldwide, provides data support for the Tsunami Warning System, and notifies appropriate disaster authorities and the public within 2 hours of the earthquake's occurrence. For several days after the occurrence of a destructive earthquake, the alerting service also acts as an information center. Major program objectives include: (1)

acquisition and dissemination of information on earthquake occurrences; (2) mapping and evaluation of earthquake hazards; and (3) development of techniques to predict the time, place, and magnitude of earthquakes.

The Worldwide Network of Standard Seismographs (WWNSS) observes and records distant earthquakes. The network in fiscal year 1975 consisted of 31 stations in the United States and 85 stations located in 68 foreign countries. It is an essential source of data for locating earthquakes worldwide, determining the internal structure of the Earth, identifying and delineating earthquake-prone regions, and estimating seismic risk. The Geological Survey operates the WWNSS in cooperation with the National Science Foundation.

The Geological Survey also operates a strong-motion engineering seismology program for the National Science Foundation. The accelerograph records obtained indicate the nature and magnitude of ground motion associated with earthquakes and are used by the engineering community to develop and improve earthquake-resistant designs for structures. Approximately 130 accelerograph records were obtained during fiscal year 1975 (U.S. Geological Survey, 1975a).

The Earthquake Hazards program conducts a variety of studies to assess the expected size and frequency of earthquakes, and to identify and to delineate areas affected by earthquake hazards such as surface faulting, strong shaking, ground failure, tectonic elevation changes, landslides, and flooding from tsunamis (seismic sea waves) or dam failure (Wallace, 1974). Activities in fiscal year 1975 included:

- *Geologic studies to determine the relation between regional structure and earthquakes,* the distribution of potentially active faults, and the nature and rates of movement along these faults. Studies are underway for the San Andreas and related fault systems, California; southern Alaska; Nevada seismic zone; the Intermountain seismic zone of Utah, Idaho, Montana, and Wyoming; the Rio Grande rift; and the central Mississippi Valley. Most of these investigations are concentrated in or near major urban areas of high seismic risk in the Western United States (fig. 28).
- *Operation of local seismometer networks in earthquake-prone regions* for detection and accurate location of small-magnitude earthquakes (fig. 28). These networks, dense arrays of sensitive instruments that permit the detection and accurate location of small-magnitude earthquakes, are used to map seismically active fault segments in three dimensions and to identify major active faults. Part of this effort is conducted by State geological surveys, universities, and the private sector under Geological Survey research grants and contracts.
- *Investigations of the factors and processes* that determined the behavior of rocks and soils when shaken by earthquakes and that cause ground failure. For example, the mechanics of liquefaction —the sudden weakening of soils because of high fluid pressure—are being explored in detail because liquefaction is the basic cause of ground-failure during an earthquake.

Accurate forecasting of the time, place, and size of destructive earthquakes could substantially reduce the potential loss of life and the number of injuries. Prediction research includes monitoring and analysis of crustal strain and local earthquake activity, the study of the behavior of rocks under conditions like those within the Earth, and investigation of the basic causes and mechanisms of earthquakes. Field measurements, laboratory experiments, and theoretical studies of geophysical precursors of earthquakes are being carried out in order to establish a firm physical basis for prediction. Permanent seismograph networks of roughly 400 stations in California and Nevada are important components of the earthquake-prediction effort.

The Geological Survey has been conducting an earthquake-prediction experiment astride a highly seismic part of the San Andreas fault near Hollister, Calif. A dense network of seismometers, tiltmeters, magnetometers, and devices for recording horizontal strain, fault creep, and water-level changes in wells at 150 different locations in that region is monitored to establish the physical characteristics of the fault zone and to develop efficient methods for recording and interpreting the changes that occur within the Earth prior to earthquakes. A long-term goal of the experiment is to test hypotheses that can explain the time of occurrence of earthquakes. Part of this earthquake-prediction research is supported by approximately 55 contracts that utilize the capabilities of university scientists to develop techniques for identifying geophysical anomalies that might signal impending earthquakes. In addition to seismic techniques for earthquake prediction, both Survey and university scientists are investigating possible earthquake precursors such as variations in electrical and magnetic properties, changes in the flow of ground water and in water geochemistry, and anomalous tilts and uplifts of the Earth's surface.

Fiscal year 1975 accomplishments of the Earthquake Hazards program included:

- *Prediction of the Thanksgiving Day 1974 earthquake* (5.2 magnitude) between the San Andreas and Calaveras faults near Hollister, Calif., from marked

◄FIGURE 27.—Damage to highways in San Fernando, Calif., caused by an earthquake on February 9, 1971.

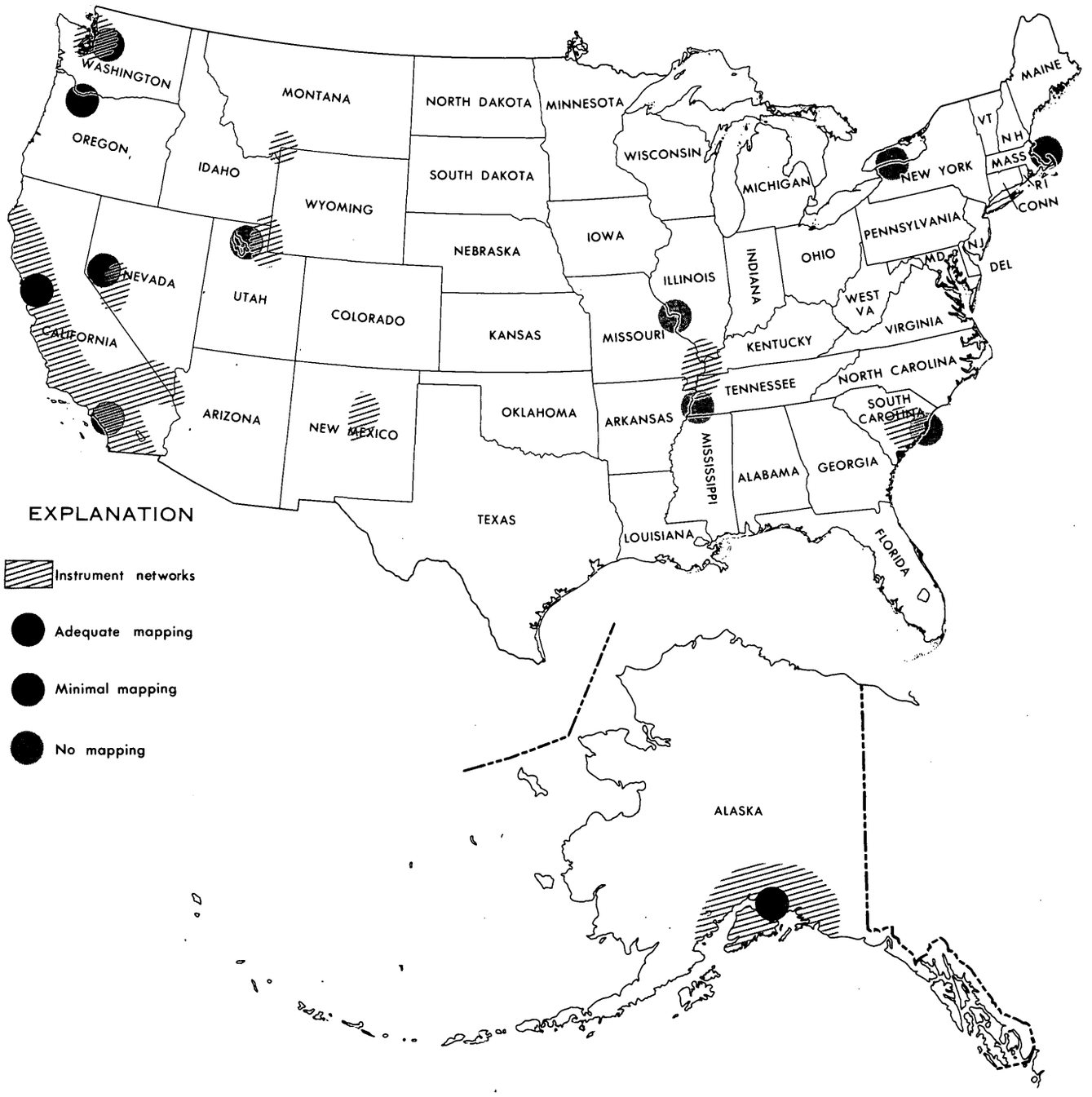


FIGURE 28.—Earthquake hazards mapping and instrument networks in fiscal year 1975.

changes observed during the preceeding weeks in deformation of the Earth's surface and in the magnetic field. Retrospective analysis of seismic data suggested an anomaly that coincided in time with changes in other geophysical signals. This was the first time that such a variety of precursory signals had been observed for a single earthquake in the United States. During 1974, 12 other earthquakes in the test area were preceded by significant changes in tilt of the Earth's surface. These observations confirmed that some earthquakes can be predicted by presently available geophysical instrumentation and analytical techniques.

- *Publication of 35 earthquake geologic hazard maps* and evaluations which are useful in establishing new building and zoning requirements in earthquake-prone areas.
- *Identification of active faults* by estimating regional attenuation of strong shaking, and the qualitative delineation of the relative shaking response of geologic units in the San Francisco Bay area (Gibbs and Borcherdt, 1974).

- *Determination of liquefaction potential and landslide susceptibility* in the San Francisco Bay area.

These analytical methods for the assessment of seismic hazards have application to other earthquake-prone regions and can be used as a basis for land use planning and engineering actions that will substantially reduce hazards caused by earthquakes.

Reliable forecasting of destructive earthquakes appears to be an attainable goal in the light of recent advances in understanding earthquake mechanisms and the geophysical anomalies that precede earthquakes. However, before prediction systems can be deployed to provide warnings to urban areas, additional research into a wide variety of earthquake precursors is required, together with development of sophisticated techniques for rapidly analyzing large quantities of geophysical data. Prediction systems will probably be deployed first for areas in California, because that is where the knowledge of earthquake mechanics is most highly developed. Prediction methods and sensors presently being used in the central California experiment need to be tested in other geologic settings. The Geological Survey plans to place a dense array of seismometers and tiltmeters astride the highly active San Jacinto fault about 96 kilometres (60 miles) southeast of Los Angeles. Gradual expansion of instrumentation to cover the highly populated San Francisco and Los Angeles areas would be the next step as prediction methods are validated from the experimental system.

Volcano Hazards

The Volcano Hazards program seeks to mitigate the hazards posed by the active volcanoes in Hawaii and the Cascade Range in the Western United States. These volcanoes have been intermittently active throughout historic time, and the possibility of eruptions and other hazardous situations will continue in the future.

Work at the Hawaiian Volcano Observatory is directed toward anticipating the time and location of future outbreaks of the active volcanoes, Kilauea and Mauna Loa, which are of concern to more than 35,000 people who live downslope. Volcano hazards maps for the Island of Hawaii, prepared in cooperation with the Department of Housing and Urban Development, outline areas exposed to varying types and degrees of hazards. In the Pacific Northwest, geologic and geophysical studies are directed toward understanding the types of hazards posed by eight Cascade Range volcanoes.

Several volcanoes in Alaska are also being investigated to study the relationships between volcanism and geothermal energy. These projects are funded through the Geothermal Energy program.

In fiscal year 1975, two events underscored the importance of the Volcano Hazards program:

- *Mauna Loa inflated in preparation for an eruption* that eventually took place on July 5–6, 1975 (fig. 29). This was the first eruption from Mauna Loa in 25 years, and it increases the probability that this volcano will erupt again in the near future. Monitoring efforts on Mauna Loa have been increased. At present, the volcano is reinflating in advance of its next eruption.
- *Thermal emissions on Mount Baker, Wash., increased* (fig. 30) in March 1975. By May, the emissions had increased to about 100 times normal. This thermal activity accelerated the melting of snow and ice on the volcano's flank. In June, the Geological Survey estimated that the likelihood of a large mudflow originating on Mount Baker was about 10 times normal. Subsequently, the Forest Service and the Puget Sound Power and Light Company restricted public access to nearby recreational areas. The Geological Survey, State agencies, and university groups have increased geophysical monitoring of the volcano.

Environmental Aspects of Energy

The Environmental Aspects of Energy program, which began in fiscal year 1975, is an integral part of the Geological Survey's energy-resource research, exploration, and evaluation effort. The program acquires, interprets, and distributes geologic, hydrologic, geophysical, geochemical, and related information that will assist in analyzing and solving environmental problems associated with energy-resource extraction and utilization and the planning, siting, and construction of facilities for energy conversion and distribution.

Much of the information and expertise developed by this program is used by the Survey to prepare and review environmental impact statements and to guide environmental monitoring required during the supervision of resource development on Federal and Indian lands.

National environmental overview maps

National environmental overview maps are being prepared to show the extent and frequency of occurrence of certain geologic processes and events that may pose constraints to safe land utilization and to mineral- and energy-resource development. This broad-scale assessment is no substitute for more detailed information and analysis, but for many areas of the country, it is a useful beginning to the complex problem of land use planning and its implementation.

Maps of the United States scheduled for preparation at a scale of 1:7,500,000 will cover the following topics: landslides, active faults, surficial materials, vol-

FIGURE 29.—Rapidly flowing lava traveled three kilometres downslope from vents on Mauna Loa's northeast rift during the eruption of July 5–6, 1975.

canic hazards, cooling water availability, karst topography and its engineering problems, swelling clays, radioactive-waste disposal sites, bedrock lithology, and the locations of nuclear power reactors and their geologic environments. Some intermediate products are 3 maps useful for planning highway routes (Wyoming, Idaho, and Montana), and 3 landslide hazard maps useful in considering the proposed Colorado land-use bill.

Energy Lands

Accelerated development of coal, and eventually oil shale, primarily by large surface mines, has the potential for causing widespread permanent damage to the environment in many areas across the country. Lack of environmental data delays this development, especially in arid and semiarid regions of the West, where natural conditions are so delicately balanced that slight disturbances can result in severe long-term degradation. The Energy Lands program establishes basic knowledge of existing environmental conditions

FIGURE 30.—Mount Baker began to display abnormal thermal ◄activity in March 1975, and this activity has continued to the present time.

in each of the principal coal and oil-shale resource areas in order to predict possible changes before mining and related industrial activity start, and then to monitor changes by means of quantitative measurements as the development takes place. The preparation of a comprehensive environmental data base includes the integration of large amounts of information on bedrock geology, surficial geology, geomorphology, quality and quantity of coal and overburden, ground- and surface-water conditions, and erosional and weathering patterns. Efforts are being concentrated in the basins of the Rocky Mountains and northern Great Plains where the greatest coal and oil-shale development is expected to take place in coming years. Seven grants to universities and State agencies for studies in their particular areas of experience and knowledge form an important part of the program.

During fiscal year 1975, 90,600 square kilometres (35,000 square miles) were geologically mapped by reconnaissance or in detail around the energy resource areas. Investigations included studies of landslide incidence and susceptibility in the Appalachian bituminous coal regions, studies of active geologic processes and rates of weathering and erosion in the coal-rich eastern Powder River Basin, Wyo., and engineering and geologic studies in the western Powder River Basin of Wyoming and Montana where underground mining operations have caused pronounced ground subsidence.

Reactor hazards

About 100 nuclear power reactors are now built or under construction (fig. 31), but several times that number may be constructed in the next two decades. This program focuses on identifying geologic hazards such as fault movement, earthquakes, volcanic eruptions, ground subsidence due to ground water and petroleum withdrawal, and failure of foundation materials that deny the use of otherwise suitable sites for reactors or that can greatly increase reactor design and construction costs. During fiscal year 1975, geologic mapping was underway in various parts of California, Oregon, and Washington to delineate these hazards. In the eastern part of the country, which contains 85 percent of the population and more than three-quarters of the power reactors now built or under construction, the nature and regional distribution of hazards are less obvious. For example, no clear basis exists for predicting the distribution of future earthquakes. Studies of earthquakes, deformation, geologic structure, and recency of faulting were conducted in New York, New England, and the Atlantic Coastal Plain from Maryland to Alabama. A study was also underway in the Texas Coastal Plain to understand better the relation of surface faulting to withdrawal of fluid from the ground. These investigations are closely coordinated with and depend upon information obtained by the Earthquake Hazards, Volcanic Hazards, Engineering Geology, and other related Survey programs.

Program accomplishments during the year included:

- *Recognition of many faults in southeast United States* including several structural zones 16 kilometres (10 miles) or more long which are young enough to suggest that active faults may be present in the region.
- *Development of a new method of dating rocks* based on certain changes in the amino acids in fossil mollusks. The method is applicable to dating rocks in the age range from 35,000 to a million years for which other methods are largely inapplicable.

Arctic Environmental Studies

The Arctic Environmental Studies program began during fiscal year 1975 as an outgrowth of the Alaska Pipeline Related Investigations activity, to take advantage of the unique opportunity to collect scientific and engineering data made available during construction of the Alaska pipeline. During the year, special attention was given to the collection of data on permanently frozen soils, glacial features, surficial deposits, and geologic processes to assess whether engineering designs for pipelines, ancillary construction, and maintenance facilities are adequate to preserve the Arctic environment. A network of 12 seismometer stations was established in northeast Alaska to collect data needed for evaluating earthquake risks along the Arctic coast and in the eastern Brooks Range. Future studies will concentrate on proposed gas pipeline routes from Fairbanks to the Canadian border and from Fairbanks to Anchorage.

Engineering Geology

The Engineering Geology program advances engineering geologic knowledge by mapping the distribution of geologic materials and by measuring and describing the properties of the materials that predict their engineering behavior. The program also provides engineering-geologic advice and assistance to local, State, and other Federal agencies. The program includes studies of: (1) rock deformation hazards in coal mines, rock-mechanics research, and other investigations that provide information for the safe and environmentally efficient extraction of energy and mineral resources from the ground; (2) landslides and mudflows, drainage characteristics, foundation condi-

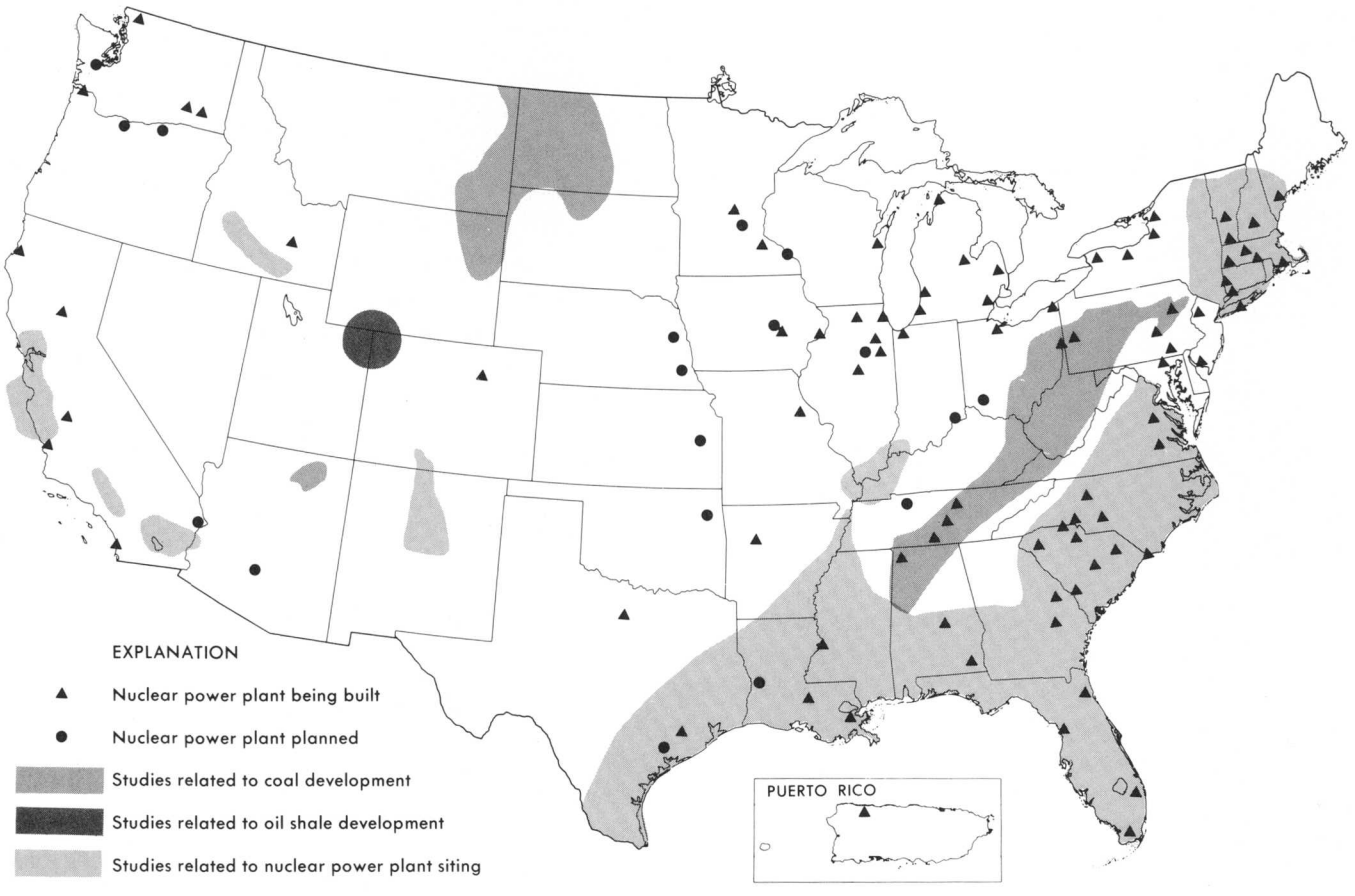


FIGURE 31.—Geologic studies relating to environmental aspects of energy development.

tions, and properties of rocks and soils that affect urban development and land use; and (3) geologic processes governing the stability of slopes, surface subsidence, and volcanic eruptions in order to understand these processes more fully and to reduce the impacts of these natural hazards. These studies focus on the engineering-geology aspects of natural hazards and thus provide technical support to other Survey programs which seek to characterize the type and extent of natural hazards. The program also conducts engineering-geology studies related to underground nuclear weapons tests at the Nevada Test Site with funds from the Department of Defense and the Energy Research and Development Administration.

Major accomplishments in fiscal year 1975 included:

- *Development of a mapping technique to portray liquefaction potential* of unconsolidated sediments under seismic loading developed for mapping techniques.
- *Provision of information on subsurface geology of underground explosions* to the Soviet Union under the terms of the proposed Threshold Test Ban Treaty.

Regional Mapping and Analysis

The Regional Mapping and Analysis program provides the earth-science programs throughout the Geological Survey with basic geologic, geophysical, and geochemical data and services such as fossil identification and age determinations. Supporting research leads to improved understanding of geologic processes and development of new instruments and analytical methods.

Geologic mapping

Geologic maps are invaluable tools in the search for water, mineral, and energy resources; evaluation of geologic hazards; assessment of environmental impacts; and planning for prudent use of land resources. These maps show the distribution of rocks and surficial material by age, and their physical and structural relationships with one another. Inferences can be drawn from these maps about an area's geologic history, the geologic processes, the orientation of rock layers, and of faults and fractures, and the shape of rock bodies beneath the surface.

The Survey maps the geology at scales ranging from 1:24,000 to 1:2,500,000 depending upon the type of information to be portrayed and the purpose of the mapping (tables 7 and 8). By the end of fiscal year 1975, geologic maps at 1:250,000 or larger scales were available for 38 percent of the United States. The Survey is increasing the amount of geologic mapping at 1:250,000 (fig. 32) in order to increase coverage more rapidly and at relatively lower cost. Greater emphasis is also being placed on cooperative arrangements by which Federal and State personnel work together to produce geologic maps.

In fiscal year 1975, the mapping program:

- *Mapped geologically about 73,000 square kilometres (28,200 square miles)* at various scales (table 7).
- *Identified resources of sand, gravel, clay, coal, and phosphate rock.*

TABLE 7.—*Distribution of geologic mapping in the Regional Mapping and Analysis program by State in fiscal year 1975*

State	Scale of mapping			Man years
	1:12,000–1:24,000	1:48,000–1:63,360	1:250,000	
TOTAL	7,703 km²	6,207 km²	59,438 km²	88
Alaska	--	2,978 km²	9,324 km²	3
Arizona	--	--	10,360 km²	1
California	--	78 km²	--	1
Colorado	65 km²	388 km²	4,920 km²	5.5
Connecticut	337 km²	--	--	7.5
Idaho	--	2,072 km²	27,972 km²	7
Kentucky	5,180 km²	--	--	31
Maryland	194 km²	--	--	1.5
Massachusetts	1,217 km²	--	--	14
Montana	--	303 km²	2,979 km²	2.5
Nebraska	--	--	906 km²	1
Nevada	103 km²	--	--	1
New Hampshire	78 km²	--	--	1
New Mexico	--	--	2,330 km²	1.5
Pennsylvania	10 km²	--	--	.04
Puerto Rico	362 km²	--	--	4
Utah	28 km²	--	--	.5
Virginia	129 km²	259 km²	--	3
Washington	--	129 km²	--	1
Wyoming	--	--	647 km²	1

TABLE 8.—*Scales of geologic maps commonly used by the Geological Survey*

Scale	Percentage of U.S. covered at this or larger scale	Type of information	Purpose
1:2,500,000 (1 cm=25 km).	100	Very general distribution of limited number of very large and heterogeneous rock units.	General planning and resource evaluation over very large regions (Federal regions, very large States).
1:500,000 (1 cm=5 km).	73	General distribution of a larger number of somewhat less heterogeneous rock units. Little information on depth.	General planning and resource evaluation over large regions (large States, river basins). Common scale for older State maps.
1:250,000 1 cm=2.5 km).	38	Semidetailed distribution of large numbers of fairly homogeneous rock units. Some information on depth. Often has topographic base.	More detailed planning and resource evaluation in medium-sized areas (small States, large counties, national forests, mineralized belts).
1:100,000 (1 cm=1 km). 1:63,360 (Alaska) (1 cm=6.33 km). 1:62,500 (1 cm=6.25 km).	24	Detailed distribution of large number of homogeneous rock and surficial units and considerable information on thickness and depth. Generally has topographic base.	Detailed planning, land-management and resource studies (mining districts, urban areas, many counties).
1:24,000 (1 cm=240 m). 1:20,000 (Puerto Rico) (1 cm=200 m).	15	Very detailed distribution of large number of quite homogeneous rock units. Surficial deposits may be shown on separate map. Much information on thickness and vertical extent of rock units. Has topographic base.	Detailed planning, zoning, site selection, resource evaluation and exploration (cities and towns, subdivisions, mining districts, mine sites, large construction projects).

- *Discovered occurrences of nickel, chromium, gold, copper, zinc, lead, and uranium.*
- *Increased knowledge of geothermal energy in* Idaho and New Mexico, oil and gas in Washington, and oil shale and coal in Wyoming, Utah, Colorado, and Alaska.
- *Located landslide areas,* areas with unstable slopes, and areas of potential earthquakes.
- *Indicated areas suitable for radioactive-waste disposal.*

Geophysical Surveys

The Geophysical Surveys program assists the other programs by providing information on the structure, composition, and dynamics of the Earth's crust. The geophysical force fields associated with distinctive types of rocks and structures are interpreted by analyzing the behavior of the Earth's present and past magnetic field. Examples of research activities in 1975 include: studies of gravity and magnetic fields; electrical and electromagnetic studies; seismic studies; heat flow studies; laboratory studies of the physical properties of rocks at high temperatures and pressures;

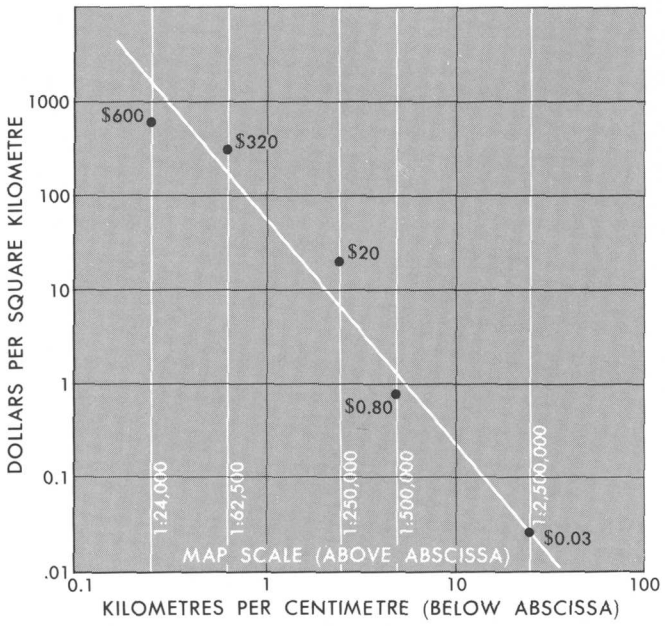


FIGURE 32.—Cost of geologic mapping at different scales.

constructing instruments for measurement of the effects of temperature, pressure, and chemical alterations on the magnetic properties of rocks; developing techniques for determining polarity reversals of the Earth's magnetic field in the geologic past; compiling charts showing components of the Earth's magnetic field; and compiling a world magnetic chart from satellite-magnetometer data. Some fiscal year 1975 findings were:

- *Recent faulting in the Rio Grande graben,* N. Mex., was found to be influenced by Precambrian structural features of deeply buried rocks.
- *Electrical measurements* in Hawaii indicated that occurrences of molten magma are associated with recently formed lava tubes.
- *Seismic studies* in California indicated that the changes preceeding earthquakes occur at great depth.
- *Heat flow studies* in the Long Valley, Calif., thermal area indicated that magma has been confirmed at considerable depth.
- *Reversed paleomagnetic fields* in Precambrian-age rocks of Arizona and Montana may be a useful tool in correlating rocks between the two areas.
- *Oxidation of lava* influenced the magnetic anomalies associated with sea-floor spreading.
- *Magnetic impulses* detected by geomagnetic observatories around the world may be explained by sunspot phenomena rather than by processes in the Earth's core.

Geochemical Surveys

Geochemical Surveys provide data on variations of chemical elements in rocks, soils, and vegetation. This information establishes baselines against which to compare future observations and provides data for pollution control and environmental health research. Activities in 1975 included development of analytical methods, compilation of rock analysis data, operation of a geochemical data system, investigation of trace elements in the human food chain, and studies of urban area geochemistry. Accomplishments during the year included:

- *Completion of geochemical surveys of trace elements* in soils and plants in Denver, Colo., and Pittsburgh, Pa. urban areas.
- *Preparation of a major treatise* on the statistical treatment of geochemical data.

Dating and correlation—isotope geology

The Isotope Geology program investigates, develops, and utilizes methods for determining ages of rocks and minerals, geochemical methods for studying geologic processes, and neutron activation methods of field chemical analysis for mineral exploration. This provides the basic data necessary for understanding Earth history and the geologic processes that have been active in shaping the Earth for the last 4.5 billion years and for solving a great variety of problems, ranging from mineral exploration to nuclear-plant site evaluation in which knowledge of the age of rocks or geologic events is essential. In fiscal year 1975, the Isotope Geology program:

- *Dated volcanic activity in Long Valley, Calif.,* which began 700,000 years ago and continued intermittently until 50,000 years ago.
- *Dated mineral deposits in the San Juan Mountains, Colo.,* which were formed 5 million to 15 million years after the main volcanic episode.
- *Dated two massive sulfide deposits in northern Wisconsin* which were formed about 1,900 million years ago. This discovery may change the direction of future prospecting for mineral deposits.

Dating and correlation—paleontology and stratigraphy

The Paleontology and Stratigraphy program acquires basic data on the distribution of fossils within the stratigraphic column and applies them to determine the age and correlation of sedimentary rocks. Accomplishments in fiscal year 1975 included:

- *Identification of 3,040 fossils* for other scientists.
- *Stratigraphic reconnaissance studies of the Caballo Mountains area* just east of Truth or Consequences, N. Mex., revealed a much greater sequence of marine Upper Cretaceous rocks than had been formerly recognized, increasing the oil potential of the area.

- *Synthesis of Ordovician history* of the Western United States showed varying climatic belts and depths of water produced four contrasting depositional terranes: dolomite and evaporites, limestone, windblown sand, and peripheral siliceous rocks.

Geologic processes

The Geologic Processes program studies the fundamental properties of rocks and minerals. Past studies of the chemical analysis of rocks, optical properties of minerals, volcanic structures, and the nature of hot springs have provided the basis for methods now used by the mission-oriented programs. Current studies of the relationship of volcanic activity to plate tectonics, the details of chemical differentiation in volcanoes and in ground water, and the mechanism of mineral crystallization to form rocks will contribute to future resource evaluations of many types of mineral deposits.

- Studies of the structural and chemical variations within the Sierra Nevada batholith gave a better understanding of active plate tectonic motions that occurred during the last 200 million years.
- Studies in the rift areas of Oman that are associated with the Arabian Shield resulted in finding important copper deposits that are associated with midplate spreading rather than a subduction boundary where continental crust overrides oceanic crust.
- Geologic studies in Hawaii provided a good model for the interpretation of the geology of seamounts in the northern Pacific, which in turn provided information on the motions of the Pacific plate through geologic time.

MINERAL RESOURCE SURVEYS

The major emphasis of the Geological Survey's Mineral Resource Surveys programs is on the identification and assessment of hitherto unknown and unsuspected sources of mineral materials, primarily on Federal lands (figs. 33 and 34). Because the assessment of minerals and the identification of new resource occurrences are complex, time consuming, and expensive tasks, the development of new, more rapid, and more effective methods to accomplish these tasks is an important element of the program.

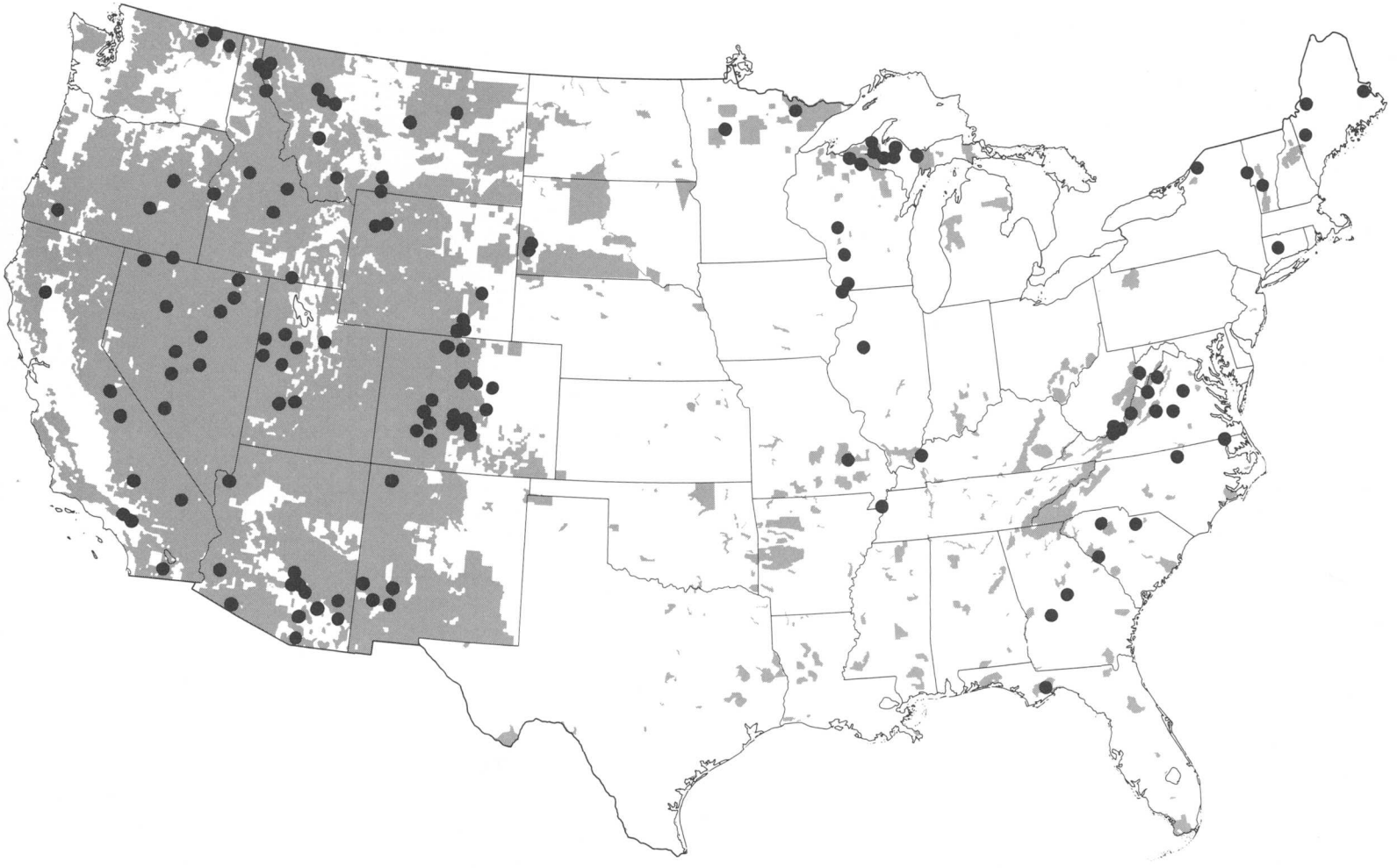


FIGURE 33.—Map of the conterminous States showing Federal lands and Indian reservations (shaded) and the location of current Mineral Resource Surveys project areas (dots).

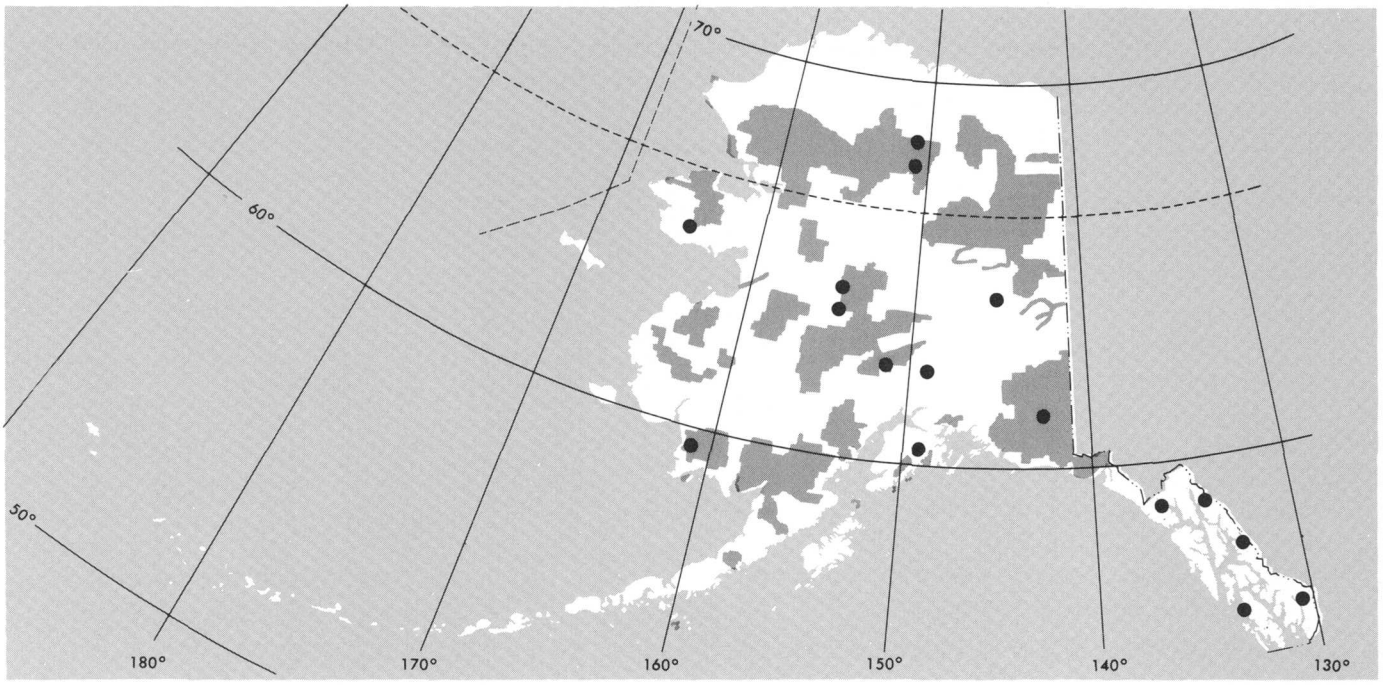


FIGURE 34.—Map of Alaska showing D–2 lands (shaded) and location of current Mineral Resource Surveys projects (dots).

Mineral Resource Appraisal

To obtain up-to-date information on mineral potential, Congress has directed the Geological Survey and Bureau of Mines to conduct mineral resource assessment programs for some of the Federal lands of immediate legislative concern and to provide reports of these programs for public use. The Survey uses three levels of resource assessment, each designed to meet specific information needs (table 9). In 1975, assessments were underway on lands proposed for designation as wilderness areas, on D–2 lands under jurisdiction of the Alaska Native Claims Settlement Act, and on lands administered by the Department of the Interior and other Federal agencies. Studies were also conducted on non-Federal lands that are believed to have substantial potential for the discovery of buried, low-grade, or new speculative resources.

Wilderness Mineral Resource Appraisal

The Nation has recognized the need to preserve fragile wilderness values for future generations. Since passage of the Wilderness Act in 1964, more than 31 million acres have been proposed for wilderness status by agencies of the Federal Government. The Congress requires an assessment of the resource possibilities before making its final dispositions, because min-

TABLE 9.—*Three levels of resource assessment used by the Geological Survey*

Level	Objective	Method of study	Advantage	Limitations
I	General inventory of past production and resource activity. Identify areas needing more detailed study.	Library and records survey; search of all sources for unpublished data on known districts; computer storage of data.	Status report: assessment of all known resource information. Important first step for any assessment.	Superficial; most data will be spotty; inadequate for determination of total resource; often biased; undeveloped areas will be overlooked.
II	Uniform reconnaissance-level appraisal to establish base for total resource estimate.	Level I plus reconnaissance geologic, geochemical, and geophysical mapping; remote sensing; sampling of broad areas that are promising. Computer storage, retrieval, and interpretation of data.	Sufficient detail to present resource evaluation for use of decisionmakers. New areas identified for classification and development.	Not sufficient to define reserves or to be used by management. Deeply buried deposits missed.
III	Sufficiently detailed geoscience data to determine reserves and to make management decisions regarding leases and environmental consequences.	Detailed geologic mapping, geochemical sampling and assaying, and geophysical surveys in small areas of known potential. Computer storage, retrieval, and interpretation of data.	Development of geologic theory leading to identification of new types of deposits; basis for stockpile decisions.	Time consuming, expensive.

ing of such potential materials is banned once an area is designated a wilderness. To date, the Geological Survey and the Bureau of Mines have completed mineral surveys of 17 million acres of land proposed for wilderness status.

Alaska Mineral Resource Appraisal

The Survey started the Alaska Mineral Resource Appraisal program in 1975 to supply basic resource information on the State of Alaska. The program (Yount, 1975) involves rapid evaluations of the mineral potential of the State by preparation of a resource map folio series consisting of geologic geochemical, and geophysical maps, and interpretive maps based on Landsat satellite imagery, and a resource-potential map based on geostatistical and mineral economic models. The first 1°×3° (1:250,000) quadrangle folios (Nabesna quadrangle) to be completed under the program consists of a text and 12 maps. Studies of 12 additional quadrangles are in progress or scheduled, and 18 others are planned but not yet scheduled. This area totals about 440,300 square kilometres (170,000 square miles) and contains about half the regions of exposed bedrock now considered to have significant potential for mineral resources in Alaska.

Geologic and Geophysical Appraisal Mapping

Resource assessments are conducted on the Federal domain and on State and private lands where there is a high probability that mineral resources may be found or for which special but longer term needs for resource information have been recognized. Such studies provide the Geological Survey with evaluations of the resource potential of large areas as well as with a basis for planning future, more detailed surveys. Geologic mapping is being done at many map scales and in many types of areas in support of resource assessments ranging from urban impacted areas, in order to assist in local zoning and planning, to surveys of mineral belts in desert, swamp, and mountainous regions in Arizona, Colorado, Michigan, New Mexico, Oregon, Utah, and Wisconsin. Geophysical mapping is being done by using gravity, magnetic, electrical, and seismic surveys to outline distinctive rocks and structures below the Earth's surface.

Commodity programs

The Commodity programs (U.S. Geological Survey, 1975b) obtain specific knowledge about the geologic availability and location, distribution, quantity, and quality of specific mineral commodities. Some mineral commodities are not now commercially mined in the United States and must be imported to meet demands. Other minerals are known to occur in domestic deposits but cannot economically compete with foreign sources. These mineral commodities are "critical" because their supply is vulnerable to potential economic and political actions by foreign governments. A second group of mineral commodities, yet to be fully evaluated, may become critical as a result of greatly increased demand to support increased production from new energy sources. A third mineral group of more abundant mineral commodities requires low-level investigation. During the past few years the Survey has reviewed the current knowledge of domestic, and, to a lesser degree, world mineral resources for nearly 100 commodities (Brobst and Pratt, 1973) and summarized the domestic resource position in 1974 with respect to 27 major energy and mineral commodities used by industry (Pratt and Brobst, 1974).

The Commodity programs consist of, the *Critical Mineral Commodities program* element and the *Minerals for Energy program element*. Primary emphasis is on the *critical mineral commodities* (aluminum, chromium, platinum, iron, nickel, manganese, zinc, tin, titanium, cobalt, mercury, tungsten, columbium, vanadium, fluorspar, and copper) for which there is present or potential national dependence on imports. The program will be expanded to include other critical materials as they are identified. Commodity specialists maintain and analyze the world commodity resource files and make periodic estimates of mineral availability. They develop and apply new concepts for the assessment and identification of new domestic and overseas sources of these materials and provide analyzed data for the Resource Analysis and Information System.

Greater self-sufficiency in energy production within the next few decades will increase the demand for *minerals required to develop, produce, and distribute energy*. Minerals required include: iron to produce steel for drill rigs, pipelines, and refineries for oil and gas, and rails and trains to transport coal; copper and aluminum for the electric industry; and exotic minerals for many uses in the nuclear industry. Aluminum and nickel were recognized early as vulnerable imported materials and studies of substitute domestic sources have been started such as high-alumina clays in southeastern Georgia and low-grade nickel resources in northern Minnesota, Michigan, and Wisconsin.

Highlights of the Mineral Resource Appraisal programs in fiscal year 1975 included:

- *Publication of 11 wilderness area assessments* (Scapegoat Wilderness and Absaroka Primitive Area, Mont.; Clear Creek-Upper Big Deer Creek Study Area, Idaho; Salmon-Trinity Alps additions,

Calif.; DuNoir Study Area, Wyo.; Conger Lakes-Mt. Aix Study Area and Alpine Lakes additions, Wash.; Lone Peak, Utah; San Pedro Parks Wilderness and White Mountains Wilderness, N. Mex.; and Indian Peaks Study Area, Colo.). Parts of five of the areas were found to contain significant mineral resources resulting in modification of wilderness area boundaries. Equally important, the mineral potential of the other six areas studied last year appears to be insignificant and will not prejudice their consideration for withdrawal for wilderness preservation status.

- *Mineral resource evaluation of the Nabesna quadrangle in Alaska* identified significant potential for copper, molybdenum, gold, silver, and several nonmetallic commodities.
- *Discovery in Alaska of chromite, tin, and copper* in geologic terrane not previously suspected to contain these elements. This discovery suggests that these elements should be looked for in similar geologic environments elsewhere.
- *Publication of maps that outline the potential for copper mineralization* in part of the Phoenix-Tucson, Ariz. urban corridor. These maps contribute to a broader study of the region by the Survey's Land Information and Analysis Office and are being used by State and local agencies to plan zoning legislation.
- *Discovery of gold, tin, and beryllium* in unusual concentrations in areas of South Carolina where no previous mining of these commodities has taken place and in areas where exploration has not been conducted for many years.
- *Completion of geologic maps of Nevada and eastern Oregon;* the compilation of a new geologic map of Colorado is well advanced.
- *Completion of aeromagnetic surveys of 117,000 square kilometres* (45,162 square miles) for parts of Alabama, Georgia, Maryland, Nevada, New Mexico, New York, North Carolina, South Carolina, Washington, and West Virginia that show the distribution of rocks potentially related to mineral deposits.
- *Compilation of a Bouguer gravity anomaly map of Alaska* that shows a marked series of linear anomalies that appear to be closely related to zones of mineralization.
- *Location of fine-grained fluorspar* deposits of potential commercial value in zedite-bearing western lakebeds about 10 to 14 million years old (Miocene age). Detailed study of some of these unusual deposits near Rome, Oreg., suggests that as much as 12 million tons of fluorspar may be available there. Similar deposits of fluorspar have been found near Eastgate, Churchill County, Nev., and may become prime sources for new domestic resources of fluorine chemicals and flux for the steel industry.
- *Determination that large amounts of zeolite minerals are available in tuffaceous lake sediments.* These minerals are potentially useful in the treatment of sewage-disposal and other wastes, as soil conditioners, and to remove undesirable components such as carbon dioxide, water, and hydrogen sulfide from natural gas.
- *Demonstration that there is no direct relationship between grade and tonnage in porphyry copper deposits,* and that the estimated large energy requirements necessary to utilize ores of lower grade than are now being used limit the availability of critical materials like copper, nickel, cobalt, and platinum.

Minerals Discovery Loan program

Under Public Law 85–701, a total of $4.8 million in financial assistance has been loaned to private industry to explore for 36 strategic minerals. The value of ore produced by mines that have received assistance totals $8.1 million, and royalties totalling about $430,000 have been paid to the Government. As an indirect benefit to the Nation, the loan program provided limited employment in small economically depressed mining communities, helped to maintain a reserve of skilled manpower in an essential industry, contributed to the collection of valuable geologic information on the Nation's mineral resources, and aided the small-mine sector of the mining industry. This program started phasing out in fiscal year 1975.

Resource Analysis and Information Systems

The Resource Analysis and Information Systems program assists in mineral-policy decisions by using automatic data processing techniques to store, retrieve, and process large amounts of resource information and to model the complex interactions of geology and economics and their impacts on mineral supply and demand. Activities during 1975 included:

- *Continued building of the Computerized Resource Information Bank* (Calkins, Kays, and Keefer, 1973). Some 31,000 records which describe the geologic occurrence of mineral commodities are now in the system.
- *Development in cooperation with the Bureau of Mines* of a file on the world's 1,000 largest mines which produce 90 percent of the world's supply of 22 major minerals.

- *Development of a Decision Oriented Resource Information System* which consists of various mathematical models and analyses, the exploration processes, the economics of resource convertibility, and long-term resource supply and demand. This system will be used in conjunction with the resource data bases to investigate the implications of various mineral policy options and to estimate the occurrence, size, and grade of as-yet-undiscovered mineral deposits.

Geology of Mineral Occurrence

Research on the geology of mineral occurrence is essential to continue successful exploration of minerals in the United States as the search to find deposits becomes more difficult. Present mineral assessment and discovery depends upon concepts resulting from past research on the geology of mineral occurrences; future assessment and discovery will be based on the continuance of these research efforts. For example, most minerals are more soluble at high temperatures than at low temperatures. Recent research, however, has revealed that molybdenite (the most important source of molybdenum) and chalcopyrite (an important copper mineral) may show the opposite behavior under certain conditions. If this is the case, then we may expect copper and molybdenum deposits to form earlier and deeper than ores of other metals such as lead and silver. On the other hand, occurrence of the latter metals at the surface may indicate deep underlying deposits of copper and molybdenum. This and other such information is useful in constructing models of ore deposits and greatly expedites assessment of regions for new deposits by limiting the search to a few well-defined geologic targets.

Significant results in 1975 included:

- *Identification of regional controls of porphyry copper mineralization* through geologic mapping at Bingham, Utah and Ray, Ariz. The temperature and composition of ore-forming fluids in these copper deposits and others in New England and Puerto Rico have been determined from examination of fluid inclusions—tiny bubbles of gas and liquid inside crystals. Potassium-argon and fission-track ages of a half-dozen different kinds of minerals at Ray, Ariz., show that the copper deposit was formed after intrusion, solidification, and cooling of molten rock over a span of some 16 million years. Electron-microprobe analyses for fluorine, copper, and other elements locked in the crystal structure of minerals are being used to decipher the composition of the ore-forming fluids and the molten rock from which they came. These facts are providing the basis for new and revised models of the formation of copper deposits, and these models will suggest new places to look for copper.
- *Defined the composition, distribution, and origin of gold at Carlin, Nev.* The data produced by these studies of gold mineralization provide valuable clues for discovery and appraisal of gold resources in other similar areas.
- *Research on beryllium in rock of Spor Mountain, Utah,* which occurs in submicroscopic form—invisible to the unaided eye of the exploration geologist as well as the oldtime prospector. Recent studies illustrate how research can provide guides to finding these difficult-to-locate resources. The Utah beryllium deposits are restricted to fluorine-bearing igneous rocks formed relatively recently in the Earth's history, suggesting that similar beryllium deposits likely will be found elsewhere in the Western United States where such rocks occur. Fission tracks —the microscopic paths made in a crystal when uranium atoms split spontaneously—were used to establish the young age of rocks related to beryllium mineralization. Computerized statistical analysis of more than 5,000 separate mineral and chemical measurements was used to discover and measure the intensity of subtle halos of trace elements in rocks surrounding the beryllium deposits. Discovery of these halos will provide a means of rapidly appraising the beryllium resource potential of other regions.
- *Discovery of small diamonds* (fig. 35) in the State Line diatreme group of the northern Front Range, Colo.-Wyo. It is estimated that these diamonds formed at a temperature and pressure of 1050°C and 42 kilobars suggesting that they originated at a depth of about 135 kilometres (84 miles).

Appraisal-Exploration Technology

The Appraisal and Exploration Technology program supports mineral resource assessments by developing geochemical and geophysical techniques that offer the best hope for locating buried or low-grade mineral deposits. Geologic processes such as volcanic activity, earth movements, ground-water circulation, and weathering can move metals such as copper, zinc, gold, and silver from mineral deposits to the surface and disperse them in the environment. Geochemical surveys provide information on the distribution of elements in rocks, soils, vegetation, volatile gases, and water. Anomalous areas of high metal concentrations may be due to mineral-bearing rocks that crop out at the surface or to the migration of metals from deeply buried deposits. Geophysical surveys provide infor-

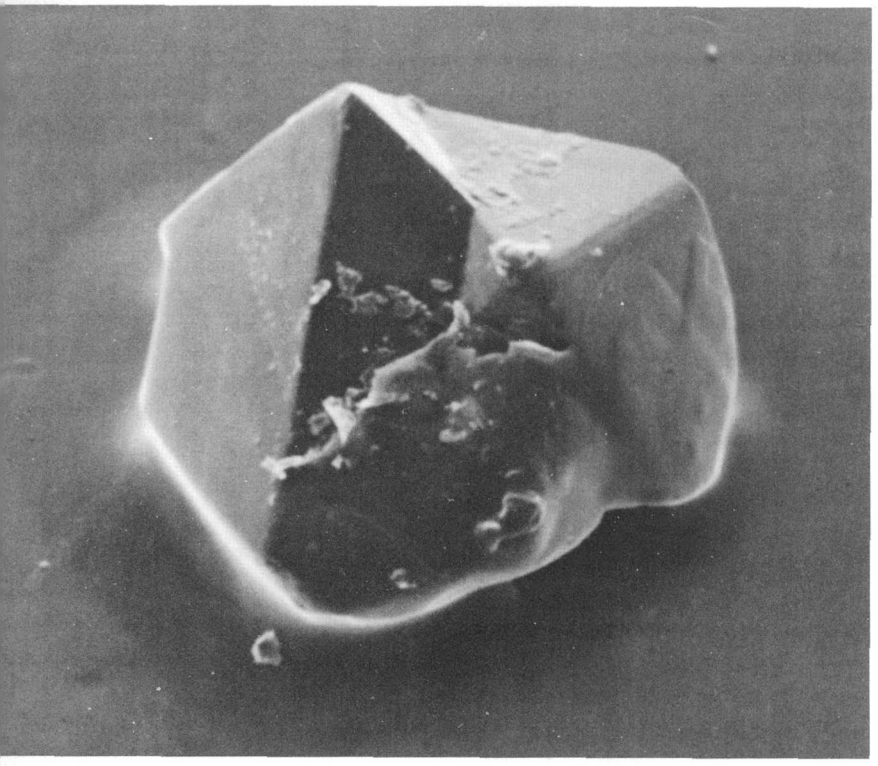


FIGURE 35.—Diamond, a crystal of two intergrown octahedrons, found in the northern Front Range, Colo.

mation on the magnetic and gravity properties of rocks that often correlate with geochemical anomalies of elements such as copper, molybdenum, silver, gold, and uranium. Landsat imagery, which is computer enhanced, has been used successfully to detect and map hydrothermally-altered areas that are spatially related to ore districts in south-central Nevada. Thermal infrared images of the Colorado Front Range near Denver have revealed anomalous textural patterns that correspond to known mining districts. Determination of the character of buried or low-grade mineral deposits depends on exploration drilling by industry.

Fiscal year 1975 program highlights included:

- *Development of new geochemical techniques to detect anomalous concentrations of metallic oxides* released into the environment by weathering processes. The technique involves chemical separation and analysis of the manganese and iron-rich fractions of stream sediments and soils. The manganese and iron oxides are very sensitive scavangers and concentrate metals such as copper, zinc, and silver, allowing the detection of subtle geochemical anomalies that may indicate deeply buried mineral deposits. This method has been successfully applied to outline metal anomalies in regions of thick rock cover in New Mexico. Here, minute amounts of metallic oxides have migrated through hundreds of feet of barren volcanic rock. Such trace indicators of mineral deposits cannot be detected by the usual geochemical surveys.
- *Development of methods to detect volatiles given off by buried mineral deposits.* Volatile elements and compounds such as helium, sulfur gases, carbon dioxide and mercury in soil gas—the air trapped between particles of soil—can be measured by new methods. Soil moisture conditions may complicate exploration of soil gas, but the anomalous concentrations of gases in soil can point to sulfur-rich minerals beneath the surface.
- *Development of electrical and seismic measurements to locate mineral deposits up to 300 metres from a borehole.* This is a vast improvement over the method of measuring the geophysical properties of rocks a few metres from a borehole currently applicable to most well-logging techniques. Results of field tests and computer-model studies indicate that these techniques can improve exploration efficiency by reducing the number of drill holes needed for locating buried ore bodies.

ENERGY RESOURCES SURVEYS

The Energy Resources Surveys subactivity provides Congress, other Federal agencies, and the public with current, systematic, and thorough assessments of the Nation's energy resources. Resource assessments are inherently uncertain and reflect the available data and state of knowledge at the time the assessments are made. Resource estimates have to be refined as more geologic information is collected and compiled and as new theories of origin and new exploration techniques discover hitherto unknown and unsuspected sources of energy commodities. Thus, resource assessments must be periodically reevaluated in the light of new knowledge and they may be expected to change over time. The resource assessments, that are the goal of the Energy Resources Surveys subactivity, are supported by research on the origin, occurrence, magnitude, and quality of energy resources, the development and evaluation of geophysical and geochemical techniques of exploration, and the implementation of computerized data systems.

Coal

The purposes of the Coal Resource Investigations program are to: increase research on the physical and chemical characteristics of coal, collect geologic data to aid in selecting future mine sites, develop geophysical techniques to provide data on buried coal beds, and establish a computerized National Coal Resource Data System.

The physical and chemical characterization effort is designed to acquire basic coal data through geologic

mapping, sedimentologic investigations, stratigraphic studies, petrologic determinations, and geochemical analyses of coal samples. Geologic, geochemical, and resource data and guidelines are needed by planners for use in regional development and siting of future coal mines. The geophysical techniques in coal exploration include borehole neutron-activation methods to provide accurate onsite chemical data on trace elements without the expense of laboratory analyses; and sonic, magnetic, and seismic methods of tracing coal beds in the subsurface. The National Coal Resources Data System consists of a series of computerized data files which contain information on the location and characteristics of the Nation's coal resources.

Fiscal year 1975 accomplishments included:

- Geologically mapping *approximately 1,900 square kilometres* (733 square miles) in coal-bearing areas of Wyoming, Montana, West Virginia, Kentucky, and Pennsylvania. Mapping was confined to areas of low-sulfur coal, including bituminous and subbituminous coal and anthracite.
- *Investigation of six potential coal mine sites on Federal land* in cooperation with the Bureau of Land Management, Bureau of Mines, Bureau of Indian Affairs, and Bureau of Reclamation.
- *Delineating previously unknown low-sulfur coal resources* in West Virginia, Virginia, and Kentucky which will aid in insuring an adequate supply of metallurgical coal.
- *Core drilling* in West Virginia, Kentucky, Wyoming, and Montana, thereby increasing the knowledge of the quantity and quality of low-sulfur coal deposits in these States.

Oil and Gas

The purposes of the Oil and Gas Resources Investigation program are to advise the Nation as to remaining oil and gas potential, emphasizing public lands onshore and offshore, and to conduct research that encourages and improves petroleum exploration. Petroleum exploration utilizes capabilities in geology, geophysics, geochemistry, remote sensing, and computer technology. In the exploration research and technology area, the objectives are to: (1) develop and apply operational laboratory methods capable of identifying and evaluating source rocks that could generate petroleum; (2) work out practical geophysical procedures that will use seismic data to indicate subtle stratigraphic traps that may contain oil or gas; (3) predict commercial reservoir porosity in ancient carbonate rocks through study of their modern counterparts; (4) predict accurately, prior to exploratory drilling, the porosity and permeability of potential sandstone reservoirs; (5) evaluate new geochemical procedures by which hidden petroleum accumulations may be identified at the surface through detection of trace-element anomalies produced by upward microseepage of oil or natural gas; and (6) develop borehole geophysical tools and methods capable of measuring reservoir porosity directly and accurately and of detecting the presence of previously overlooked and (or) cased-off oil and gas horizons.

Accomplishments in 1975 included:

- *Publication of new oil and gas resource estimates* for undiscovered recoverable oil and gas resources in the United States (Miller and others, 1975). The estimates, which involved more than 70 specialists who analyzed 102 possible petroleum provinces, indicate that undiscovered recoverable resources onshore and offshore amount to 50–127 billion barrels of crude oil, 322–655 trillion cubic feet of gas, and 11–22 billion barrels of natural-gas liquids. The ranges represent estimates at the 95- and 5-percent probability levels, respectively.
- *Identification of two geochemical anomalies in Colorado and Oklahoma* as promising oil and gas exploration targets.

Oil Shale

The purpose of the Oil-Shale Resource Investigations program is to determine the distribution and grade of oil shale deposits of the Green River Formation, Colo., Wyo., and Utah. The program also evaluates trace elements and the sodium and aluminum minerals associated with the oil shale. The oil-shale resource studies provide information pertaining to lease tract selections, equitable exchanges of private and public lands, shale-oil extraction methods, legal ownership of unpatented claims, and national energy policy. The resulting information supports the land classification and lease management activities of the Conservation Division. During 1975 the program mapped nearly 4,800 square kilometres (1,853 square miles) of land underlain by oil shale. These maps have been used by government and industry to establish the value of many parcels of land, and to appraise engineering and environmental problems related to oil-shale exploration and development.

Uranium and Thorium

The Geological Survey has been investigating the nuclear raw materials, uranium and thorium, since 1939. A large program was carried out from 1947 to 1958 in cooperation with the Atomic Energy Commission, and, in fiscal year 1975, the effort was again increased in cooperation with the Energy Research and Development Administration.

The Uranium and Thorium investigations improve the understanding of the nature and distribution of our nuclear fuel resources. These investigations call for resource assessments to aid Government planning and policy development, and exploration research to help industry obtain new supplies of uranium needed in the near future.

The program, which is closely coordinated with the Energy Research and Development Administration, includes studies in theories of origin of uranium in high-grade sandstone-type and vein deposits and the identification of new geologic environments of uranium occurrence, research in geophysical and geochemical exploration techniques and instrumentation, field studies of structural and sedimentological basin analyses, and detailed field and laboratory studies of selected uranium and thorium mining districts. Guides to new mining districts resulting from these various studies will be applied to delineate favorable areas for resource assessment and exploration by private industry. A National Uranium Resource Data Bank has been assembled to serve as a base for resource estimation and to permit evaluation of deposits and geologic environments.

Fiscal year 1975 accomplishments included:

- *Location of a geological discontinuity* closely associated with important known uranium ore-bearing strata in the San Juan Basin, N. Mex. This feature provides a key to future exploration of the region.
- *Location of an area favorable for uranium exploration* in the Wind River Basin, Wyo.
- *Demonstration that uranium can be detected by* a hole-to-hole electrical survey technique.
- *Location by remote sensing techniques of altered ground associated with uranium* in Wyoming and channels filled with potential conglomerate host rocks for uranium in Texas. A new fission-track method for determining the uranium in water and a new truck-mounted helium detector for field use have advanced the geochemical techniques.
- *Initiation of a nationwide survey of uranium concentrations in stream water and sediments* in cooperation with the Water Resources Division and the Energy Research and Development Administration
- *Investigations of various theories of uranium origin* have led to important new discoveries, such as the Shirley Basin and Powder River Basin districts.
- *Indication that uranium resources in Alaska* may be much greater than previously suspected as shown by recent reconnaissance geologic mapping.

Geothermal Energy

The Geothermal Energy Investigations program appraises the magnitude of regional and national geothermal resources, identifies promising target areas and regions for further exploration and development by industry, develops a scientific basis for improving appraisal and exploration methodology, and assists the Energy Research and Development Administration (ERDA) in locating sites for demonstration facilities. Current studies include: identifying areas of young silicic volcanic rocks; delineating areas of high heat flow; locating hot waters; mapping areas of geopressured aquifers; and developing mathematical methods and computer programs for calculating geothermal resources and reserves. Many of the exploration techniques used in the search for oil, uranium, and other minerals are of limited value in finding geothermal reservoirs. Therefore, new geological, geophysical, geochemical, and hydrological techniques must be found to explore and evaluate geothermal reservoirs and to evaluate individual Known Geothermal Resource Areas before leasing Federal lands.

Use of geothermal energy, unlike oil or gas, requires that conversion plants be within or near the producing fields. Before a specific geothermal reservoir can be developed, a method for predicting the energy potential of various types of geothermal systems must be available. Prediction of the energy potential of geothermal systems, however, is dependent on knowledge of the physical and chemical conditions in the systems at various depths.

Drilling will provide data on the lower boundary conditions of reservoirs and provide an understanding of how geologic and hydrologic hazards, such as land subsidence, induced microearthquakes, ground- and surface-water pollution, and ground-water depletion, might be created by withdrawal and reinjection of geothermal fluids. The changes in the temperature and pressure resulting from extraction of geothermal energy results in the solution and deposition of minerals that impede the energy-extraction process. In order to establish the basic thermodynamic properties of geothermal fluids essential for maintaining reservoir permeability and productivity, studies are being made to: evaluate existing data on thermodynamic properties of solutions and associated minerals, determine the thermodynamic properties of minerals and fluids where existing data are poor or lacking; determine the viscosity and volumetric properties of brines; and develop computer models to predict chemical reactions when geothermal fluids are withdrawn or waste fluids reinjected.

The accomplisments in fiscal year 1975 included:

- *Completion of an evaluation of the geothermal resources* of the United States in cooperation with ERDA (White and Williams, 1975). The geothermal resources are extensive in the United States, and that geothermal energy could indeed supply a significant part of the country's energy needs. In particular, the evaluation highlighted the huge amounts of energy stored in the geopressured resources of the Gulf Coast and concluded that these resources might well become economic within the next few years (fig. 36).
- *Development of a method of locating subsurface magma* by using the relative delays of seismic waves from distant earthquakes.
- *Demonstration of advanced electromagnetic and audio-frequency magnetotelluric techniques* to be rapid, inexpensive, and reliable for reconnaissance work in many geothermal areas.
- *Refinement of exploration models for geothermal systems* related to intrusive activity on the basis of investigations at the Geysers, Long Valley, and Coso Range, Calif., and Yellowstone Park, Wyo.

Energy Resource Data

An integral part of each of the energy resources surveys described above is the maintenance of a computerized data system. The Energy Resource Data program provides timely, accurate energy-resource data in useful form at minimal cost for Government planners, the exploration and scientific community, and the concerned public; builds and maintains computer-based energy-data files containing information from Government, both Federal and State, industry, and the universities; makes the files responsive to user needs in readily accessible format; and has the capability for graphic display of the data by digitized maps of resource occurrence and machine-processed charts and histograms.

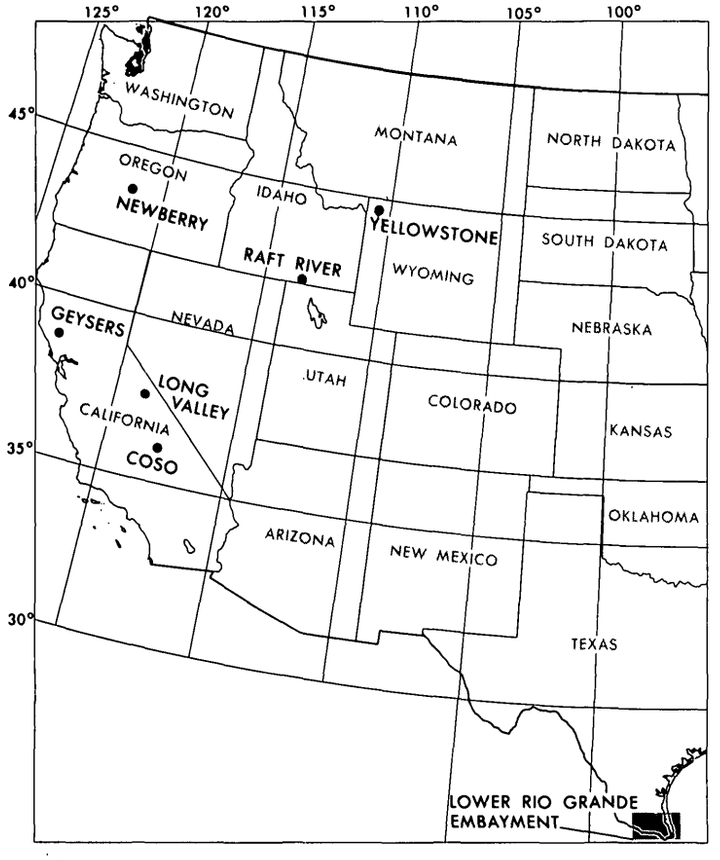


FIGURE 36.—Areas where geothermal investigations were conducted in fiscal year 1975.

The National Coal Data System consists of information on the major coal beds in the United States. The information contains type of coal, location, formation name and age, thickness of coal, thickness of overburden, and the source and reliability of the data. A separate file contains physical and chemical analyses for each coal bed sampled.

The Oil and Gas Data System contains information on the location, production, history, reservoir characteristics, and oil, gas, and water chemical analyses of oil and gas pools in the United States and Canada. At the end of fiscal year 1975, the system contained over 68,000 records of individual oil and gas pools.

The Oil Shale Data Storage contains information on Fischer Assay Analyses, saline analyses, chemical analyses, lithology, stratigraphy, thickness, and geophysical data of oil shale. Maps showing oil-shale thickness, content of volatiles, and overburden are prepared from the data for use in estimating the amount of shale-oil yield.

The National Resource Uranium Data Bank is being assembled from data on the location, physiographic province, rock type, mineralogy, and other information collected by the Geological Survey and the Atomic Energy Commission (now the Energy Research and Development Administration) during the 1950's. When completed the data will be entered in the Computerized Resources Information Bank. Thorium deposits will be added to the file at a future date.

The Geothermal Resources Data System contains information on location, surface-temperature data, well or drill-hole data, chemical analyses of steam vapor and water samples, heat-flow data and other information that characterize the resource and its energy potential. At present the file contains information on 155 locations throughout the United States.

OFFSHORE GEOLOGIC SURVEYS

The continental margins of the United States are the sites of sediment-filled basins which contain accumulations of petroleum and other mineral resources. Geographically, the margins consist of a continental shelf, slope, and rise (fig. 37). The Outer Continental

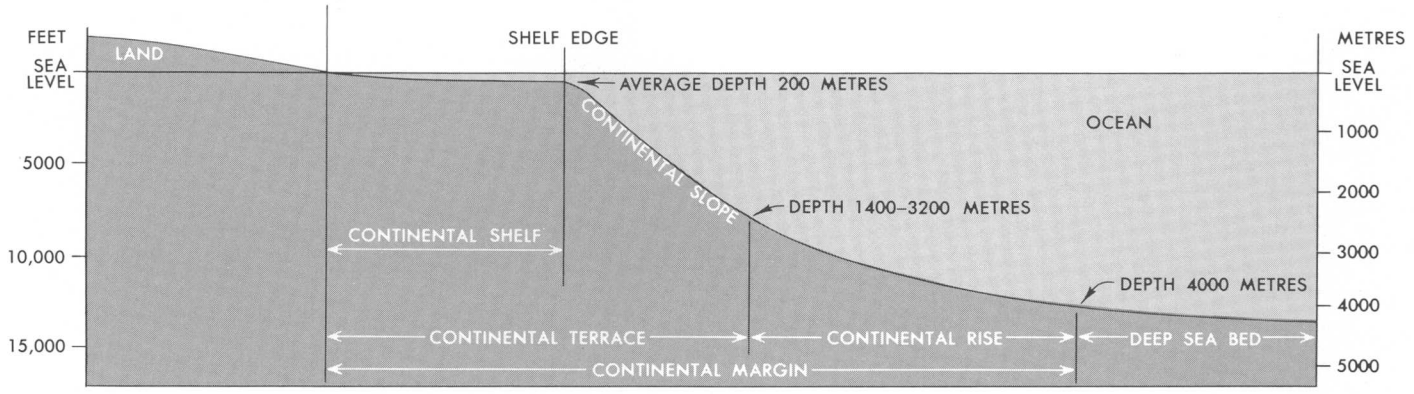


FIGURE 37.—Diagrammatic profile of the continental margin.

Shelf is the submerged land lying seaward of a State's jurisdiction—commonly 4.8 kilometres (3 miles). The continental shelf includes lands out to 200 metres (656 feet) water depth, and the continental slope, which is peripheral to the shelf, is in water depths ranging from 200 metres (656 feet) to about 2,500 metres (8,200 feet). The relationship of the continental shelf, slope, and rise to the landmass of the conterminous 48 States and Alaska is shown on figure 38.

The Offshore Geological Surveys subactivity assesses the potential mineral wealth of subsea areas and determines the nature of the geological and environmental hazards that might affect the siting of offshore energy facilities such as drilling rigs, production platforms, and pipelines. Because there is little information available about some of the offshore areas, a substantial amount of data needs to be collected and integrated in order to make reliable resource assessments. The assessments and support data are used by the Department of the Interior and the Bureau of Land Management to identify offshore areas for possible leasing and for preparation of environmental impact statements. Later on in the leasing process, the data supplement that data acquired by the Conservation of Lands and Minerals activity's Outer Continental Shelf Lands program. The combined data and interpretations assist the Bureau of Land Management in selecting tracts for inclusion in proposed lease sales.

The Department of the Interior's accelerated Outer Continental Shelf leasing program calls for about six oil and gas lease sales per year through calendar year 1978. This proposed schedule defines for the most part the timing of the Survey's data collection activities in the various sale areas. In frontier areas such as the Alaskan Outer Continental Shelf, substantial lead time is necessary because weather conditions limit data collection to only a few months each year.

Oil and Gas Resources Appraisal

The Offshore Oil and Gas Resource Appraisal program delineates sedimentary basins favorable for the occurrence of hydrocarbons, assesses the existence of geologic conditions conducive to the accumulation of oil and gas in giant fields, estimates the oil and gas resource potential of particular basins, determines specific areas within basins which have significant petroleum potential for Outer Continental Shelf lease sales, and provides geological and resource data and analyses to the Government, to coastal States, and to the public.

The Resource data are used to interpret basin configuration in three dimensions, generalized basin geologic framework, basin history (age of sedimentary rocks and structure), structural type and distribution of hydrocarbon traps, sediment thickness and quality, potential source beds and reservoir rocks (quality, quantity, and distribution), and analogy with known producing basins.

The estimates released by the Geological Survey in 1975, (Miller and others, 1975) are that the undiscovered recoverable resources for the offshore areas (including State water) to a depth of 200 metres (656 feet) total 10 billion to 49 billion barrels of oil, 1 billion to 6 billion barrels of natural gas liquids, and 42 trillion to 181 trillion cubic feet of natural gas. Petroleum resource estimates were not prepared for the continental slope and rise areas because the geological and geophysical data were insufficient to determine the amounts that could be discovered and recovered economically. However, recent discoveries in deep waters of the Gulf of Mexico and in the Santa Barbara Channel of California indicate that future production may extend down the continental slope.

Activities during 1975 included refinement of resource estimates released on the 17 continental shelf areas (1.4 million square kilometres or 540,400 square miles), development of preliminary estimates on the continental slope areas (1.2 million square kilometres or 463,200 square miles), and initiation of studies of the continental rise (2.8 million square kilometres or 1.08 million square miles).

Results of 1975 geological and geophysical investigations and interpretations suggests that:

- North, Middle, and South Atlantic Shelf areas have promising potential for oil and gas production.
- Substantial petroleum resources could be present in the Gulf of Alaska.
- Large accumulations of petroleum may exist in the area between the Aleutian Arc and the Beaufort Sea.

Environmental Investigations

The Environmental Investigations program identifies faults, slumps, sand waves, and other features which may pose a hazard to offshore energy development, investigates the manner in which oil and gas exploration and development might be a hazard to the onshore and offshore environments, and collects information for use in preparing environmental impact statements prior to Outer Continental Shelf lease sales. Examples of activities during the year include studies of potential geologic hazards in the Baltimore Canyon and Georges Bank areas (Atlantic Coast); studies of recent faulting in and around Monterey Bay, Calif.; studies of sea-floor sediments and faults off the southern California coast; and studies of environmental assessment of the Gulf of Alaska and in the Gulf of Mexico.

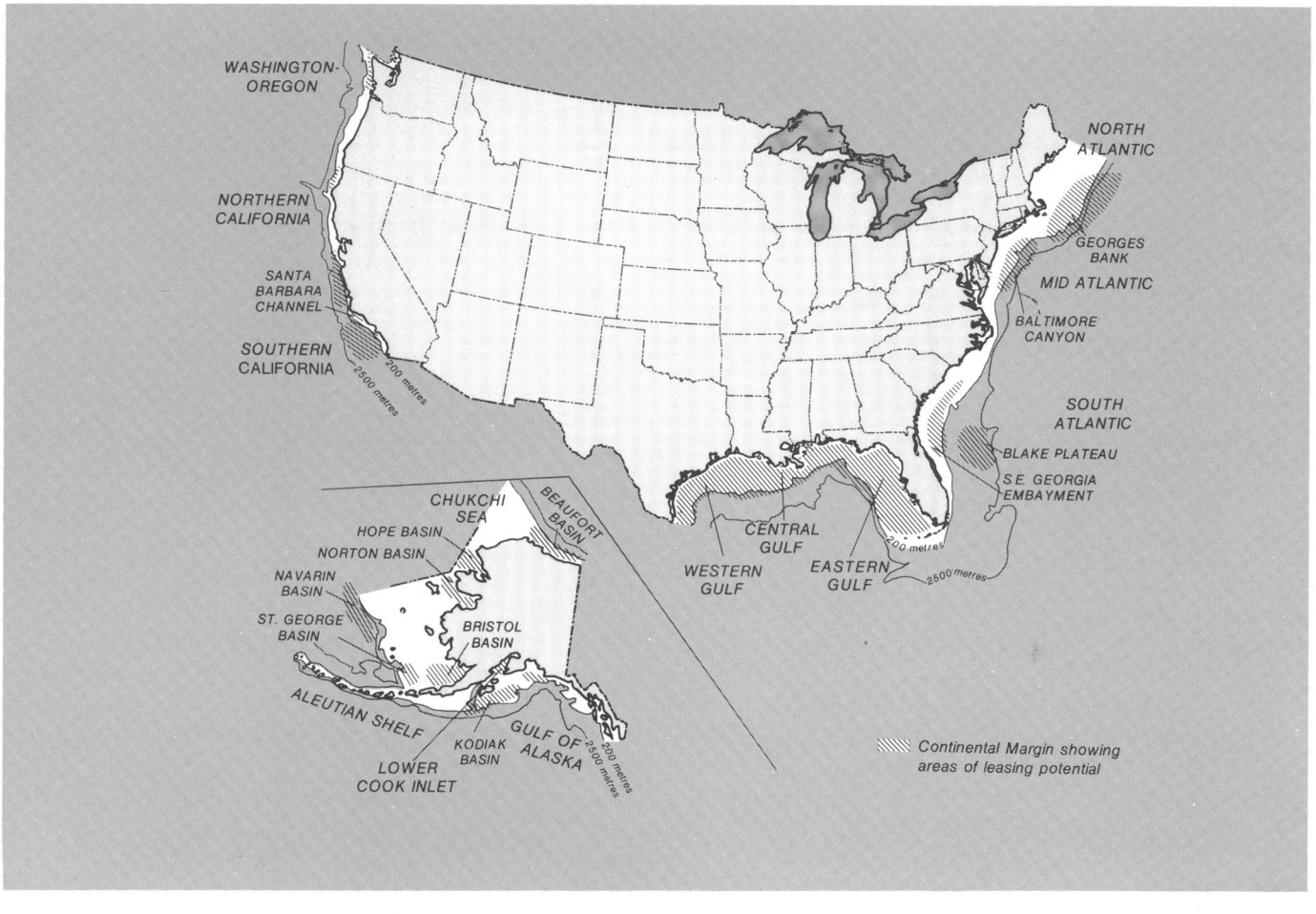
Highlights of fiscal year 1975 investigations included:

- *Identification of the sediment sources,* transport mechanisms, circulation patterns, and depositional environments of San Francisco Bay.
- *Identification of potential hazards* related to sedimentary instability of bottom sediments and to tectonic activity in the Mississippi delta area, where oil platforms have failed in the past.

Marine Geology

The Marine Geology program reinforces the other two programs of the Offshore Geologic Surveys subactivity. It develops better techniques for data collection and better analytical methods for data interpretation in order to increase the understanding of geologic history, existing conditions, and processes operating in marine areas. The current program includes: on the Atlantic Continental Margin, studies of the nature, extent, and type of nonpetroleum deposits, such as sand and gravel and the geologic history associated with them; on the coastal areas of Massachusetts, studies of the engineering properties of bottom sediments; in the Gulf of Mexico, studies of sediment instabilities and associated engineering properties of

FIGURE 38.—Outer Continental Shelf areas showing depth of water and areas leased or soon to be leased.



the sea floor; studies of coastal processes along the Texas shoreline and diagenesis in clays adjacent to diapirs; studies of tectonic hazards for nuclear reactor siting along the southern California coastline; and in the Alaska region, studies of gold placer deposits deep-sea clays. Interdisciplinary geologic and hydrologic studies with the Water Resources Division and the Land Information and Analysis Office are in progress in San Francisco Bay and Monterey Bay, Calif. and Willapa Bay, Oreg. in order to anticipate potential problems related to offshore energy development.

INTERNATIONAL ACTIVITIES

Geological Survey international activities during World War II responded to needs for strategic minerals. After the war, these activities evolved into long-range technical assistance programs under the United States Foreign Assistance Act, sponsored mostly by the Agency for International Development and its predecessors in the Department of State. In the last few years, however, a major part of the technical assistance program has been funded by reimbursable agreements with foreign governments and international organizations through the Department of State.

Since 1970, the Geological Survey has also participated in an expanded program of scientific cooperation and assistance with other countries, partly on behalf of other United States agencies and partly to gain a better understanding of geological phenomena and resources that are under investigation in the Survey's domestic program. The Survey is collaborating with the Department of State and Bureau of Mines to expand the Minerals Attaché and Reporting program to improve and standardize resource assessment procedures for the benefit of all countries.

Highlights of the 1975 program included:

- *Provision of technical guidance and assistance to* evaluate the potential for potash development in *Thailand and Laos.*
- *Identification of structurally controlled mineral belts in Saudi Arabia.* Detailed mapping and drilling extended several mineral districts containing gold, silver, and copper.
- *Documentation of a rapid decline of water levels in the Sanaa Basin* as a result of ground-water studies in the Yemen Arab Republic.
- *Continuation of the Circum-Pacific map project* to compile and publish a series of geologic, tectonic, mineral, and energy resources maps of the Pacific sea floor and adjacent continental areas on behalf of three international scientific organizations and in cooperation with 35 countries.

ASTROGEOLOGY

The Survey established the Astrogeology program in 1960 on behalf of the National Aeronautics and Space Administration to support lunar and planetary exploration. The program seeks to understand better the origin and evolution of the Earth, Moon, and planets, to map the geology of the Moon and planets, to formulate theories on planetary geologic phenomena that can be applied to terrestrial geologic problems, and to develop procedures and techniques to facilitate geologic investigations of the Earth, Moon, and planets. Current activities of the Astrogeology program include: systematic mapping of the stratigraphy and structure of the Moon, Mars, and Mercury; terrestrial analog studies, including field studies of natural and man-made impact craters and craters created by chemical and nuclear explosions; and laboratory studies of terrestrial rocks and minerals subjected to shock.

The most important result of planetary exploration will be an improved understanding of the early history of the Earth. The more that is known about each planet, the more that will be known about fundamental processes affecting the Earth. Little evidence remains of the events and processes that took place during the first 2 billion years of Earth's history. However, the early histories of the Moon and Mercury have been remarkably well preserved, and Mars, having a thin atmosphere, provides an experiment intermediate in complexity between primitive planetary bodies (Moon and Mercury) and Earth.

Geologic studies of the Moon, Mars, and Mercury have shown that these bodies had similar early histories. Geologic mapping and studies of returned lunar samples confirmed that the large circular lunar basins were formed by the impact of large moonlets at least 100 kilometres (60 miles) in diameter at ultra-high velocities. One of the most surprising results of the Mariner 9 mission to Mars was the discovery of huge volcanoes on the Martian surface. These volcanoes are enormous by terrestrial standards. Olympus Mons, for example, is 600 kilometres (370 miles) across and stands 25 kilometres (82,000 feet) above the surrounding plains. Another intriguing discovery on the surface of Mars is the abundance of channels and large canyons of various sizes and forms. Small channels are characteristically sinuous, with branching tributaries, much like terrestrial river channels. At least five types of channels have been delimited, ranging in age from about 2.5 billion years to near recent times.

ALASKA PIPELINE RELATED INVESTIGATIONS

The Alaska Pipeline Related Investigations activity began in fiscal year 1969 to collect geologic and hy-

drologic information upon which to base safeguards against possible pollution and environmental damage that might result from the construction and use of the Trans-Alaska Pipeline from Prudhoe Bay across predominantly Federal lands to Valdez. To date personnel from the Topographic, Geologic, and Water Resources Division have collaborated to publish more than 50 reports describing the terrain, geology, location of sand and gravel deposits, flood, ice, and water-quality characteristics of streams, ground water, earthquake hazards, the distribution and characteristics of permafrost (perennially frozen ground), and the environmental characteristics that control permafrost along the 15,500 square kilometres (6,000 square miles) of pipeline corridor. In addition, the Survey published 118 topographic and 14 engineering-geologic maps covering the pipeline route and, as lead agency, prepared the Department of the Interior's six-volume pipeline environmental impact statement (U.S. Federal Task Force on Alaskan Oil Development, 1972). These data are used by the Department's Alaska Pipeline Office to establish engineering design criteria and to assure that the pipeline contractor conforms to the technical and environmental stipulations of the construction permits.

With a staff of 12 and a budget of $344,000 in fiscal year 1975, the program continued geologic, hydrologic, and seismic investigations needed to support the construction and initial operating and monitoring phases of the pipeline project. Upon completion of the pipeline, the contractor will reimburse the Federal Government for this work ($6.0 million to date).

The Arctic Environmental Studies programs augments the Alaska Pipeline Related Investigations by conducting certain engineering geologic studies which are not covered under the reimbursibility clause of the pipeline program.

The Geological Survey has been instrumental in solving many of the serious engineering and environmental problems that were posed by the construction and operation of the 1,290-kilometre (800-mile) large-diameter hot-oil pipeline.

Highlights of fiscal year 1975 included:

- *Publication of ground motion values* for use in the seismic design of the pipeline.
- *Continuation of streamflow and water-quality* monitoring at 35 locations along the pipeline route to collect baseline data.
- *Continuation of earthquake* monitoring at several locations along the pipeline corridor.

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Water Resources Investigations

OVERVIEW

Many people take water for granted because it is as close as the nearest faucet, is safe to use, and is usually plentiful and inexpensive. To the farmer, industrialist, waterworks superintendent, home developer, and others, however, an adequate and safe supply of water in the right place at the right time is a matter for serious concern.

A number of local, State, and Federal agencies are involved in the investigation, management, and conservation of this vital national resource. The Geological Survey is the Federal agency that has principal responsibility for the continuing appraisal of the source, quantity, quality, and movement of the Nation's water resources; analytical and interpretive resource and environmental studies, including the hazardous aspects of water; and supportive basic and problem-oriented research.

At the direction of the President's Office of Management and Budget (U.S. Bureau of the Budget, 1964) and as further delegated by the Department of the Interior, the Survey's responsibilities were broadened in 1964 when it was designated the lead agency for coordinating the activities of all Federal agencies in the acquisition of certain water data from streams, lakes, reservoirs, estuaries, and ground water.

The Survey is in the unique position of being charged with gathering and publishing water facts without having the responsibility for managing or developing water resources. Through the years, the organization has established a reputation for maintaining high standards in scientific and engineering studies and for substantial and widely distributed reporting of the results of water-resources investigations. For example, during fiscal year 1975 alone, more than 900 different water reports and 1,198 maps authored by Survey personnel were made available to the public in Federal, State, and local publications, in technical journals, or in depositories for public inspection (tables 45 and 46).

Another important characteristic of the Geological Survey's water program is the large and widespread financial support given to it by State and local agencies. The Federal-State Cooperative program of water investigations comprises more than one half of the entire water effort and is funded by equal amounts of Federal and State and local appropriations. Such an arrangement of many years' standing has helped assure consideration of and program responsiveness to the mutual water-information needs at Federal, State, and local levels. To carry out this work, the Survey's Water Resources Division has one or more offices in all 50 States, Puerto Rico, and Guam (fig. 39).

In addition to their responsibilities for water-resources investigations, the Water Resources Division's district offices also serve as points of contact for those wishing to obtain information about the status of other Geological Survey programs in each State. The addresses and telephone numbers of these offices are listed on page 145.

Programs

The Water-Resources Investigations activity consists of two subactivities: the National Water Data System and Critical National Water Problems.

The National Water Data System programs comprise 95 percent of the water-resources studies carried out by the Geological Survey and constitute a large part of governmentwide water-data collection activities. For example, in 1972, the Geological Survey operated more than 70 percent of all surface-water stations (streamflow, lake level, and water stage) reported by 17 Federal and 193 non-Federal agencies. The Survey also was responsible for 35 percent of all sites at which the quality of ground and surface water was measured. The objectives of the National Water Data System are to appraise the Nation's water resources and to provide the water data and information needed to develop and manage these resources efficiently. Investigations include collecting basic information at hydrologic-data stations, making areal studies, and conducting supportive research.

The Critical National Water Problems subactivity focuses on data collection, problem-oriented studies, and research to aid in solving water problems of national concern. In fiscal year 1975, for example, critical water problems included studies of water availability for energy development, studies of groundwater recharge in the High Plains of Texas and on Long Island, N.Y., delineation of geologic formations suitable for waste storage, mapping of flood-prone areas, and investigations of estuaries and water resources of coastal areas.

Budget and personnel

In fiscal year 1975, $101.4 million obligated by the Water-Resources Investigations activity came from three sources (fig. 40 and table 26):

- Direct Congressional appropriations for the Federal program.
- Joint Congressional and State and local appropriations for the Federal-State Cooperative program.
- Funds transferred from other Federal agencies and State and local agencies for reimbursable programs.

FIGURE 39.—Location of principal offices of the Geological Survey's Water Resources Division in the conterminous United States. Cities named are those where regional and district offices are located. In addition to the subdistrict offices noted on the map, there are two subdistrict offices in Alaska, three in Hawaii, and one on Guam, all in the western region.

The work funded by these three sources is subdivided into a number of subactivities and programs listed in table 10.

The teamwork and expertise of almost 3,000 full-time personnel are essential to carry out the many water-resources studies and data-collection activities of the Water Resources Division. In 1975, the Division employed 1,280 hydrologists, 202 other professional engineers and scientists, 1,205 technical specialists and aids, and about 270 persons who provided administrative, secretarial, and clerical services. An additional 653 persons were temporarily employed as field assistants and technicians.

Federal program

The Federal program, amounting to $26.4 million [1] in fiscal year 1975 (26 percent of the Geological Survey's total water program), is designed to provide the nationwide base level of resource data for planning and management and to improve the scientific basis of hydrologic investigations and techniques. Water-data collection, resources investigations, and research activities support that segment of the National Water Data System in which the Federal interest is paramount, including the public domain, interstate river basins and aquifers, and other areas of international or interstate concern.

The Federal program supports the operation of more than 700 surface-water measurement—stage and (or) discharge—stations throughout the Nation, including nearly 650 sites where stream discharge is gaged continuously. The program also includes the operation of the National Stream Quality Accounting Network (fig. 41), hydrologic research, and the publication of water reports.

Federal-State program

The Federal-State Cooperative program consists of projects funded on an equal matching basis by the Geological Survey and State and local agencies—some 550 in fiscal year 1975 (table 11). These projects contribute to the solution of urgent National and State problems and complement the federally funded part

[1] In fiscal year 1975, $53.4 million was appropriated for the Water-Resources Investigations activity, $27.0 million of which was used to match State and local agency funds (table 36). The balance, $26.4 million, is referred to here as the Federal program.

of the National Water Data System. Once the existence of a Federal interest in a proposed project is identified, cooperative projects are jointly planned at grassroots levels by State (or local) and Federal representatives, and thus optimum melding of Federal and State priorities is assured. The Cooperative program totaled $54 million,[2] 53 percent of the total water program, in fiscal year 1975.

Efficient and effective conservation, development, and utilization of the Nation's water resources are dependent upon an adequate data base. The Cooperative program provides more than half of that base and is a continuing program which directly responds to the changing mutual needs of Federal, State, and local governments for data.

Ongoing activities in the Cooperative program in 1975 were distributed as follows:

- Data collection, analysis, and dissemination, including nearly 5,000 continuous-record and 7,700 partial-record (high and (or) low flow) streamflow sta-

[2] Includes $27.0 million specifically appropriated for the Federal-State Cooperative program (table 36) and $27.0 million of matching State and local agency funds.

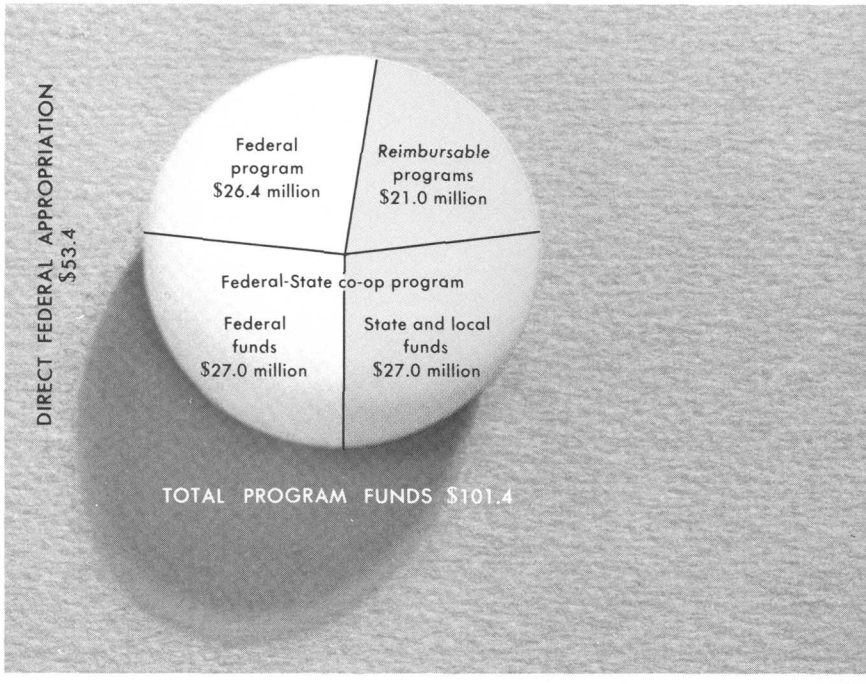


FIGURE 40.—Sources of fiscal year 1975 funds for Water-Resources Investigations (dollars in millions).

TABLE 10.—*Water-Resources Investigations activity obligations for fiscal year 1975, by program*
[Dollars in millions]

Program	Source of funds					Percent change relative to fiscal year 1974	
	Federal program[1]	Federal-State Cooperative program[2]	Other Federal agency programs[3]	Non-Federal programs[4]	Total	Current dollars	Constant dollars
TOTAL	$26.42	$54.00	$18.57	$2.45	$101.44	+15	+4
National Water Data System	21.19	54.00	18.57	2.45	96.21	+12	+1
Collection, analysis, and dissemination of streamflow, water-quality, ground-water, and sediment data[5]	12.01	26.40	3.70	1.66	43.77		
Regional and areal resource appraisals	.98	15.08	4.90	.30	21.26		
Studies related to critical water problems	----	5.80	7.00	.15	12.95		
Core program of hydrologic research	4.90	----	----	----	4.90		
Other data collection and applied research	----	6.72	2.97	.34	10.03		
Hydrologic investigations on public lands (soil and moisture conservation)	.23	----	----	----	.23		
Publications and other supporting services	3.07	----	----	----	3.07		
Critical National Water Problems	5.23	----	----	----	5.23	+114	+93
Accelerated energy research and development programs	2.60	----	----	----	2.60		
Coal hydrology	1.20	----	----	----	1.20		
Oil-shale hydrology	1.30	----	----	----	1.30		
Underground heat storage	.10	----	----	----	.10		
Ground-water recharge	.93	----	----	----	.93		
Subsurface waste storage	1.10	----	----	----	1.10		
Flood-hazard mapping	.30	----	----	----	.30		
Estuarine and coastal studies	.30	----	----	----	.30		
Percent change relative to fiscal year 1974:							
Current dollars	+31	+7	+19		+15		
Constant 1967 dollars	+18	−4	+8		+4		

[1] Federal funds excluding those used to match funds from State and local agencies.
[2] Includes Federal funds used to match State and local agency funds on a 50-50 basis.
[3] Funds from 21 other Federal agencies transferred to the Geological Survey.
[4] Includes unmatched funds from State and local agencies, funds from permittees and licensees of the Federal Power Commission, and funds from minor miscellaneous sources.
[5] Federal funds include support of coordination of national water data and the National Water Data Exchange.

tions, more than 4,000 stations for measuring the chemical, physical, and biological quality of streams, lakes, and ground water, and more than 8,000 ground-water observation wells.

- Areal resource appraisals and problem-related studies, including urban hydrology, sedimentation, lakes, hydrobiology, stream-system modeling, aquifer modeling, water-quality modeling, saline waters, flood frequency and magnitude, floods and droughts, waste disposal, and others, for a total of 576 areal resource projects.

- Studies related to critical problems, including 15 projects on burial of wastes, 13 projects on estua-

TABLE 11.—*State and local agencies, by State, with which the Geological Survey had a written agreement for fiscal cooperation (Federal-State Cooperative program) in Water-Resources Investigations in fiscal year 1975*

State	Number of agencies				
	State	County	City	Other	Total
TOTAL	197	118	122	113	550
Alabama	2	1	1	---	4
Alaska	5	---	6	3	14
Arizona	4	3	3	6	16
Arkansas	4	---	---	---	4
California	5	36	7	26	74
Colorado	5	4	7	10	26
Connecticut	1	---	3	1	5
Delaware	2	---	---	---	2
District of Columbia	1	---	---	---	1
Florida	8	22	25	11	66
Georgia	4	2	1	---	7
Hawaii	3	---	2	---	5
Idaho	2	---	---	---	2
Illinois	6	6	1	4	17
Indiana	3	---	2	1	6
Iowa	6	1	3	---	10
Kansas	4	---	1	1	6
Kentucky	1	---	---	---	1
Louisiana	3	---	---	1	4
Maine	3	---	---	---	3
Maryland	4	1	1	2	8
Massachusetts	4	---	---	---	4
Michigan	2	---	---	---	2
Minnesota	4	---	1	1	6
Mississippi	5	2	1	3	11
Missouri	3	1	1	---	5
Montana	7	1	---	---	8
Nebraska	6	5	---	4	15
Nevada	3	---	---	---	3
New Hampshire	2	---	---	---	2
New Jersey	3	2	---	4	9
New Mexico	6	---	2	4	12
New York	9	14	4	8	35
North Carolina	3	1	6	---	10
North Dakota	2	1	---	---	3
Ohio	3	---	2	2	7
Oklahoma	4	---	1	---	5
Oregon	4	5	9	4	22
Pennsylvania	3	1	4	2	10
Rhode Island	3	---	---	---	3
South Carolina	5	---	1	---	6
South Dakota	2	---	2	2	6
Tennessee	6	2	6	2	16
Texas	2	1	4	2	9
Utah	3	1	---	1	5
Vermont	2	---	---	---	2
Virginia	4	2	5	---	11
Washington	4	1	5	5	15
West Virginia	3	---	2	---	5
Wisconsin	4	2	2	---	8
Wyoming	6	---	1	---	7
Puerto Rico	3	---	---	---	3
Virgin Islands	1	---	---	---	1
American Samoa	---	---	---	1	1
Guam	---	---	---	1	1
Trust Territories	---	---	---	1	1

rine problems, 19 projects on artificial recharge, and 4 projects on flood-hazard mapping.

- Applied research on hydrologic problems, principles, and techniques.

One of the quickest ways to gain an insight into the nature and wide scope of the effort involved in the Federal-State program is to scan the titles of a few of the more than 600 reports published from Cooperative projects:

Salt-balance study of Pauba Valley, upper Santa Margarita River area, Riverside County, California.

Chemical and biological quality of Lake Dicie at Eustis, Florida, with emphasis on the effects of storm runoff.

Application of statistical techniques to the estimation of ground-water withdrawals (Kansas).

Floods in East Baton Rouge Parish and adjacent areas, Louisiana, for the period 1953–74.

Availability of ground water in the Saco River basin, east-central New Hampshire.

Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota.

Estimating streamflow characteristics for streams in Utah, using selected channel-geometry parameters.

A method for the relative classification of lakes in the State of Washington from reconnaissance data.

Other Federal agency programs

Other Federal agency programs, amounting to $18.6 million in fiscal year 1975, consist of work carried out by the Geological Survey at the request of 21 other Federal agencies to provide them with information for use in support of their missions.

Examples of work performed for 6 of the 21 Federal agencies are:

Department of Agriculture.	Stream discharge, quality, and trap-efficiency studies; hydrologic studies on small watersheds.
Department of Housing and Urban Development.	Flood-insurance studies (flood-plain delineation, flood profiles, flood frequency).
Department of Transportation.	Stream discharge and flood-frequency data; hydrologic studies on small watersheds, scour, and bank erosion.
Energy Research and Development Administration.	Hydrologic and water-supply exploration studies at test sites; research in field of radiohydrology related to interaction between radioactive materials and the environment, both above and below ground.
Environmental Protection Agency.	Collection of water-quality information; study of relationship of ground water to lakes; national eutrophication survey; waste-disposal site studies.
National Aeronautics and Space Administration.	Applications of remote sensing to hydrologic problems (ground water, estuaries, water temperature, lakes, glaciology, snowcover mapping).

As with the Federal-State program and much of the Federal program of the Geological Survey, the work of other Federal agency programs is classified into four main elements (data collection, resource appraisals, critical problems, and research) for the purposes of budgeting and planning (table 10). Thus, the work of the three major programs that constitute the total effort of the Geological Survey in Water-Resources Investigations—Federal, Cooperative, and other Federal agencies—is mutually supportive in terms of measuring and appraising the Nation's water resources.

Non-Federal program

Non-Federal reimbursable funds are unmatched funds received by the Geological Survey from State and local agencies ($1.54 million) in situations where there is both Federal and State interest in investigation of water resources but where matching Federal funds are either unavailable or are not otherwise applicable to cost sharing. A large part of the work in this category during fiscal year 1975 was for energy-related water studies in Colorado, Utah, and Wyoming. Also included with the non-Federal reimbursable funds are monies ($901,000) received from permittees and licensees of the Federal Power Commission.

Highlights

Studies that received strong emphasis during fiscal year 1975 included:

Water and energy

The energy problems of the winter of 1973–74 not only stirred the Nation to reappraise and intensify the development of its fuel resources but also turned the spotlight on water. Would there be enough water for mining, refining, and transportation of fuels at the times and places needed? What would be the effects on existing water sources and uses in those places? A significant start toward finding answers to such questions was made during fiscal year 1975, including the beginning of energy research and development studies in 22 States, principally on oil-shale hydrology, coal hydrology, and nuclear hydrology.

Water quality

A much strengthened and broadened water-quality measurement network for the Nation's streams was begun during the 1973–75 period. The National Stream Quality Accounting Network is commonly referred to by its acronym, NASQAN. NASQAN measures chemical, physical, and biological characteristics of water to provide baseline water-quality information for national and regional evaluation and planning.

The network not only shows geographic variations and changes in stream quality but also determines trends and provides baseline data for future assessments of changes in stream quality. As of January 1, 1975, there were 345 stations, about 60 percent of the total planned network (fig. 41).

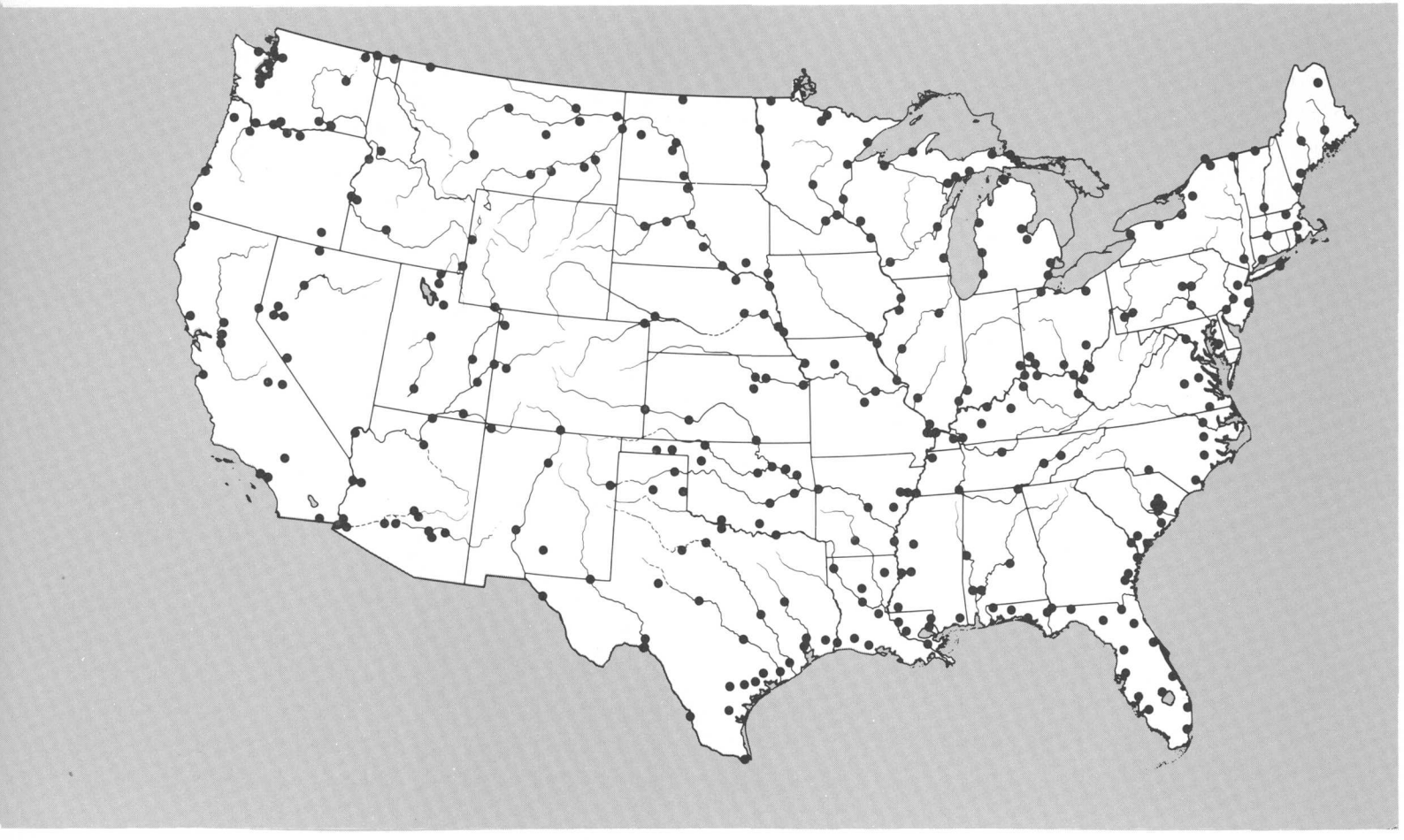


FIGURE 41.—Locations of stations in the National Stream Quality Accounting Network (NASQAN) in operation as of January 1, 1975, in the conterminous United States (Ficke and Hawkinson, 1975, p. 9). Stations not shown include six in Alaska, six in Hawaii, and three in Puerto Rico.

Ground water

Substantial progress was made on the regional appraisals of ground-water resources that began in 1970. These regional assessments—a series of 21 reports that will describe ground water throughout the Nation, including Puerto Rico—will give an overall picture of this somewhat "hidden" segment of the country's water resources. They will also identify ground-water problems and the locations of major present and potential ground-water development. Ground water is a large, important, and manageable resource that, in many parts of the Nation, can play a significant role in regional water supply and warrants full consideration as an alternative or supplemental source of water. In 1975, appraisal reports were published in the Geological Survey's professional paper series for three river-basin regions: Ohio, Rio Grande, and Upper Colorado. Reports for the Upper Mississippi, Texas-Gulf, and California-South Pacific regions were in press; manuscripts completed for four other regions were under review.

National Water Data Exchange (NAWDEX)

Preparations for the implementation of the National Water Data Exchange were nearly completed by the end of fiscal year 1975. The purpose of the Exchange is to give all water-data users better and more rapid access to water data by coordinating and linking, via computer terminals, major Federal and non-Federal water-data collector and user organizations. During fiscal year 1975, a contract was completed that included (1) designing the structure, formats, and operating procedures for the Master Water Data Index and (2) preparation of initial operations manuals. The first data that will be available directly to NAWDEX participants from computer storage will be the "daily

values" file containing data on stream discharge (flow) and reservoir contents as well as daily water-quality data such as temperature, specific conductance, and suspended sediment concentration.

Mapping in flood-prone areas

During 1975, many flood-prone areas in the United States were mapped to provide a basis for minimizing future flood hazards and damages through land use planning, structural design, and insurance. Much of the mapping, begun in fiscal year 1969 and funded by the Department of Housing and Urban Development, carries out a recommendation made in 1966 by the Task Force on Federal Flood Control Policy (White and others, 1966). The Survey published 1,140 maps in 1975, each showing on a topographic base map the boundaries of areas that would be under water from a major flood (one likely to occur on the average once in 100 years); 938 of the maps were prepared by district offices of the Survey, and 202 were prepared by the Soil Conservation Service. Figure 42 shows the number of maps published each year since 1969.

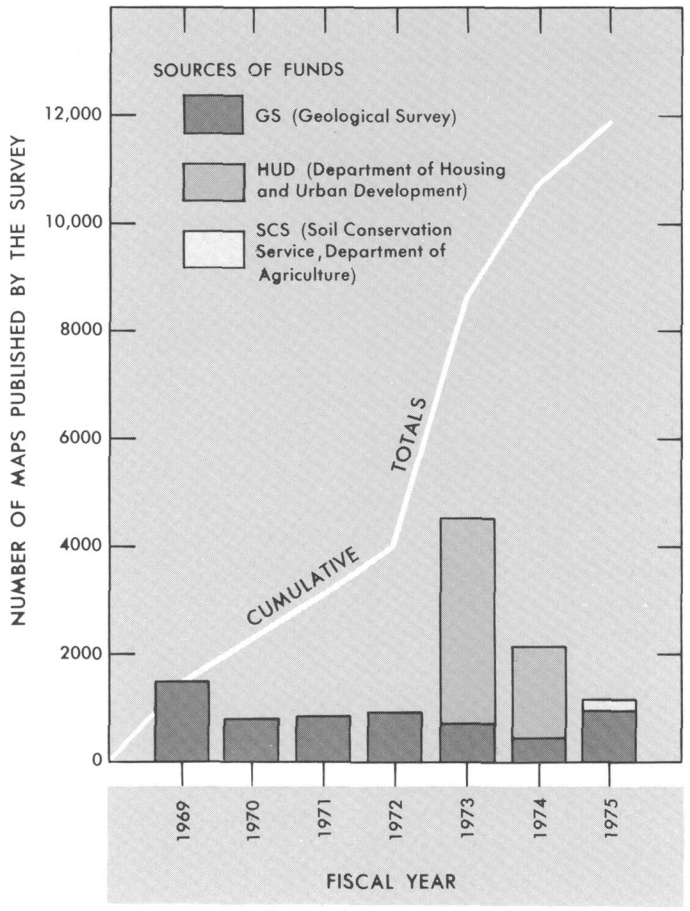


FIGURE 42.—Maps of flood-prone areas published by the Geological Survey, fiscal years 1969–75, and sources of funds. All maps were prepared by Geological Survey except for 202 maps prepared by Soil Conservation Service in 1975.

Other national water problems

The Survey continued to give strong emphasis during 1975 to research on ground-water recharge and subsurface waste storage. Ground-water-recharge studies are using water-spreading basins and injection wells located in the semiarid High Plains of west Texas and New Mexico and in the glacial deposits on Long Island, N.Y., to investigate the feasibility of artificially augmenting ground-water supplies with surface water that would normally leave the area as streamflow or evaporate into the atmosphere. Subsurface waste-storage investigations are providing planners and managers of waste-storage and disposal activities with information that will be used to prevent or minimize ground-water pollution. Studies conducted in 1975 continued to concentrate on the fundamental principles that control (1) the chemical reactions of wastes and other pollutants with aquifer materials and (2) the subsurface movement, dilution, and dispersion of pollutants in ground water.

New series of hydrologic maps

In 1975, the Survey published the first 14 maps in the new series of Hydrologic Unit maps of States. The new four-color maps use the Survey's State base map series at a scale of 1:500,000 to show hydrologic boundaries with numerical codes identifying each subdivision and counties or county equivalents. The maps, developed in cooperation with water-oriented Federal and State agencies, including the U.S. Water Resources Council, are designed for use in planning activities and in organizing and disseminating data on both a civil-unit and a hydrological basis. The maps for the remaining States and the Caribbean region are to be published during fiscal year 1976.

ELEMENTS OF NATIONAL WATER-DATA SYSTEM

Interagency water-data coordination

The Survey's Office of Water-Data Coordination continued during fiscal year 1975 to work closely with a large number of governmental agencies and representatives (see table 12) in the planning, design, and documentation of water-data networks and in the planning and development of standards for water-data acquisition. This closely coordinated effort is especially important because about 19 Federal and at least 200 non-Federal agencies collect water data, and 40 Federal agencies and more than 600 non-Federal agencies use water data.

TABLE 12.—*Activities and participants of interagency water-data coordination committees and groups associated with the Survey's Office of Water Data Coordination*

Activity	Participants
Coordination of Federal agency water-data programs through Interagency Advisory Committee on Water Data.	31 Federal agencies.
Consultation with non-Federal community of data users through Advisory Committee on Water Data for Public Use.	24 members.
Design of national system for handling water data.	13 Federal agencies.
Development of recommended methods for collecting water data; includes Coordinating Council for Water Data Acquisition Methods (17 Federal agencies).	21 Federal agencies and 150 scientists in 10 working groups.
Design of small-watershed network.	10 Federal agencies.
Field coordination and development of 21 regional plans annually for water data.	27 Federal agencies and 120 field officials.
Assessment of river quality—Ad Hoc Working Group of Advisory Committee on Water Data for Public Use.	9 members.

Strong emphasis was placed during 1975 on work-group activities designed to produce a comprehensive "National Handbook of Recommended Methods for Water-Data Acquisition," an update of a preliminary report issued in 1972 (U.S. Geological Survey, 1972). Particularly important was the addition of methods and concepts by non-Federal members of the work groups. Another major activity during the year was preparation and publication of the first 14 maps in the new nationwide series of four-color State Hydrologic Unit maps, scale 1:500,000, covering 18 States (fig. 43).

Collection, analysis, and dissemination of basic water data

The collection and analysis of basic water records, such as the flow (discharge) of a stream, the level (stage) of a lake, the water level in a well, the chemical quality and sediment load of a stream, and the amount of water used by a large industry or public supply, are fundamental building blocks upon which all other aspects of water-resources investigations rest. These kinds of measurements are necessary first steps in determining how much and what kind of water is available when and where and then in comparing these quantities with water used and water needed. Basic water data are essential not only to determine the adequacy of water supplies but also to design culverts, bridges, dams, and other public works, to prevent or lessen the damages and impacts of floods and droughts, to determine the feasibility of water-power and irrigation developments, and to some extent to plan projects for water-pollution control, navigation, and outdoor recreation. About 40 percent of the water funds that the Geological Survey receives from all sources supports basic-data activities—the largest single major element of the National Water Data System.

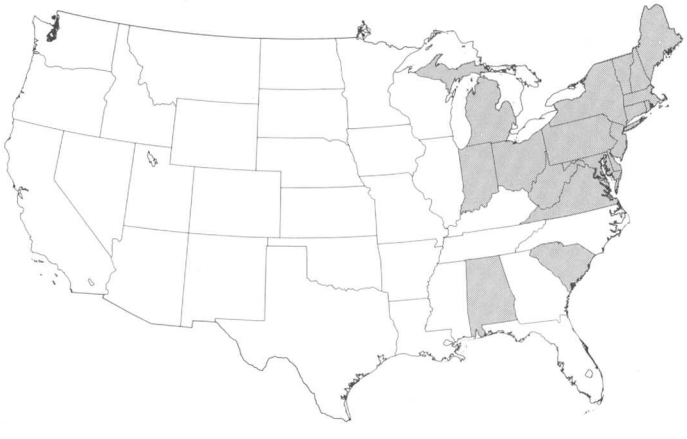


FIGURE 43.—Location of areas covered by maps published in fiscal year 1975 in the Survey's new series of State Hydrologic Unit maps (scale 1:500,000).

In 1975, the Survey maintained continuous discharge records at 7,700 stream sites, analyzed water quality at nearly 5,000 stream sites, and measured water levels or other parameters periodically in more than 8,000 wells (table 13).

Most of the streamflow and stream-quality data that the Survey collects and analyzes is not only published in various Federal and State reports but is also filed in computer storage. Plans are underway to have much of the Survey's ground-water data, including water levels and chemical quality, added to its national water-data storage and retrieval system, WATSTORE. Also, WATSTORE itself is being made more accessible to the water-data user by the installation of computer terminals in most district offices of the Survey's Water Resources Division (fig. 39).

During the year, major emphasis was placed on "baseline water quality." The baseline surface-water-quality concept is a system of continuing multipurpose measurements of stream quality, designed to be the factual base for waste-management and water-supply studies by all concerned levels of government. During fiscal year 1975, 245 sites were added to the 100 stream sites that were already part of the baseline NASQAN system; about 60 percent (see fig. 41) of the total planned network has now been completed.

More than 40 chemical, physical, and biological characteristics (table 14) are being measured at each of the 345 NASQAN stream sites (fig. 41); in addition to these analyses, radiochemical analyses are being made at 50 sites and pesticide analyses at 153 of the network sites. The NASQAN program will provide a balanced and unbiased basis for evaluating stream-quality conditions and changes in the United States for use by Federal, regional, and State agencies in

TABLE 13.—*Number and type of measurement sites (stations) of the Geological Survey and sources of funds for station operation, April 1975*

Type of station	Federal program	Federal-State Cooperative program	Other Federal agency programs	Non-Federal program [1]	Total
SURFACE-WATER FLOW OR CONTENTS					
TOTAL	711	13,007	2,433	591	16,742
Continuous discharge	643	4,884	1,789	391	7,707
Partial discharge (high flow and/or low flow)	43	7,684	463	42	8,232
Lake reservoir and contents	25	439	181	158	803
SURFACE-WATER QUALITY					
TOTAL	608	4,188	1,220	41	6,057
Surface-water stations (excluding temperature only)	418	3,570	954	40	4,982
Sediment stations	190	618	266	1	1,075
GROUND WATER					
Sites at which at least one ground-water parameter (such as water level) is collected on a recurring basis	---	-----	----	---	8,133
Sites at which ground-water parameters are collected on a nonrecurring basis	---	-----	----	---	9,197
Sites for which well records are maintained in computer files	---	-----	----	---	109,737
Sites for which spring records are maintained in computer files	---	-----	----	---	2,139
Sites for which water-quality data are on file	---	-----	----	---	62,205

[1] Includes permittees and licensees of the Federal Power Commission.

judging the effectiveness of current quality-control programs and in assessing management alternatives on a nationwide scale. In terms of Federal interest, NASQAN is designed to respond to the stream-information requirements of agencies such as the Water Resources Council, the Council on Environmental Quality, the Corps of Engineers, and special commissions such as the National Commission on Water Quality. In addition to responding to these demands, the network complements the efforts of the Environmental Protection Agency in fulfilling the information requirements specified under section 104(a)(5) of the Federal Water Pollution Control Amendments of 1972 (Public Law 92–500), which calls for the establishment of a nationwide water-quality surveillance system.

The Survey is also conducting a pilot program of river-quality assessments. The objective is to develop and demonstrate an approach and a technical methodology by which water-resource planners and managers can use basic water-quality information to assess river-quality problems and evaluate management alternatives.

TABLE 14.—*Characteristics measured at NASQAN stations (Ficke and Hawkinson, 1975, p. 8)*

[Frequencies: C, continuous; D, daily; M, monthly; Q, quarterly]

Characteristic	Frequency
Field determinations:	
Water temperature	[1]C, D, or M
Specific conductance	[1]C, D, or M
pH	M
Discharge	C
Coliform, fecal	M
Streptococci, fecal	M
Common constituents (dissolved): (Bicarbonate, carbonate, total hardness, noncarbonate hardness, calcium, magnesium, fluoride, sodium, potassium, dissolved solids, silica, turbidity, chloride, and sulfate).	[2]M or Q
Major nutrients:	
Phosphorus, total as P	M
Nitrite plus nitrate, total as N	M
Nitrogen, total Kjeldahl as N	M
Trace elements (total and dissolved): (Arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, selenium, and zinc).	Q
Organics and biological:	
Organic carbon, total	Q
Phytoplankton, total, cells/ml	M
Phytoplankton, identification of 3 co-dominants	M
Phytoplankton, 3 codominants, percent of total	M
Periphyton, biomass, dry weight g/m^2	Q
Periphyton, biomass, ash weight g/m^2	Q
Periphyton, chlorophyll *a*	Q
Periphyton, chlorophyll *b*	Q
Suspended sediment:	
Suspended sediment concentration	M
Percent finer than 0.062-mm sieve diameter	M

[1] Continuous or daily depending upon whether the station is equipped with a monitor or whether daily observations are made. Monthly measurements made at stations where a long-term record is available.

[2] Quarterly or monthly, depending upon whether relationships have been established between conductance and concentrations of various common constituents.

The intensive river-quality assessment of the Willamette River basin in Oregon was within a few months of completion by the end of June; several reports on methods and results were being reviewed, and several others were in preparation. Near the end of the year, two new pilot river-quality assessments were begun—one in the Chattahoochee River basin in Georgia and the other in the Yampa River basin of Colorado and Wyoming. The Chattahoochee study will address problems related to thermal loading and heat dissipation, wastes from concentrated urban-industrial areas, effects of hydropower pulsations on river quality, and sediment movement and deposition. The Yampa assessment will investigate water problems related to development for energy production, especially the impact on river quality of water derived from coal extraction and conversion.

Regional and areal resource appraisals

The Federal-State Cooperative program is the principal source of funds for areal water-resources investigations. In fiscal year 1975, 576 areal projects were a part of the program. Most such projects are studies of ground or surface water (or both) in a river basin, aquifer, county, metropolitan area, or city. These projects are generally completed in 1 to 3 years with a published report.

An important component of areal water-resources investigations in 1975 was the substantial progress made on a nationwide series of regional appraisals of ground water. During fiscal year 1975, 3 of the regional reports were published, and 11 others moved ahead toward completion (fig. 44).

A few highlights from the first three reports are:

- The Ohio region—Bloyd (1974) reported that:

  Nearly 80 percent of the total potable ground water available from natural storage (water-bearing formations) in the region is from the outwash and alluvial aquifers in the Ohio River valley.

  Annual regionwide water use is a small fraction of the average annual recharge—only 3 percent in 1965, for example.

  Of the region's subbasins, the Wabash and the White probably have the highest potential for additional ground-water development.

FIGURE 44.—Status of regional ground-water appraisals as of June 30, 1975. (Studies of the remaining seven regions, including Alaska, Hawaii, and Puerto Rico, will begin as other studies are completed.)

- The Rio Grande region—West and Broadhurst (1975) reported that:

  Withdrawal of ground water in 1970 was about 3,300 cubic hectometres (2.7 million acre-feet), of which nearly 90 percent was for irrigation.

  The largest ground-water reservoirs are in the San Luis Valley and Albuquerque subregions, each of which contains about 2.5 million cubic hectometres (2 billion acre-feet) of fresh and slightly saline water.

  Salvage of water lost to noneconomic evapotranspiration in wet phreatophyte-infested areas offers the greatest possibility of improving the effective water supply of the region.

- Upper Colorado region—Price and Arnow (1974) reported that:

  The sparsely populated region is used chiefly for grazing, recreation, and mineral development; only about 2 percent of the region's water use in 1970 came from ground-water sources.

  Projected consumptive water use from all sources by the year 2020, including water exports to adjacent regions, may total more than 8,000 cubic hectometres (6.5 million acre-feet) per year; ground water could help meet those needs.

  Most of the ground water is in consolidated rocks that generally yield water to wells slowly; much of the water is saline and in some places occurs at great depths; compensating advantages are the relatively uniform distributions, both areally and with time.

The Geological Survey began this program of rapid, regional appraisals of the ground-water resources of the United States in 1970 in order to develop and publish as quickly as possible a broad-perspective analysis of the Nation's ground water as one means of alerting planners to its potential value and widespread availability. These reports will include an assessment of the significance of ground water in the regional water supply, quality characteristics and their importance, and present and potential hydrologic and economic problems associated with the use of ground water. As the prospective limits of water availability are approached, it is important to consider conjunctive surface-water–ground-water development, induced infiltration systems, artificial recharge, recycling of waste water, streamflow augmentation, and other innovative plans for improving ground-water development and management.

Another kind of areal investigation made by the Survey is the documentation and analysis of the cause-and-effect relationships of an extreme hydrologic event such as a flood or drought. A case in point was Nevada's Eldorado Canyon disaster of September 14, 1974—a flash flood that took nine lives and caused extensive damage to recreational facilities. The peak flow was estimated to be 2,200 cubic metres per second (76,000 cubic feet per second) from the 60-square-kilometre (23-square-mile) drainage area (a flow equivalent in weight to 2,182 tonnes of water per second). A report published in 1975 by the Geological Survey and prepared in cooperation with the National Park Service points out that, although floods of this magnitude would on the average not occur in the same area for many years, a similar flood could occur in any given year. "These types of flash floods, although common in the desert Southwest, are not fully understood and are frequently ignored, and therefore the danger to developed areas is not decreased. With proper understanding and informed planning, the risk of damage from similar floods in the future can be greatly reduced" (Glancy and Harmsen, 1975, p. 1).

Studies related to critical water problems

New energy-related water projects begun in 1975 dealt with determining the quantity and quality of water available at potential energy-development sites, such as mines, and coal and oil-shale processing centers, and with defining energy-development impacts on water resources. These and other critical national water problems, such as ground-water recharge and subsurface waste storage, received direct Federal funding in situations where the Federal interest was paramount and where an accelerated time schedule for project completion was vital.

The States also gave substantial support to critical water problems in the Federal-State program, including cooperative funding for (1) 15 projects on burial of wastes, (2) 13 projects on estuarine problems, (3) 19 projects on artificial recharge, and (4) 4 projects on flood-hazard mapping. Examples of Cooperative energy-related projects during 1975 are given below for eight States:

State	Project title or objective
Arizona	Black Mesa study; to monitor hydrologic effects of ground-water withdrawals and strip mining at Black Mesa.
Alabama	Relation of oil and gas industry to water resources; to monitor for surface- and ground-water contamination at selected points along oil-well pipelines and around production wells.
Montana	Ground water in Fort Union Formation; to determine ground-water conditions before and after strip mining.
New Mexico	Energy-resource development and the hydrogeologic environment in northwestern New Mexico.

State	Project title or objective
North Carolina	Evaporation and thermal loading in Hyco Lake; to relate evaporation losses to increased powerplant capacity.
	Hydrology of estuaries and sounds of North Carolina; thermal effects of powerplants, including nuclear site at Wilmington.
Pennsylvania	Water resources of western Pennsylvania.
Utah	Water-quality reconnaissance of the Dirty Devil River basin.
Wyoming	Water resources of Weston County; anticipates increased demand on ground water for coal mining in Powder River basin.
Wyoming and Montana	Water availability from the Madison and associated limestones in Powder River basin.

In addition to the above-noted projects, several high-priority, energy-related studies were fully supported by funds from three Western States:

State	Project
Colorado	Surface-water quality in Piceance Creek, oil-shale area.
Utah	Hydrology of oil-shale area, Uinta Basin.
Wyoming	Streamflow contribution to recharge of Madison Limestone, an important source of ground water with which to support future coal development.

The Survey's major energy-related water studies are discussed under Critical National Water Problems.

Core program of hydrologic research

During 1975, the Geological Survey carried on 66 major hydrologic research projects. This core program, constituting the federally funded part of the Survey's hydrologic research, is subdivided into seven principal categories:

- *Exploration of natural water systems*—mathematical and computerized analysis and description of ground-water systems, significant aquifers, and ground-water regions.
- *Lakes and reservoirs*—investigations of the physical interchange of water between lakes and ground water, methods for minimizing water loss from lakes by evaporation, and the effect of plant growth on lake-water quality.
- *Water consumption by phreatophytes*—studies to determine the relationships between types of vegetational cover and water loss as a means of predicting loss of water under various types of environmental conditions.
- *Flow and diffusion*—studies on the development and implementation of models of the flow and movement of water, heat, and dissolved and suspended material in open channels, estuaries, and the unsaturated zone.
- *Chemistry*—basic research studies on the composition, distribution, and movement of inorganic, organic, and radiochemical constituents in ground and surface water. Applied aspects seek to predict the source and fate of pollutants and the effects thereof on the use of the water resource as well as on the confining environment.
- *Geomorphology*—basic and applied research studies on weathering, erosion, transport and deposition of sediments, and channel morphology, including the role of sediments as pollutants and transporting agents in fluvial and estuarine environments.
- *Glaciology*—basic and applied research on the extent, movement, and water-supply potential of glaciers, as well as other aspects related to navigation, floods, flow measurements, and bridge construction.

A large part of the Survey's water-research activity is carried on at the Gulf Coast Hydroscience Center of the National Space Technology Laboratories (formerly the Mississippi Test Facility) in Bay St. Louis, Miss. An indoor hydraulics laboratory is used to test and calibrate hydrologic instruments and to obtain experimental data used in research studies on the mechanics of flow and the transport and dispersion of heat, solvents, and solids in rivers and estuaries. An outdoor flood-plain simulator is used for research on factors affecting the mechanics of flow in open natural channels. The Survey's water projects in progress at the Laboratories during 1975 were basic and applied research on (1) open-channel experiments, (2) operational models of surface-water systems, (3) physical modeling of hydrologic systems, (4) the oxygen cycle in streams, lakes, and estuaries, (5) heat transfer and the air-water interface, (6) satellite data relay support, (7) microwave remote sensing, (8) subsurface waste storage, and (9) instrument development.

Additional water-research activities are conducted as parts of the Federal-State program and other Federal agency programs on projects where there are objectives of mutual Federal and State or local interest (and therefore cooperative funding) or where there is a need for such research by Federal action agencies, but the nature and scope of the research work itself is of a kind normally or most effectively carried out by the Geological Survey.

Accomplishments in research projects during fiscal year 1975 included:

- Development of mathematical models that can simulate the production behavior of geothermal reservoirs and thus contribute to the proper management of the Nation's geothermal resources. The energy potential of the geopressured reservoirs of the Gulf Coast is also being evaluated.
- Development and demonstration of a computer-automated scheme for processing randomly col-

lected estuarine hydrographic data into the initial-condition bathymetry used in two- and three-dimensional modeling. This methodology is being applied in Tampa Bay, Fla.

- Demonstration of the practicality and advantages of employing an orthogonal curvilinear coordinate system for developing a mathematical model to predict the steady-state two-dimensional distribution of solute concentration in a meandering nonuniform natural channel. This methodology has direct application for streams experiencing natural or man-induced stresses.
- Development of models for predicting the movement of contaminants from shallow or deep subsurface waste-disposal sites, taking into account simple chemical reactions that may take place along the path of movement.
- Establishment of the absence of significant variation in the deuterium and oxygen-18 isotope content of Coastal Plain ground water over the past 30,000 years. This finding contrasts markedly with oceanographic conditions and thus permits differentiation of recharge sources in regional aquifer systems.
- Development of computer methods for the calculation of pH and equilibrium distribution of inorganic species as a result of net reaction progress involving the seven principal solute components of natural waters. This methodology will be useful in establishing expected steady-state conditions that are required prior to determining the predictive effects of induced changes.

Hydrologic investigations on public lands

The public-lands hydrology studies have for several years consisted of the collection and evaluation of data on the hydrologic effects of land use and land treatment practices on the public domain. This program investigates the effects of (1) grazing, (2) changes in vegetative cover, and (3) mechanical treatments of the land to increase the efficiency of onsite use of surface water. More recently, the focus of hydrologic studies on public lands has shifted to energy-resource development, the environmental impacts of surface mining, and the rehabilitation potential of surface-mined lands. These investigations are being done in cooperation with the Bureau of Land Management.

Supporting services

This program includes primarily the training of personnel and the printing of publications. The water-resources training center is located at Lakewood, Colo., where 1- and 2-week courses are given throughout the year (35 in 1975) to scientific, technical, and administrative personnel, usually in groups of 20 to 30. Participants include not only Survey personnel but also representatives of State cooperating agencies and foreign hydrologic organizations.

During 1975, the Geological Survey prepared about 1,000 water reports and maps (in addition to 1,140 maps of flood-prone areas); 364 of these reports were published in several of the Survey's series of book and map publications (Water-Resources Investigations, Water-Supply Papers, Professional Papers, basic data reports, and Hydrologic Investigations Atlases). Significant progress was made in publishing annual basic data promptly; 43 State reports in the annual series were published within 9 months of the close of the water year (the 12 months ending September 30, 1974).

In addition to the above-noted books and maps, two particularly informative and colorful reports published in the Survey's bulletin series described the geology of two Western park areas—Arches National Monument and Canyonlands National Park, Utah—areas in which the hydrologist author had wide knowledge and interest (Lohman, 1974, 1975).

Other supporting services include the three large water-quality laboratories—at Atlanta (Doraville), Ga., Albany, N.Y., and Salt Lake City, Utah—that comprise the Central Laboratory System of the Water Resources Division. During 1975, more than 1.7 million water-quality characteristics were analyzed and funded on a reimbursable basis from the Federal and Cooperative programs and other Federal agency programs. All data are stored in and are available from WATSTORE.

CRITICAL NATIONAL WATER PROBLEMS

Accelerated energy research and development programs

"Water-for-energy" studies were begun in 1975 as a result of the energy crisis and the subsequent emphasis on rapid exploration and development of the Nation's energy resources. These studies are of two principal types: (1) investigation and appraisal of the water supplies needed in mining, transportation, refining, and conversion processes and (2) evaluation of environmental impacts on water resources associated with the development of energy resources, including the effects of radioactive waste disposal. Work in 1975 concentrated on defining the hydrology of coal, oil-shale, and geothermal resource areas primarily in the Western States and included arranging for exploratory drilling, making aquifer tests, and establishing

sites for monitoring water quality and quantity to measure baseline water conditions prior to energy development. Although current efforts have centered on the Western coal and oil-shale areas, several investigations are also in progress in coal-mining regions of the Appalachians, the Midwest, and the Far West. The Survey also began testing the feasibility of using ground water as a means of storing the large amounts of waste heat generated by powerplants during the summer for use during the winter at suitable locations. The locations and types of 100 energy-related water projects in progress during 1975 are listed in table 15. The list includes projects that were supported by funds from the Federal and Federal-State programs (see table 10, "Studies related to critical water problems").

The coal hydrology program consists of three elements: mining-water supply and quality, coal slurryline demands and impacts, and water-supply impacts of waste management in conversion processes. After necessary surface and subsurface hydrologic data have been acquired, they will be used to design predictive models so that the impacts of energy development upon water resources under various planning alternatives can be analyzed.

The oil-shale hydrology program measures (and models as appropriate) the parameters of different water-bearing formations (aquifers), the connection between aquifers, the occurrence of fresh and saline ground water, and the relation between different ground-water zones and surface water. Observation wells and aquifer tests establish initial ground-water conditions and record subsequent changes due to developments. Also, streamflow and quality-of-water stations are being established at key locations to document changes in surface-water and ground-water discharge resulting from oil-shale developments, increased municipal and industrial demands, and changes in the irrigation patterns of farm lands.

Another important component of the water-for-energy program is the development of hydrogeologic criteria for use in selecting and locating sites for future shallow land burial of low-level radioactive waste. The studies will document what has occurred physically and geochemically during the past 10 to 20 years at three currently used waste-burial sites.

Accomplishments during the year included:

- Publication of a report (Weeks and others, 1974), prepared in cooperation with the Colorado Department of Natural Resources, which concluded that development of oil-shale deposits in the 2,330-square-kilometre (900 square-mile) Piceance basin in northwestern Colorado will have significant effects on the hydrology of the region. A digital computer simulated the possible effects on the hydrologic system of precipitation changes due to the introduction of (1) atmospheric pollutants from oil-shale development or cloud seeding and (2) mine dewatering. The model results showed that, for the hypothetical dewatering scheme simulated, one proposed mine will produce enough water to meet the demands of oil-shale processing and disposal over a 30-year period and that a second hypothetical mine will not produce enough water. Such an

TABLE 15.—*Locations and types of energy-related water-resource projects begun or in progress during fiscal year 1975, by State*

State	Coal	Oil-shale	Nuclear	Geo-thermal	Heat storage
Totals	39	13	20	27	1
Eastern United States					
Alabama	1	--	--	--	1
Illinois	1	--	1	--	--
Indiana	1	--	--	--	--
Kentucky	1	--	1	--	--
Mississippi	--	--	1	1	--
New York	--	--	1	--	--
Ohio	1	--	--	--	--
Pennsylvania	1	--	--	--	--
South Carolina	--	--	1	--	--
Tennessee	1	--	1	--	--
Virginia (including regional projects)	2	--	4	3	--
West Virginia	1	--	--	--	--
Central and Western United States					
Arizona	1	--	--	1	--
California (including regional projects)	--	--	1	10	--
Colorado (including regional projects)	10	11	3	5	--
Idaho	--	--	3	2	--
Montana	6	--	--	1	--
Nevada	--	--	1	1	--
New Mexico	1	--	2	1	--
North Dakota	2	--	--	--	--
Oregon	--	--	--	1	--
Utah	1	1	--	1	--
Washington	1	--	--	--	--
Wyoming	7	1	--	--	--

assessment is particularly important because water is of great value to the region not only for any future oil industry but also for existing ranches and farms in the immediate area as well as in downstream parts of the Colorado River basin.

- Publication of a summary of information on the demands placed on water by different methods of energy production (Davis and Wood, 1974).
- Installation of 99 new stream-gaging stations and 122 new stream-sampling stations (quality of water) in the coal and oil-shale regions in order to determine natural hydrologic conditions and subsequent changes in those conditions. In addition, 510 ground-water observation wells were installed to measure water levels; 272 of these are also being sampled to obtain baseline data on the quality of ground water.

Ground-water recharge

Ground-water-recharge studies include the use of both spreading basins and injection wells and are conducted mainly in two areas—the semiarid High Plains of Texas and New Mexico and the glacial deposits on Long Island, N.Y. These studies are developing methods to predict the amount of water that can be returned to aquifers by studying the fundamental properties that control movement of water into aquifers, the rock-water interactions that occur during storage, and the diffusion-dispersion phenomena accompanying water movement after emplacement. A report is in preparation on the relative merits of the various techniques as they relate to artificial-recharge pit design on Long Island. In another area, recharge studies have been completed in the fractured carbonate rock at St. Paul, Minn.

Accomplishments to date in these ground-water-recharge studies include:

- Demonstrations under experimental field conditions that recharge is technically feasible for selected locations on the southern High Plains.
- Development of unique instrumentation for extraction of water samples from the unsaturated zone to depths greater than 30.5 metres (100 feet) below land surface. This instrumentation makes it possible for the first time to monitor quality changes in percolating water in the unsaturated zone beneath spreading sites.
- Improvement of core-barrel sampling equipment that has resulted in increased core-sample recovery from unconsolidated or poorly consolidated aquifers.
- Development of geophysical logging techniques that relate logged parameters of gamma radiation, neutron response, resistivity, and natural gamma radiation to the movement of recharge water.
- Development of methodology for visual demonstration of pore space and clogging mechanisms through use of the scanning electron microscope and microanalysis.

Flood-hazard mapping

The flood-prone-area mapping program was begun in 1969 and consists of locating on 7.5-minute topographic quadrangles the approximate boundaries of areas having a 1 percent chance of being flooded in any given year. These maps alert the public, including local, State, and Federal agencies and others such as builders and insurance companies, to the flood hazards along flood plains and other low-lying areas. A large share of this work and other flood-mapping activities has been supported by funds from the Department of Housing and Urban Development's Federal Insurance Administration.

The flood-prone maps and pamphlets are stocked in field offices of the Water Resources Division for general distribution to the public without charge. At the request of the Soil Conservation Service, the Geological Survey arranged to publish and distribute in 1975 some 200 maps of flood-prone areas prepared in 1974 by the Service under the Department of Housing and Urban Development's accelerated flood-prone-area mapping program. From 1969 through fiscal year 1975, the Geological Survey has produced maps of nearly 12,000 flood-prone areas (figure 45).

The program has progressed in two phases. The first phase, now essentially completed, was directed toward defining flood limits in populated areas where significant flood problems were known and flood information was urgently needed. The second phase, begun during fiscal year 1973, expanded the areal coverage to include areas where future development was anticipated, including areas within the public domain where management or planning decisions were needed. The flood boundaries in about 6,000 quadrangles will be mapped in order to complete the second phase and thereby provide flood boundaries for 50 percent of the 30,000 different 7.5-minute topographic quadrangles now available for the conterminous United States.

In addition to conducting reconnaissance flood mapping, normally at a scale of 1:24,000 (1 centimetre equals 240 metres), the Geological Survey delineates flood boundaries of greater accuracy on city or community maps of equal or larger scale such as 1:4,800 (1 centimetre equals 48 metres) as part of detailed flood studies sponsored by the Department of Housing and Urban Development. Since 1970, such studies have been undertaken in 299 communities.

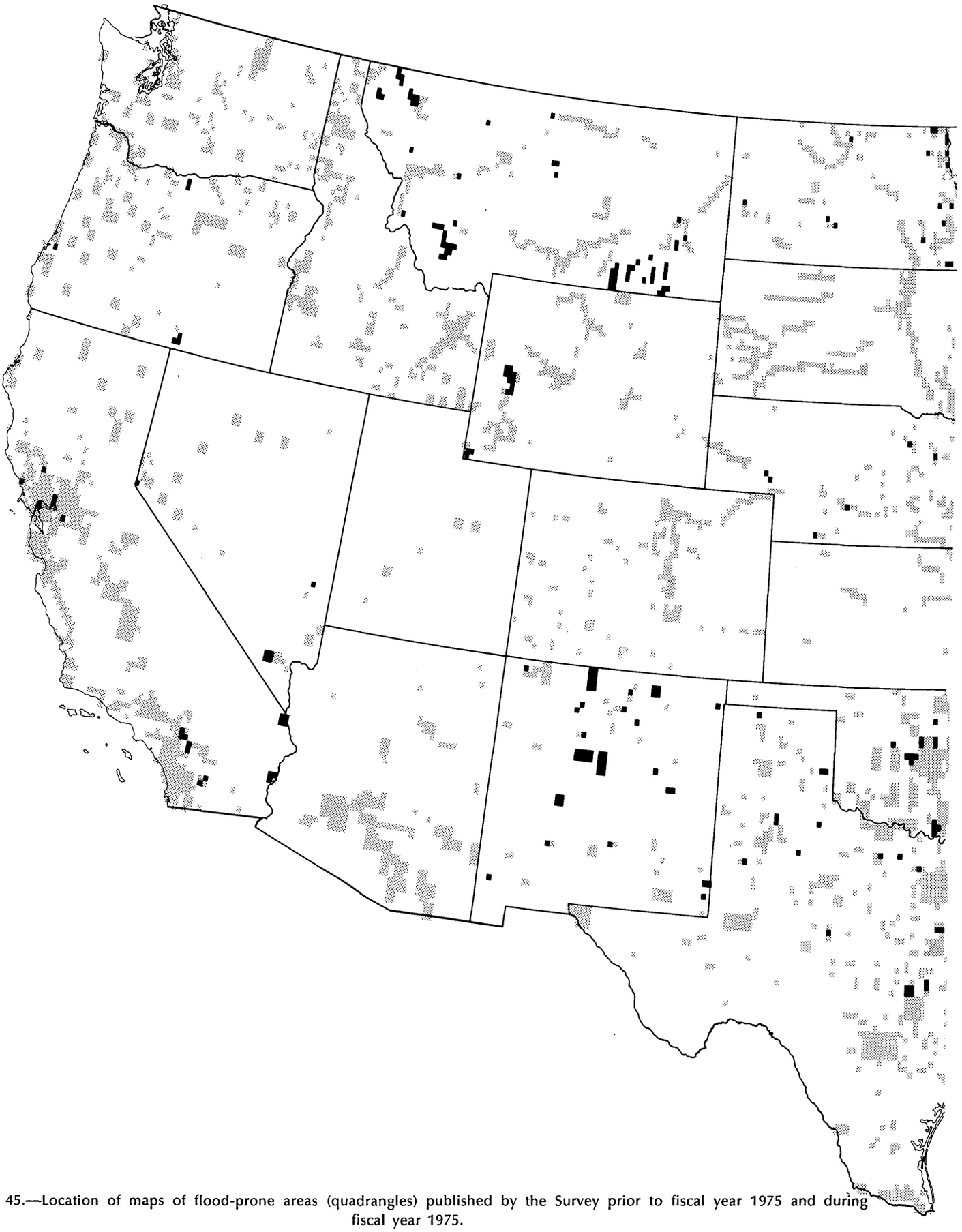
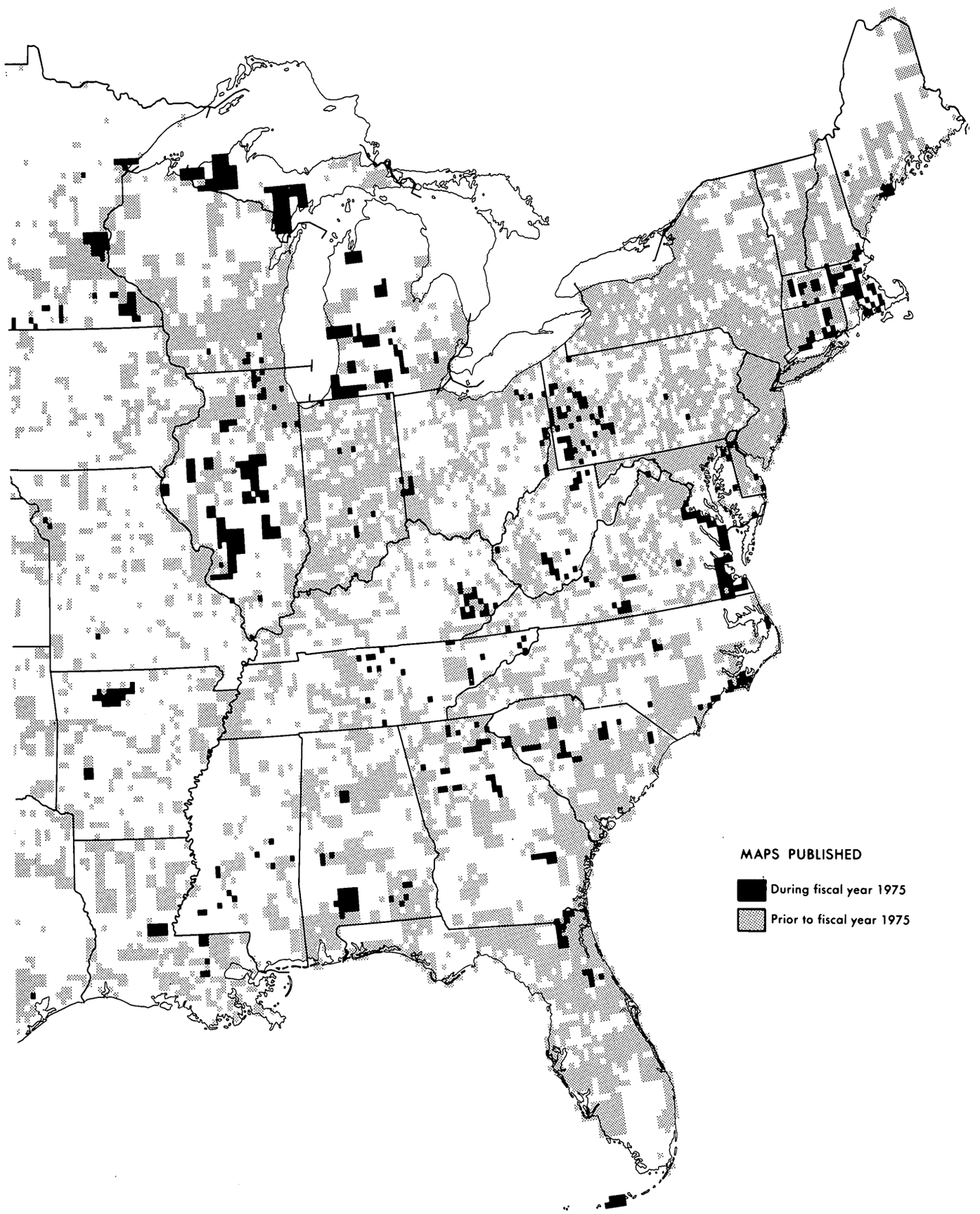


FIGURE 45.—Location of maps of flood-prone areas (quadrangles) published by the Survey prior to fiscal year 1975 and during fiscal year 1975.


MAPS PUBLISHED
During fiscal year 1975
Prior to fiscal year 1975

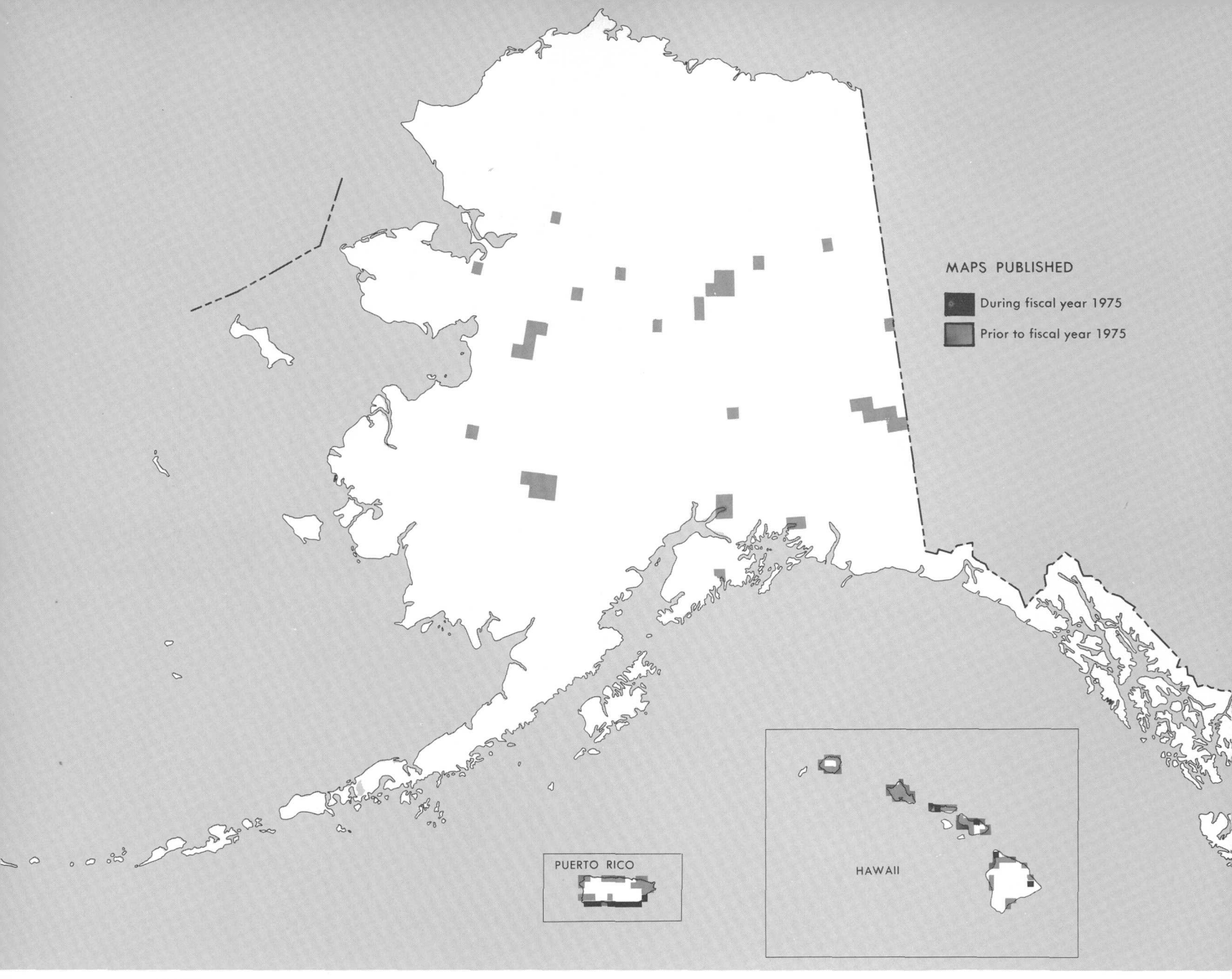


FIGURE 45.—Location of maps of flood-prone areas (quadrangles) published by the Survey prior to fiscal year 1975 and during fiscal year 1975.—Continued

Subsurface waste storage

The Survey's subsurface waste-storage program consists of regional delineation and description of aquifer systems that contain geologic formations suitable for waste storage, assessment of existing activities that may cause or have caused degradation of groundwater quality, determination of the field values of hydrodynamic dispersion of waste in ground water, and other fundamental studies in geology, hydrology, chemistry, and physics. The purpose of the program is to define hydrologic principles and techniques relevant to the use and management of subsurface waste storage and to prevent endangering usable water resources. Subsurface waste storage is becoming more common because of increasing legal restraints on surface storage and disposal practices. The impact of waste on ground water is long lasting, although usually limited in area. However, each year, many new points of pollution are created and few are eliminated, so that the effects of all points, old and new, are cumulative.

New projects in 1975 included a study of organic wastes percolating from spent oil-shale and coal-mine wastes and a study of the role of microbes in decreasing or increasing the solubility of minerals in oil-shale and coal-mine wastes. Continuing projects include monitoring seismic events near injection wells at Tuscaloosa and Birmingham, Ala.; investigation of the biological effects of landfill leachate on a stream near Albany, N.Y.; and development and use of about 15 municipal and industrial waste injection wells in Florida. Mapping of potential waste-injection aquifers

continued in the Wilcox Formation in Texas, Triassic grabens in the Atlantic Coastal Plain, and three saline aquifers in the Atlantic Coastal Plain in the southeast.

Only part of the subsurface waste-storage program is directly concerned with energy-related waste disposal such as mine tailings. However, data on industrial waste-injection problems and potential disposal horizons (porous rock formations) or on the percolation from landfills, industrial lagoons, and spray irrigation all find applications to energy developments. Many of the studies that yield data and insights into waste movement involve areas where waste disposal was active for many years before pollution was observed or before the public became concerned. Studies of these sites are likely to show the long-term effects of waste movement, dispersion, dilution, retention, and dimunition and furnish information useful to all kinds of waste-disposal developments, including those that are energy related.

Estuarine and coastal studies

The objectives of estuarine and coastal studies are to determine the substances entering estuaries and coastal waters, their movement in the waters, their effect on the environment, and their subsequent fate and to determine factors and impacts affecting present and future usability of freshwater supplies in coastal areas. The studies provide knowledge of the processes involved in the movement of water and water-borne materials within the estuaries and coastal areas and the responses of the environment to the introduction of extraneous materials.

During 1975, estuarine and coastal studies continued on the geochemistry and circulation patterns in San Francisco Bay and the effects of quality of water on estuary biota in Chesapeake Bay. Coupled with hydrologic studies and data from Port Royal Sound, Delaware Bay, and Tampa Bay, Fla., and other bays where studies are supported by the Federal and the Federal-State programs, models are being developed that will be able to appraise some of the present and future effects and interrelationships of natural and manmade impacts on estuaries. The first models will be two-dimensional models of water circulation and solute transport in Port Royal Sound and Tampa Bay. Research into the development of three-dimensional models is underway. The 25 estuarine and coastal studies in progress or underway in 1975 are in Florida, Massachusetts, Oregon, Puerto Rico, South Carolina, Texas, Virginia, and Washington.

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Oil and gas platform in the Gulf of Mexico (lower right). Draglines removed overburden from coal in strip mine operation (left and top right).

Conservation of Lands and Minerals

OVERVIEW

The Conservation of Lands and Minerals activity encompasses regulatory responsibilities delegated to the Geological Survey by the Secretary of the Interior under laws governing the leasing, mining, and use of mineral and water resources on Federal and Indian lands. The Conservation Division, the organizational unit within the Survey which executes these responsibilities, has three major missions:

- Classification of public lands as to their mineral character and their value for waterpower and water storage purposes.
- Evaluation of mineral tracts that are subject to competitive leasing.
- Supervision and regulation of operations associated with the exploration, development, and production of minerals on Federal, Indian, Naval Petroleum Reserve, and Outer Continental Shelf lands under lease, license, and prospecting permits, including the collection of royalties and certain rentals which result from those operations.

From data acquired in pursuit of these missions, the Geological Survey provides technical advice and information on the leasing or disposal of mineral rights to land management agencies such as the Bureau of Land Management, the Bureau of Indian Affairs, the Bureau of Reclamation, the Forest Service, the General Services Administration, and the Department of Defense.

The importance of Federal and Indian lands to the Nation's domestic supply of energy and mineral resources is illustrated in figure 46. In fiscal year 1975, 7 percent of the coal, 17 percent of the uranium, 18 percent of the oil, and 21 percent of the natural gas produced in the United States came from Federal and Indian lands.

The impact of the operations supervised by the Geological Survey on the Nation's economy is substantial. In fiscal year 1975, the product value of all energy and mineral commodities produced from leased Federal and Indian lands amounted to about $6.2 billion. Bonuses, royalties, and rentals during the same period totalled more than $3.0 billion.

Authority

The authority to classify public lands and regulate mineral development on Federal and Indian lands, to protect the environment, and to collect a fair return from extracted resources lies in a complex body of mineral and land laws some of which date back to the 1870s.

Congress stipulated in the Act of March 3, 1879, which created the U.S. Geological Survey, that the Director of the Survey should classify the public lands to identify features pertaining to land values for many purposes. In 1906, the President directed the Secretary of the Interior to immediately withdraw from entry all valuable coal lands on the public domain. Coal lands in Alabama, Arkansas, and Wyoming were withdrawn and later classified under this directive. Subsequently, Congress passed the Withdrawal Act of 1910 which authorized the President to withdraw public lands from settlement, location, sale, or entry. This Act resulted in the immediate reservation of about 100 million acres of public lands for their potential value for coal. Once withdrawn, the Geological Survey began to examine these lands and classify them; the lands found to be noncoal were restored to entry and those found to contain workable coal beds were appraised and priced at varying amounts per acre.

Since the lands withdrawn included some lands that were valuable for farming, Congress passed the "Separation Acts" of 1909 and 1910 which provided for the separation of the surface estate from the subsurface estate, thus permitting land claimants to obtain patents to the land surface while reserving to the United States the mineral deposits and the right to prospect and mine them.

The Mineral Leasing Act of 1920 ended the practice of disposing of coal lands at appraised values and provided for the leasing of coal and certain other mineral commodities. The leasable minerals on public lands now include oil, gas, coal, potash, sodium, phosphate, oil shale, asphaltic minerals, sulfur (only in New Mexico and Louisiana), and geothermal resources. Under the provisions of the 1920 Act, as amended and supplemented, a permit to explore public land for minerals other than oil, gas, oil shale, and geothermal resources may be obtained; however, if the land is determined by the Geological Survey to contain a known leasable mineral deposit, it is subject to competitive bidding for a lease. All minerals on acquired and Indian lands are leasable. A lessee is required to pay the Federal Government a stipulated royalty on production.

Other laws authorize the leasing and management of metallic and nonmetallic minerals on Indian lands, railroad and other rights-of-way across public lands, acquired lands, and Outer Continental Shelf lands.

Pursuant to these various statuatory authorities, the Secretary of the Interior has promulgated in the *Code of Federal Regulations,* numerous rules and procedures pertaining to the development of minerals on the Federal and Indian lands. The principal codes governing operations on Federal mineral leases are:

- Outer Continental Shelf Leasing Regulations—Part 3300 of Title 43.
- Outer Continental Shelf Operating Regulations—Parts 225a, 250, and 260 (Proposed) of Title 30.
- Onshore Federal Lands Leasing Regulations—Parts 3100, 3200, and 3500 of Title 43.
- Onshore Federal Lands Operating Regulations—Parts 211, 221, 223, 225, 226, 231, 270, and 271 of Title 30.
- Indian Lands Leasing and Operating Regulations—Parts 171, 172, 173, 174, 176, and 177 of Title 25 and the pertinent onshore Federal operating regulations contained in Title 30.

Leasing regulations are issued by the Bureau of Land Management and the Bureau of Indian Affairs, but some provisions of leasing regulations and all provisions of operating regulations are implemented and enforced by the Geological Survey.

Programs

Because of the distinctly different operating environments, logistics, and technologies used to explore and develop the resources offshore as compared with onshore, the Conservation of Lands and Minerals activity is divided into an Outer Continental Shelf Lands subactivity and an onshore Federal and Indian Lands subactivity. Both, however, involve prelease responsibilities for evaluation of resources; the postlease responsibilities for supervision of exploration, development, and production operations; and the computation and collection of royalty and certain rental payments. The onshore program also includes the classification of Federal lands for mineral and water resource development potential.

Resource classification and evaluation

- *Resource classification*—The purpose of resource classification actions by the Geological Survey is to retain for the Federal Government the title to leasable minerals which otherwise might be inadvertently lost with disposal of the surface rights. Survey geologists classify public domain lands and certain acquired lands at the request of other Federal agencies by considering all available geologic evidence in order to determine which legal subdivisions of land meet the standards for mineral lands.

- *Resource evaluation*—Once classified as to their mineral character, resources must be evaluated prior to being offered for lease. On the Outer Continental Shelf, resource evaluation activities are concentrated on identifying target areas for future lease sales, advising the Bureau of Land Management on the selection of tracts to offer for sale, estimating the value of oil and gas on each tract offered, and determining the minimum acceptable bid for each tract.

Onshore leases may be awarded competitively or noncompetitively, depending upon whether or not the area lies within a "known leasing area." The Geological Survey performs a presale evaluation of each parcel of Federal land offered competitively for leasing. Principal responsibilities in this regard are:

1. To make recommendations to the leasing agency about the size of each parcel offered and any special stipulations required.
2. To evaluate each parcel on the basis of current geologic, geophysical, economic, and engineering data, and, prior to the sale, to furnish the leasing agency with the minimum acceptable bid for each parcel and the technical basis by which the minimum bid was derived.
3. To make subsequent recommendations as to whether the high bid submitted for each parcel should be accepted or rejected.

Most Indian lands are leased by competitive bidding methods. The Bureau of Indian Affairs has relied heavily on the Geological Survey to parcel the individual tracts for each sale and to make recommendations as to lease stipulations and as to the acceptance or rejection of high bids offered.

The procedures used for both onshore and offshore mineral evaluation assure the public a fair market value in return for the leasing of their mineral resources.

Supervision of operations

After leases are issued by the Bureau of Land Management or the Indians, the Geological Survey supervises the exploratory, development, and production operations of the lessee or the lease operator. Supervision is designed to assure that operations are conducted in conformance with Interior Department operating regulations and orders and that royalties paid to the Government or to the Indians are correct and represent a fair market value for their share of the resources produced. Supervision of lessee operations involves:

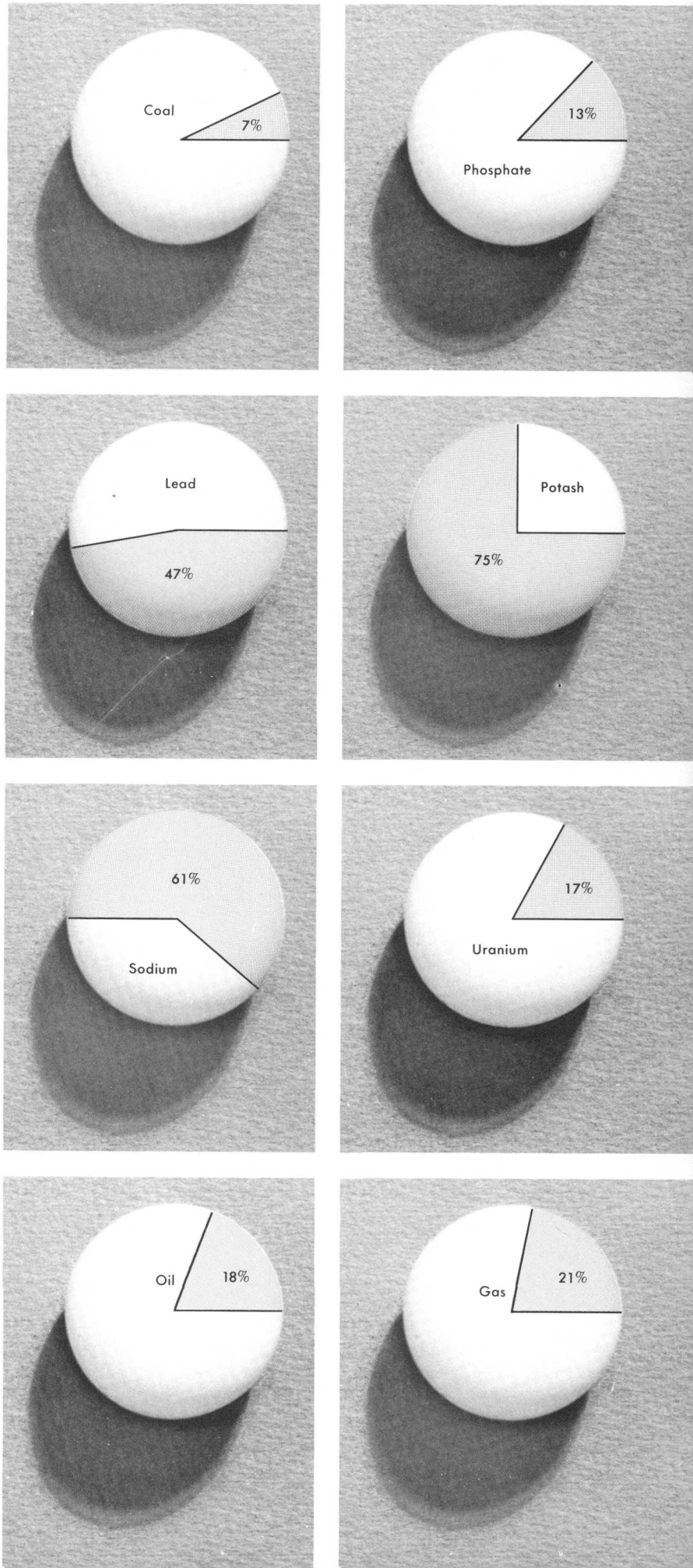


FIGURE 46.—Production from Federal and Indian lands as percentage of total U.S. production in 1975. ▶

- *Review and approval of plans*—No industry operation, such as the drilling of new wells, workovers or abandonments of existing wells, new mining operations, or departures from previously approved plans, may be undertaken without the prior approval of the Geological Survey. The review and approval of such plans insures that exploration and development will proceed in an efficient and orderly fashion and that the maximum amount of resources will be recovered. For proposals such as exploratory drilling, prospecting, development, and production of oil and gas fields, mines, or geothermal resources, the Survey is required to prepare an environmental analysis to determine if the proposed operation will have significant impact on the human environment. If it is determined that a significant impact will occur, the Survey must prepare an environmental impact statement as required by the National Environmental Policy Act of 1969.
- *Inspection of operations*—Survey personnel make periodic field inspections of operations to insure that permittees, licensees, lessees, and operators comply with the approved operating plans, Department of the Interior regulations, lease terms, and environmental stipulations. Periodic reports filed by industry also keep the Survey informed about the progress of operations.
- *Computation and collection of rents and royalties*—On the basis of production sales reports, purchaser statements, field measurements of production, and other pertinent information, the Survey computes royalties due the Government or the various Indian Tribes and Allottees and bills the operators monthly. Each producing lease account is audited periodically to determine whether or not the royalties paid were based on the fair market value of the products sold and to see that previous calculations are correct. Bonus bids and most rental payments on nonproducing leases are collected by the Bureau of Land Management; however, once a lease becomes producible the Survey assumes the responsibility for the collection of advance rentals.

Budget and personnel

Fiscal Year 1975 marked a period of substantial growth for the Conservation of Lands and Minerals activity. Increased workloads and funds were directly related to the increasing importance of Federal and Indian lands to domestic energy and mineral supplies and to the continued high priority placed on environmental assessment and protection.

In 1975, the budget for this activity increased 98 percent to $36 million (table 16), 64 percent of which was expended on the Outer Continental Shelf (fig. 47). Staffing of the activity increased from 612 permanent full-time employees at the end of 1974 to 926 in 1975 (table 44). Most of the increased positions were filled by geophysicists, geologists, and petroleum engineers.

TABLE 16.—*Conservation of Land and Minerals activity obligations for fiscal year 1975, by program*

Program	Fiscal Year 1975 (Dollars in millions)	Percent change relative to fiscal year 1974	
		Current dollars	Constant dollars
Total[1]	$36.03	+98	+78
Outer Continental Shelf Lands	23.20	+112	+91
Regulation OCS oil and gas	10.05	+58	+43
OCS oil and gas tract selection and resource evaluation	13.15	+184	+156
Federal and Indian Lands	12.84	+78	+60
Regulation of operations	8.43	+51	+36
Oil and Gas	5.26	+33	+20
Energy Minerals (coal and uranium)	.51	+29	+16
Oil Shale	.32	New program	
Geothermal	1.01	+583	+423
Nonenergy Minerals	1.33	+24	+12
Resource Classification and Evaluation	4.41	+165	+139
Oil and Gas	.22	+10	0
Coal	2.38	+186	+158
Oil Shale	.30	New program	
Geothermal	.96	+596	+528
Nonenergy Minerals	.08	+14	0
Water-Resource Development	.47	+11	0

[1] Total direct program. Reimbursable program amounted to $50,000 bringing total program to $36,082,000 (table 26).

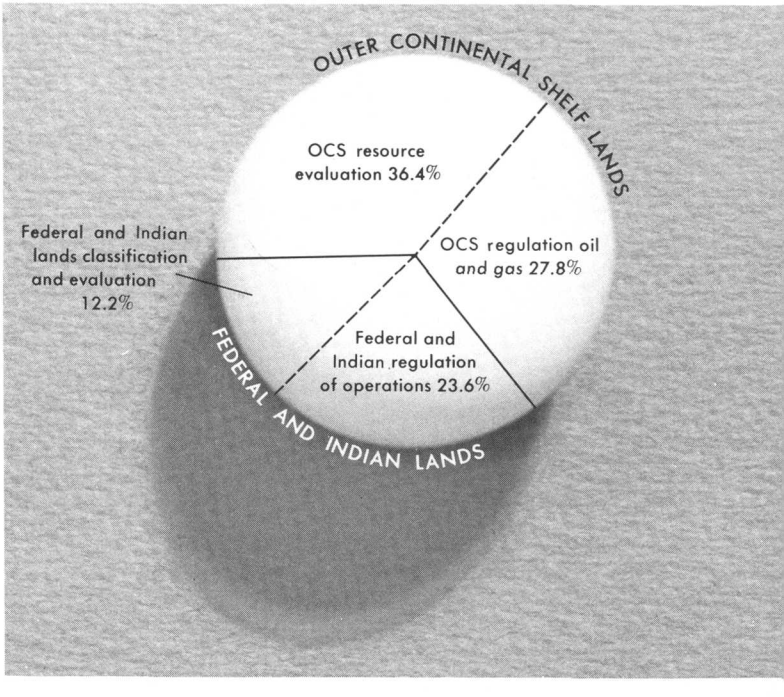


FIGURE 47.—Distribution of Conservation of Land and Minerals funds for fiscal year 1975 by subactivities and programs.

The Outer Continental Shelf Lands subactivity funding increased $12.2 million (112 percent) over fiscal year 1974. The increase was related to the Administration's decision to select and evaluate an increased number of Outer Continental Shelf tracts to support a policy to increase energy production from Federal land and the need to inspect additional drilling and production operations on recently leased tracts and increased activity on older tracts. The increased funds covered additional staff, several large contracts for helicopter services to transport inspectors offshore to monitor operations ($1.8 million), and the acquisition of geophysical data with which to select and evaluate tracts for lease sales ($7.5 million).

Increased workload in resource classification and evaluation, and supervision of development and production operations also resulted in a budget increase of $5.6 million (78 percent) for the Federal and Indian Lands subactivity. In addition, the Survey started two new programs. Two million dollars and 50 positions were allocated to classify and evaluate geothermal resources and to supervise and monitor operations on Federal lands. An Oil-Shale program was also established during fiscal year 1975 with $610,000 and 16 new positions to review and approve development plans, and to monitor the collection of environmental baseline data on four prototype oil-shale leases in Colorado and Utah.

Highlights

Accomplishments of the Conservation of Lands and Minerals activity included:

- Completion of tract evaluations for five Outer Continental Shelf lease sales covering 5.0 million acres in calendar year 1974 and for four sales covering 7.2 million acres in calendar year 1975. During these two calendar years, 1.8 and 1.7 million acres were leased for bonuses of $5.0 billion and $1.1 billion, respectively.
- Revision and updating Outer Continental Shelf orders for the Gulf of Mexico and Pacific areas.
- Supervision of 1,590 offshore oil and gas leases covering 7.2 million acres in calendar year 1974 and 1,784 leases covering 8.2 million acres in calendar year 1975.
- Supervision of 123,652 onshore oil and gas leases covering 89.8 million acres in calendar year 1974 and 126,718 leases covering 93.6 million acres in calendar year 1975.
- Supervision of 2,479 mineral leases covering 8.0 million acres in fiscal year 1975.
- Collection of $850 million in royalties and rentals from all sources during fiscal year 1975.

Also during the year a number of issues received much attention.

Outer Continental Shelf leasing

Considerable public discussion continued to center during the year around the advisability of opening Outer Continental Shelf lands in frontier areas to leasing. The Administration decided to assess the environmental and socioeconomic impacts of an accelerated leasing program in these areas and subsequently a report, "OCS Oil and Gas—An Environmental Assessment," by the Council on Environmental Quality (1974) was completed in April 1974, and the final environmental impact statement, on the proposed increase in oil-and-gas leasing on the Outer Continental Shelf was completed in July 1975 (Bureau of Land Management, 1975).

Authors of these reports concluded that leasing in frontier areas could proceed provided that very high priority was given to environmental protection, the best technology available was used to minimize environmental risks, and that States and local communities had an opportunity to participate in the management and regulation of the Outer Continental Shelf. The most recently proposed planning schedule of lease sales released in June 1975 calls for about six lease sales per year on the average through fiscal year 1978 (table 17).

Oil and gas reserve studies

Studies of the oil-and-gas reserves in five fields (four in the Gulf of Mexico and one in Santa Barbara Channel) were made for the Federal Energy Administration for their National Energy Survey. The Federal Energy Administration reports are now complete. Also in response to public concern over shut-in gas, the Federal Power Commission and the Survey jointly reviewed the shut-in gas fields in the Gulf of Mexico Outer Continental Shelf. The Federal Trade Commission challenged the estimates in the Federal Power Commission report, and the report is now being reviewed by the National Research Council of the National Academy of Sciences at the request of the Director of the Geological Survey.

Geologic and geophysical data

In November 1974, the Secretary of the Interior instructed the Geological Survey to require that processed geophysical data be submitted by geophysical surveying companies as a condition for obtaining surveying permits. A number of steps were taken in fiscal year 1975 to finalize regulations pertaining to the collection of Outer Continental Shelf geological and geophysical data. Proposed regulations were published in the *Federal Register* as proposed rulemaking on April 22, 1975.

Outer Continental Shelf stratigraphic drilling

During fiscal year 1975, the Department of the Interior authorized deep off-structure stratigraphic testing for the first time. A group of companies drilled two deep test wells off South Texas to provide stratigraphic information in the OCS Sale no. 37 area. The tests showed that the area lacked sandstone or limestone reservoir rocks, thus indicating that there was only limited potential for the accumulation of petroleum deposits. The adverse information obtained in drilling these tests is believed to be responsible for so few bids being received for tracts offered near the two well sites and one reason why there were fewer bids for far lower amounts for the entire sale than had been estimated.

Royalty oil

The various mineral leasing acts authorize the Secretary of the Interior to sell royalty oil accruing to the United States under oil and gas leases issued under those acts. In order to assist small business enterprise, the Congress has authorized and directed the Secretary, when he determines that sufficient supplies of crude oil are not available in the open market to refineries not having their own source of supply for crude oil, to grant a preference to such refineries in the sale of royalty oil for processing or use in such refineries but not for resale in kind. The Act of July 13, 1946, provides that the sale of royalty oil to such refineries may be at a private sale at not less than the market price and that in selling such oil the Secretary may at his discretion prorate such oil among such refineries in the area in which the oil is produced.

During fiscal year 1975, 27.1 million barrels of royalty oil from operations conducted on the OCS (Gulf of Mexico and Pacific) were taken by oil refineries under 41 separate contracts and 11.0 million barrels of royalty oil from Federal onshore leases were taken by oil refineries under 23 separate contracts. The royalty oil was allocated pursuant to the regulations contained in Title 30, Parts 225 and 225a of the *Code of Federal Regulations* as they apply to onshore and OCS royalty oil, respectively. It is anticipated that the total volume of royalty oil distributed during fiscal year 1976 will increase substantially.

Geothermal resources leasing

Leasing of geothermal resources began during 1974. By the end of the calendar year, 552 leases had been awarded. Eight geothermal wells had been drilled on five leases and five additional wells were being drilled on three leases. Although none of these leases is yet in a producing status, the first commercially producible geothermal well on Federal lands was completed in May 1975, near the Castle Rock Springs area in California, and a potentially producible well was completed in June 1975, at Roosevelt Hot Springs in Utah.

OCS Tract Evaluation Procedures

During fiscal year 1975, the General Accounting Office issued a report on "Outer Continental Shelf Oil and Gas Development—Improvements Possible in Determining Where to Lease and at What Dollar Value" (General Accounting Office, 1975). The report found that the Survey had difficulty in hiring qualified personnel, particularly experienced geophysicists, to fill the positions authorized for tract evaluation. The shortage of experienced personnel limited the preparation of geophysical structure maps for many tracts to only one seismic horizon, although mapping on two or more horizons would have defined the structures more accurately. The General Accounting Office concluded that the size and timing of lease sales should be based upon the ability of the Survey to evaluate tracts. Since the release of the General Accounting Office report, the tract-evaluation staff has been brought up to authorized strength, and new employees have been trained in OCS-evaluation procedures. The quality of the work has improved, and the Survey now has the capacity to map two or more seismic horizons for each tract proposed for leasing in fiscal year 1976.

Onshore Lease Management

In December 1973, the Geological Survey began an intensive review of the onshore lease management program in order to define deficiencies in the program and to recommend corrective actions. The National Aeronautics and Space Administration, assisted by the Martin Marietta Corporation, was requested to study the Conservation Division's responsibilities, authority, and procedures for supervising leases on Federal and Indian lands, to define techniques for measuring program performance and industry compliance, to recommend ways of improving leasehold inspections, and to suggest general management improvements. The Geological Survey also requested that the Department of the Interior's Office of Audit and Investigation undertake a study of the onshore-royalty accounting system. This second study had two parts: oil-and-gas–royalty accounting and solid-minerals–royalty accounting.

The National Aeronautics and Space Administration's component of the study was completed in December 1974 (National Aeronautics and Space Administration and Martin Marrietta Corporation, 1974). Their report contained 79 numbered recommendations, many of which had subparts. The study recommendations addressed overall program management

and contained various suggestions for clarifying and interpreting Departmental regulations governing onshore operations. These regulations provide guidelines but do not explicitly define the criteria which lessees or operators must meet in conducting operations on leases. In the past, it has been left to local Survey officials to interpret and enforce these regulations, and, as a result, there has been a lack of uniformity in the application of standards and procedures.

Subsequent to the completion of the National Aeronautics and Space Administration's study, the Survey established a task force to review the onshore-lease management report. After extensive review by the managers responsible for the various operations, in May 1975, the Survey adopted nearly all of the recommendations as presented or as slightly modified (U.S. Geological Survey, 1975a). Implementation of the recommendations will proceed as adequate resources are made available.

The Office of Audit and Investigations' report on accounting procedures (Office of Audit and Investigations, 1975a) concluded that improvements were needed in the following areas:

- *Lessee reporting procedures*—The Survey should require lessees to submit all reports and sales and production data needed to verify royalty computations in a single package, and thereby reduce the time required to sort and collate reports which are currently submitted individually. Furthermore, standardized royalty forms should be developed for Federal and Indian leases, and greater use should be made of magnetic-tape data by companies which have such capabilities and where the volume of transactions warrants such an approach.
- *Royalty accounting procedures*—The Survey should establish subaccounts within each lease account to reflect the status of royalty liability to the Federal Government of each entity that holds an interest in the lease and that is responsible for making payments. While increasing the number of accounts from about 14,500 to 23,900, the change would encourage more rapid payment of delinquent balances. Lessees should also be informed of adjustments and corrections made by the Survey to their royalty reports, so that errors will not recur, and so that the lessees will understand why they are being billed for additional royalties. In addition the Survey should seek timely payment of royalties, quickly follow up on delinquent accounts, and collect penalties for overdue royalty reports and royalty payments. Finally, greater emphasis should be placed on the postaudit review of lease accounts and the preaudit of royalty data should be reduced.
- *Value and volume of oil and gas production*—The Survey should develop improved guidelines to determine royalty value and to establish the validity of oil-and-gas prices used by lessees to compute royalty payment. Also the Survey should attempt to find ways of verifying production volumes. With respect to independent verification of the production volumes, the Office of Audit and Investigations recognized that it is a complex technical problem and that verification may be costly. They accepted a suggestion by the Survey that a production and analysis team evaluate the internal controls of one major and one large independent producer to determine if such controls are adequate to accumulate and report accurately volumes of oil and gas produced and sold from Federal and Indian lands.
- *Increase staff*—The Office of Audit and Investigation concluded that, "the main reason the RAS [Royalty Accounting Section] has so many operational and procedural problems is because of a chronic understaffing condition. And being realistic, there is no way these problems can be addressed unless the staff is expanded significantly" (Office of Audit and Investigations, 1975a, p. 9).

In its comments on the Office of Audit and Investigations report (U.S. Geological Survey, 1975b), the Geological Survey generally agreed with the findings of the study and immediately took steps to implement them. Although little could be accomplished in the remaining weeks of fiscal year 1975, detailed plans were made to complete nearly all suggested actions in fiscal year 1976. A request for 45 new positions for onshore oil-and-gas-royalty accounting was approved by the Department on August 6, 1975. With these additional people in fiscal year 1976, the Survey will restructure the Chief Accountant's responsibilities to provide for overall systems management and policy development and to streamline accounting operations through such means as requiring uniform reporting, eliminating duplicative reporting, and making more extensive use of automation to handle accounting data and audit reporting. Coupled with those modifications will be an aggressive effort to insure prompt and accurate royalty reporting and payment.

The second part of the Office of Audit and Investigation study of the onshore royalty accounting system relating to solid minerals, was completed in August 1975. The report included: "In our opinion, excepting certain weaknesses in internal control, the EGS [Geological Survey] royalty accounting system is procedurally adequate to account for and collect royalties on leasable solid minerals produced from Federal lands" (Office of Audit and Investigation, 1975b, p. 4).

The Office of Audit and Investigation noted that the accounting activities are much the same for solid minerals as for oil and gas. However, the accounting activities related to the management of solid minerals are less complex than those related to the management of oil and gas because of the smaller number of leases and the absence of most of the royalty reporting, payment, and accounting problems caused by multiple lease assignments, fragmented royalty reporting and payment practices, and unitization and communitization agreements.

The report made recommendations in four main areas:

- *Internal accounting controls*—One person in each of the seven Area Mining Offices of the Conservation Division is basically responsible for all accounting operations, that is, the receiving and depositing of royalty payments and the recording of royalties due and paid by lessees. The Survey should separate the duties of collection, accounting, and billing to insure that all royalty payments are properly collected, deposited, and recorded in the lease accounting records.
- *Improvement of independent financial audits*—Department of the Interior mining regulations provide for periodic independent audits of accounting records of solid-mineral leases to be performed and for copies to be sent to the Survey. The Survey should use these reports to greater advantage by requiring: the lessee and the auditor to include all information needed to verify that correct royalties have been paid as well as the auditors opinion as to the accuracy of the royalties reported and paid on each lease; a statement about the consistency of accounting procedures used to determine royalties with those used in preceding reporting periods; that the lease documents, amendments, and all applicable laws, rules, regulations, and Department of the Interior decisions have been considered in formulating the auditor's stated opinion; and a statement about the condition of the lessee's internal controls over the production and shipment of minerals from the lease and over the accumulation of production, shipment, and gross revenue data used to compute royalties.
- *Late royalty payments*—The Survey should enforce timely payment of royalties as required by leases. In those cases where the actual value of production cannot be determined within the required time period, arrangements should be made for the lessee to pay estimated royalty payments.
- *Accounting responsibilities for Indian leases*—The Bureau of Indian Affairs historically has been responsible for the accounting functions related to solid minerals on Indian leases. However, Departmental regulations identify the Geological Survey as the agency responsible for the maintenance of accounting control over revenue derived from Indian leases. Accordingly, the Office of Audit and Investigations' report recommended that the Survey should assume accounting control for these leases.

The Survey accepted all of the Office of Audit and Investigations recommendations and on July 11, 1975, instructed all Area Mining Supervisors to:

- Designate a person other than the Area Mining Accountant to prepare a listing of all rental and royalty checks received prior to the delivery of the checks to the Area Mining Accountant. The monthly listing of checks will be sent directly to the Chief Accountant for later verifications against the royalty accounts. All mining royalty statements of accounts will be mailed directly to the lessee by the Chief Accountant's Office.
- Send each lessee a formal notice requiring an annual audit report and specifying information and auditor's opinions to be included in the report. All reports must be reviewed and followup action taken if the report does not meet the criteria shown in the notice.
- Review the timeliness of the receipt of all royalty reports and payments and advise all lessees who are not presently paying and reporting in accordance with the lease terms to do so.
- Provide the Chief Accountant's office with a list of producing Indian leases to permit the Survey to initiate action to place producing Indian leasing in the royalty accounting system.

All actions, with the exception of the assumption of accounting control of Indian leases, were completed by September 1975.

Shut-in wells

One of the major concerns during fiscal year 1975 was the question of shut-in oil and gas wells. As of June 30, 1975, 172 leases were shut-in and not producing. A Congressional subcommittee contends that some oil companies are deliberately leaving producible wells and reservoirs, particularly gas wells and reservoirs shut-in waiting for better prices before producing them. Industry's response was that reserve figures include behind-the-pipe reserves in wells with multiple sands which could not be produced concurrently. Where multiple horizons occur, the productive sands are produced sequentially. In January 1975, the Survey asked 10 companies that appeared to have the most questionable cases of shut-in wells on leases to start production immediately or submit reasons and data explaining why shut-in status should be per-

mitted. Subsequently, in March 1975, 3 of these 10 lessees were required to submit additional data supporting the shut-in status of their wells. As a result of these actions, two lessees chose to terminate one lease each. However, in general, the inquiries indicated that the wells and leases were shut-in because transportation facilities did not exist, production equipment was ordered but not yet delivered and installed, or the gas reserves had been depleted to the point where further production was not economic. While investigations continued into fiscal year 1976, the findings so far have not supported the contention that a substantial number of wells had been shut-in for price speculation.

OUTER CONTINENTAL SHELF LANDS

Outer Continental Shelf leasing regulations are chiefly administered by the Bureau of Land Management, but some sections of these regulations and the operating regulations are implemented and enforced by the Geological Survey.

In practice the Bureau of Land Management and the Geological Survey consult closely on the significant actions that take place before each lease sale (Adams and others, 1975). The Survey provides the Bureau of Land Management with:

- Petroleum-resource assessments and other technical information used to identify areas for leasing and to schedule lease sales.
- Environmental baseline data and geologic hazards information for use in preparing environmental impact statements for each lease sale.
- Resource evaluations for use in jointly selecting tracts for each lease sale and for establishing fair market value for each tract.

After a lease is awarded, the Survey supervises exploration, development, and production operations and collects royalties and rents due to the United States. The workload of these Survey programs is dependent upon the Department of the Interior's leasing schedule for Outer Continental Shelf lands (table 17) and upon lessees' successes in making commerical discoveries.

Outer Continental Shelf resource evaluation

In 1967, the Geological Survey established a mineral resource evaluation program to improve methods of selecting and evaluating Outer Continental Shelf tracts for leasing. The Survey has since expanded considerably its geological, geophysical, and engineering capability to map, select, and evaluate the potential resource of the Outer Continental Shelf.

For tract selection, geophysical maps are produced which show the structural configuration of the area proposed for leasing. Facies changes are interpreted from geologic data to identify the areas favorable for the occurrence of petroleum. A preliminary estimate of potential resources is derived from known geological and engineering factors. Tracts that have potential geologic hazards may require special stipulations for development or may be deleted from the sale.

For the tract evaluation process, geophysical multihorizon maps are produced and models of expected reservoirs are constructed using geological, geophysical, and engineering data. Wildcat risk, exploration and development costs both for dry structures and commercial fields, the most probable resource value, and annual production are estimated for each tract.

Because the values of many of the geological and engineering variables used in the computation cannot be measured directly before a tract is drilled, and many of the economic variables are also uncertain, a distribution of values is estimated for each variable. Then, using discounted cash-flow analysis, the value of the resources on the tract is repeatedly computed up to 500 times by randomly sampling each of the variable distributions (Monte Carlo simulation) to obtain a range of values for the present worth of the tract.

These resource values, together with recommendations on bid acceptance or rejection and supporting data, are provided to the Bureau of Land Management. The Secretary of the Interior makes the final decision to accept or reject bids received in the competitive lease sales. During calendar year 1974, tract evaluations were completed for five sales in the Gulf of Mexico covering a total of 5.0 million acres offered, and 1.8 million acres were leased for bonuses totaling $5.0 billion. During calendar year 1975, evaluations were completed for four sales covering 7.2 million acres, of which 1.7 million acres were leased for bonuses of nearly $1.1 billion.

Tract evaluations were begun in fiscal year 1975 for Sales 38A and 41 in the Gulf of Mexico, Sale 35 off Southern California, and Sale 39 in the Gulf of Alaska. Preliminary work was also in progress for Sale 40 in the Mid-Atlantic Area, Sale 42 in the North Atlantic, Sale 43 in the South Atlantic, Sale 45 in the Bering Sea, and Sale 46 in the western Gulf of Alaska.

The Survey purchased 132,230 kilometres (82,200 miles) of common-depth-point seismic data to locate potential hydrocarbon-bearing structures, 74,830 kilometres (46,500 miles) of high-resolution seismic data to detect the presence of shallow geological hazards, and 62,440 kilometres (38,800 miles) of gravity data and 123,110 kilometres (76,500 miles) of magnetic data for specialized studies, at a total cost of $7.5 million.

Regulation of operations

On January 28, 1969, a well being drilled in the Santa Barbara Channel off southern California blew out. Although the flow of fluids from the well was effectively controlled by closing the blowout preventor, oil and gas continued to flow for 11 days through subsurface fractures to the ocean floor and subsequently to the water surface. The Santa Barbara oil spill focused national attention on the potential damage from offshore oil and gas installations if adequate safety and environmental controls were not maintained. Public concern was further heightened when a fire broke out on an oil and gas platform in the Gulf of Mexico on February 10, 1970. This fire destroyed the platform and damaged equipment to the extent that oil and gas flowed for several weeks after the fire was extinguished. Although no injuries or environmental damage were reported, the potential for such damage existed.

These incidents precipitated a number of major studies of oil and gas operations on the Outer Continental Shelf:

- National Aeronautics and Space Administration (1971)—A study, made at the request of the Geological Survey, to review the applicability of National Aeronautics and Space Administration contract quality management techniques and failure-mode effect analysis procedures to the Outer Continental Shelf oil and gas lease management program.

TABLE 17.—*Proposed OCS planning schedule*

JUNE 1975
(REVISES NOVEMBER 1974 SCHEDULE)

SALE AREA		1974						1975												1976												1977												1978											
		J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
SOUTH TEXAS	37		DES	PH		BSI FES		N	Sale					S	A	L	E		H	E	L	D		I	N		F	E	B	R	U	A	R	Y		1	9	7	5																
CENTRAL GULF	38	ND			T		DES	PH		FES	N	Sale							S	A	L	E		H	E	L	D		I	N		M	A	Y		1	9	7	5																
CENTRAL GULF	38A	ND			T		DES	PH		FES	N			Sale																																											
SOUTHERN CALIF.	35		T						DES			PH	BSI		FES	N	Sale																																								
COOK INLET [1]		F	E	D	E	R	A	L		I		S	T	A	T	E		S	A	L	E		I		D	A	T	E		U	N	C	E	R	T	A	I	N																
GULF OF ALASKA	39	BSI				C	ND			T			DES		PH		FES	N	Sale																																						
GULF OF MEXICO (GENERAL)	41						C	ND		T				DES		PH			FES	N	Sale																																				
MID-ATLANTIC	40									C		BSI ND			T		DES		PH		FES	N	Sale																																		
NORTH ATLANTIC	42											C		ND		BSI		T		DES		PH		FES	N	Sale																														
GULF OF MEXICO (DRAINAGE)	44																		T			DES		PH			FES	N	Sale																											
SOUTH ATLANTIC	43													C				BSI ND		T			DES		PH			FES	N	Sale																										
GULF OF ALASKA (INCLUDING KODIAK)	46													BSI			C		ND		T			DES		PH			FES	N	Sale																									
BERING SEA (ST. GEORGE)	45						C	ND				BSI		T											DES			PH			FES	N	Sale																								
GULF OF MEXICO (DEEP)	47																		C			ND			T			DES		PH			FES	N	Sale																				
SO. CALIFORNIA	48																				C	ND			T			DES		PH			FES	N	Sale																			
MID-ATLANTIC	49																BSI					C	ND			T			DES	PH			FES	N	Sale																		
BEAUFORT SEA	50											BSI												C		ND			T			DES		PH			FES	N	Sale																
OUTER BRISTOL BASIN	51											BSI													C		ND			T			DES	PH			FES	N	Sale															
NORTH ATLANTIC	52															BSI										C		ND			T			DES	PH			FES	N	Sale														
CALIFORNIA GENERAL INCL. WASH. & OREGON	53																							BSI			C		ND			T			DES	PH			FES	N	Sale												
SOUTH ATLANTIC (BLAKE PLATEAU)	54																		BSI									C		ND			T			DES	PH			FES	N	Sale											
BERING SEA (NORTON BASIN)	55																				BSI									C		ND			T			DES	PH			FES	N	Sale										
GULF OF ALASKA – ALEUTIAN SHELF	56													BSI																C		ND			T			DES	PH			FES	N	Sale									
CHUKCHI SEA HOPE BASIN	57																							BSI								C		ND			T			DES	PH			FES	N	Sale								

BSI Baseline Studies Initiated
C Call for Nominations
ND Nominations Due
T Announcement of Tracts
DES Draft Environmental Statement
PH Public Hearing
FES Final Environmental Statement
N Notice of Sale
[1] State May Conduct Sale

Baseline studies scheduled are contingent upon scientific personnel and equipment being available to perform the studies.
Sales are contigent upon technology being available for exploration and development. A decision whether to hold any of the lease sales listed will not be made until completion of all necessary studies of the environmental impact and the holding of public hearings; as a result of the environmental, technical, and economic studies employed in the decision – making process, a decision, may, in fact, be made not to hold any sale on this schedule.

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Curt Berklund

Director,
Bureau of Land Management

- U.S. Geological Survey (1972)—An in-house study of the Survey's inspection program and procedures for enforcement of regulations.
- National Academy of Engineering (1972)—A study done at the request of the Survey, by the Marine Board of the National Academy of Engineering, which reviewed the technology and recommended regulatory practices that would minimize pollution of the Outer Continental Shelf from oil and gas operations.
- Kash and others (1973)—An exhaustive study, conducted under the aegis of the University of Oklahoma's Science and Public Policy program through a grant from the National Science Foundation which resulted in a technological assessment of Outer Continental Shelf oil and gas operations.
- Council on Environmental Quality (1974)—A study which assessed the environmental impact of oil and gas production on the Atlantic Outer Continental Shelf and in the Gulf of Alaska.

Shortly following the Santa Barbara blowout, the Survey began to review and revise its operating procedures and regulations. A set of revised regulations and Outer Continental Shelf orders which implemented the regulations were issued August 28, 1969. Subsequently, the Survey commissioned three of the studies cited above (National Aeronautics and Space Administration, 1971; U.S. Geological Survey, 1972; and National Academy of Engineering, 1972) and established a work group on Outer Continental Shelf safety and pollution control, chaired by the Survey's Associate Director, to review the study's findings and recommendations. This work group issued its first report and recommendations in May 1973 (U.S. Geological Survey, 1973). Two supplemental studies (U.S. Geological Survey, 1974 a, b) evaluated the two other reports listed above (Kash and others, 1973; Council on Environmental Quality, 1974).

These recommendations and their status in fiscal year 1975 are listed in table 18.

TABLE 18.—*Status of Outer Continental Shelf recommendations*

Work group recommendation	Implementation in fiscal year 1975
1. Failure reports and corrective actions.	A system was established for operators to report quarterly failures of subsurface safety valves. The system can be expanded to include other types of equipment failures. Failure reporting forms are being designed.
2. Accident investigation and reporting.	Accident reporting procedures were revised to define better causes and effects of accidents. Geological Survey reports of accidents are available for public inspection.
3. Information exchange.	Reports on failures of subsurface safety valves are distributed quarterly to all operators. A safety alert system has been established to inform operators of the causes of accidents and pollution events.
4. Research and development.	American Petroleum Institute sponsored committees have been formed to encourage industry research on sand-probe development and testing, orifice coefficients, and oil detection and removal. The Survey has contracted with the Harry Diamond Laboratories to assess industry research and development concerning safety and pollution control and development of communications equipment and flow meters.
5. Standards and specifications.	The American Petroleum Institute is establishing standards and specifications for: design, installation, and operation of subsurface safety valve systems; analysis, design, installation and testing of surface safety systems on offshore platforms; wellhead surface safety valves; design and installation of production platform piping systems. The Survey received agreement from the American National Standards Institute to form committees to review standards.
6. Systems analysis.	The Geological Survey has contracted for pilot studies on the analysis of the design of platform facility systems. The Survey has also provided a research grant to Rice University to draft standards on platform-systems design analysis.
7. Engineering documentation.	The revision of OCS Order No. 8 (Platforms and Structures) requires extensive documentation of construction design and safety systems.
8. Wearout prevention.	The revision of OCS Order No. 8 requires the monitoring of sand erosion of valves and lines. Industry is conducting research on sand-erosion detectors.
9. Training and certification.	OCS Order No. 2 (Drilling Procedures) (Pacific Area) requires well-control training for supervisory and drilling personnel. OCS Order No. 8 requires training for all personnel working with safety devices. Procedures have been established to insure that minimum training standards are met. Training of inspectors is to be evaluated on an individual basis. Training sources are (1) on-the-job training, (2) technical schools, and (3) indoctrination sessions.
10. Motivation.	As a result of work group recommendations, industry has published a bulletin on ways to motivate employees to be concerned with safety and pollution prevention.
11. Lease Management program.	This program on the OCS has been buttressed to provide adequate staff and funds to mount an optimum effort.
12. Inspection procedures.	Uniform inspection and enforcement procedures have been established. A computerized platform inspection system has been developed.
13. OCS Order development.	Procedures were established for development of OCS Orders and revision of existing Orders. Public participation in the development of OCS Orders is provided through the placing of notices of proposed rule making in the *Federal Register*.

TABLE 18.—*Status of Outer Continental Shelf recommendations* —Continued

Work group recommendation	Implementation in fiscal year 1975
13. OCS Order development—Continued	The technical adequacy of OCS Orders was assured by providing for review by the American National Standards Institute.
14. Standardization of forms.	A pollution report form was revised and is in use.
15. Safety and advisory committees.	The Marine Board of the National Academy of Engineering established a committee to review OCS operations (National Academy of Engineering, 1974a, b; National Research Council, 1975a, b) The Geological Survey established safety committees in field operations offices. Oil companies have established internal safety and anti-pollution groups.
16. Memorandum of understanding with the Occupational Safety and Health Administration.	Negotiations failed to produce a procedural memorandum of understanding.
17. Memorandum of understanding on pipelines.	A memorandum of understanding is in effect with the Bureau of Land Management. Discussion is continuing between the Department of the Interior and Department of Transportation (Office of Pipeline Safety).
18. Memorandum of understanding, on standards for discharge from platforms and rigs.	The Environmental Protection Agency has begun to establish discharge criteria.
19. Subsea production systems.	A task force was assembled to assess the current state of the art, and comments were solicited through *Federal Register* notice. Two reports on subsea systems have been prepared.

Outer Continental Shelf Orders are formal numbered requirements issued by Oil and Gas Supervisor, with the prior approval of the Chief, Conservation Division, that implement the OCS operating regulations by applying them uniformly to a region or a major portion thereof. Considerable activity was directed in fiscal year 1975 to the updating of the following OCS Orders:

Gulf of Mexico Area

OCS Order No. 2 (Drilling Procedures)
Revised Order effective January 1, 1975

OCS Order No. 6 (Completion of Oil and Gas Wells)
Federal Register Notice of December 11, 1974, solicited comments on a revision to include workover procedures.
Draft revision has been prepared and is being reviewed.

OCS Order No. 7 (Pollution and Waste Disposal)
A request for comments for revision of this order was published in the *Federal Register* during December 3, 1974.
Revision of the Order is being prepared and reviewed for publishing in *Federal Register* during fiscal year 1976.

OCS Order No. 8 (Platforms and Structures)
Proposed revision published in *Federal Register* January 21, 1975.
Public meeting held to discuss technical aspects of the Order on February 25, 1975.

OCS Order No. 12 (Public Inspection of Records)
Revised Order effective February 1, 1975.

Pacific Area

OCS Order No. 2 (Drilling Procedures)
Proposed revision published in *Federal Register* for comment on August 19, 1974.

OCS Order No. 11 (Oil and Gas Production Rates)
Final Order issued effective May 1, 1975.

OCS Order No. 12 (Public Inspection of Records)
Final Order issued effective December 1, 1974.

Gulf of Alaska Area

OCS Order Nos. 1 through 9, 11, and 12 published in the *Federal Register* for comment on January 6, 1975

Atlantic Area

Notice of Intention to Develop OCS Orders published in *Federal Register* on October 1, 1974.

A list of all the Outer Continental Shelf Orders and their status as of the end of fiscal year 1975 is shown in table 19.

The Survey supervised oil and gas operations on 1,590 OCS leases covering 7.2 million acres during calendar year 1974 (table 47). The bulk of these operations were located in the Gulf of Mexico, although 68 leases were located offshore of California. Total production from these leases amounted to 361 million barrels of oil, and 3,515 billion cubic feet of natural gas. The total value of all petroleum products produced on Outer Continental Shelf lands was $3.6 billion.

During calendar year 1974, Survey personnel for the Gulf of Mexico made 1,300 inspections of drilling rigs, 2,505 inspections of production platforms, and many overflights of other sites, while flying between inspections, in order to check for oil spills. As a result of these inspections the Survey issued 1,690 warnings on individual items found not to be in compliance with regulations, and ordered 1,244 zones and 290 platforms shut-in until violations of orders and regulations were corrected. The number of oil spills and fires and explosions associated with Outer Continental Shelf oil and gas operations during the last 5 years are summarized in tables 20 and 21.

TABLE 19.—*Status of Outer Continental Shelf Orders at the end of fiscal year 1975*

Order number and title	Gulf of Mexico Area	Pacific Area	Gulf of Alaska Area	Atlantic OCS Area
1. Marking of Wells, Platforms and Fixed Structures	Effective 8/28/69.	Effective 6/1/71.	Draft of OCS Orders 1 thru 9, 11 and 12 were published in *Federal Register* 1/6/75.	Notice of Intention to develop OCS Orders published in *Federal Register* 10/1/74.
2. Drilling Procedures	Revision effective 1/1/75.	Effective 6/1/71; under revision.		
3. Plugging and Abandonment	Effective 8/28/69.	Effective 6/1/71.		
4. Suspensions and Determination of Well Producibility	Effective 8/28/69.	Effective 6/1/71.		
5. Subsurface Safety Devices	Effective 6/5/72.	Effective 6/1/71.		
6. Completion of Oil and Gas Wells	Effective 8/28/69; under revision.	Effective 6/1/71.		
7. Pollution and Waste Disposal	Effective 8/28/69.	Effective 6/1/71.		
8. Platforms and Structures	Proposed revision published in *Federal Register*.	Effective 6/1/71.		
9. Oil and Gas Pipelines	Effective 10/30/70.	Effective 6/1/71.		
10. Sulphur Drilling Procedures	Effective 8/28/69.	Effective 6/1/71.	Not applicable.	Not applicable.
11. Oil and Gas Production Rates, Prevention of Waste, and Protection of Correlative Rights.	Effective 5/1/74.	Effective 5/1/75.		
12. Public Inspection of Records	Revision effective 2/1/75.	Effective 12/1/74.		

TABLE 20.—*Summary of hydrocarbon spills on Outer Continental Shelf, 1971–74*

Calendar year	Spills of 50 barrels or more		Spills of less than 50 barrels	
	Number	Barrels spilled	Number	Barrels spilled
1971	11	1,285	1,245	1,493
1972	2	150	1,159	1,032
1973	4	22,175 [1]	1,171	921
1974	8	22,721 [2]	1,129	667

[1] 9,935 barrels were spilled from a storage tank rupture (1/9/73) and 7,000 barrels were spilled from a leaking barge (1/26/73).
[2] 19,850 barrels were spilled from a pipeline break caused by a ship's anchor dragging on the seabed (4/17/74).

TABLE 21.—*Summary of fires and explosions on the Outer Continental Shelf, 1970–74*

Calendar Year	Number of events	Injuries	Fatalities
1970	10	31	11
1971	17	16	1
1972	30	9	0
1973	27	9	2
1974	22	15	0

In calendar year 1974 royalty revenue from the sale of petroleum and sulfur products amounted to $560 million, an increase of $159 million over calendar year 1973, and $197 million over calendar year 1972.

Oil production from the Outer Continental Shelf has been declining since 1971 (fig. 48) as new discoveries have not kept pace with the decline in production from older fields. A major disappointment during the year was the failure of exploratory drilling on the Destin dome offshore of Florida to locate the substantial oil and gas resources that had been anticipated for this structure.

Since production usually lags behind lease sales by 3 to 10 years, the impact of the accelerated leasing program has not yet been fully experienced; however, requests for approval of exploration plans and notices of intent to drill have increased.

FEDERAL AND INDIAN LANDS

The Geological Survey classifies and evaluates the mineral resources on Federal lands onshore and supervises exploration, development, and production operations on both Federal and Indian land leases. Specific procedures for leasing and development are governed by a multitude of different laws and regulations which complicate the administration of the onshore program. For example, unlike public land laws which

provide for the leasing of specific minerals, such as oil and gas, coal, oil shale, asphaltic minerals, sodium, potash, phosphate, geothermal resources, and sulfur (in New Mexico and Louisiana only), Indian land and acquired land laws authorize the leasing of all metalliferous and nonmetalliferous minerals.

The Survey also, by cooperative arrangement with the Department of the Navy, furnishes technical advice with respect to Naval Petroleum Reserve lands and supervises operations for the drilling and production of oil and gas on Naval Petroleum Reserve No. 2 (Buena Vista) in California.

As is the case with the Outer Continental Shelf Lands subactivity, the Federal and Indian Lands subactivity also consists of two programs, Resource Classification and Evaluation and Regulation of Operations.

Resource Classification and Evaluation

Resource classification involves the collection of basic data needed to (1) classify Federal mineral lands, (2) delineate prospectively valuable mineral areas in order to determine whether or not the mineral rights should be retained by the Government in land disposal and exchange actions, and (3) modify or eliminate outstanding mineral-, waterpower-, and reservoir-site classifications or withdrawals.

Survey geologists classify Federal lands as to their potential for leasable minerals by considering all the available geologic data in order to determine which legal subdivisions of land are mineral lands. The Survey prepares and reviews its standards from time to time in order to make the classification action uniform and objective. Standards have been recently published for coal (Bass, Smith, and Horn, 1970) and geothermal resources (Godwin and others, 1971). Standards for other minerals are being revised.

To identify which lands are underlain by leasable minerals within the limits set by the classification standards, Survey geologists prepare geologic maps, collect drill-core samples, and make laboratory analyses to determine the quality or grade of the mineral commodity. Limits for classification are expressed for coal in terms of depth, thickness, and heat values (Bass, Smith, and Horn, 1970). At the end of fiscal year 1975, 41.9 million acres of withdrawn land had been classified as mineral land, and 45.7 million acres remained to be classified (table 22).

Potential waterpower and water-storage sites on Federal lands are also classified as valuable or not valuable for development in order to retain the Government's right to authorize or license hydroelectric or water-storage development on such lands. Of the 13.9 million acres so withdrawn, 143,000 acres were classified or reclassified in fiscal year 1975. About 9 million acres of the total are withdrawn for possible use at the Ramparts Reservoir site on the Yukon River, Alaska.

As a result of complying with requests for 15,000 mineral reports by other Federal agencies during the year, the Survey designated 1.17 million acres of land as prospectively valuable for leasable minerals.

Once Federal land has been classified as mineral land it must be evaluated to determine whether or not it is subject to competitive or noncompetitive leasing. Where lands are designated as subject to competitive leasing they must be divided into tracts, and the Survey must determine the value of the resources for each tract in order to establish a minimum acceptable bid. The Survey then provides this information to the agency responsible for leasing the land.

The applicable leasing procedures and regulations differ with each commodity. Lands within the boundaries of Known Leasing Areas are subject to competitive leasing and are not subject to lease by application. For example, when the initial discovery of an oil and gas field is made, the Survey establishes an undefined Known Geologic Structure and informs the Bureau of Land Management. This action pre-

TABLE 22.—*Status of Federal land classifications, fiscal year 1975*
[Acres in thousands]

Commodity	Mineral lands withdrawn	Classified lands		Prospectively valuable Federal lands [1]	Known Leasing Areas	
		Nonmineral	Mineral		Undefined	Defined
Total	45,708	38,145	41,958	2,341,324	5,834	24,462
Oil and gas	-----	-----	4	1,476,001	5,151	11,864
Oil shale	14,206	75	-----	14,375	----	-----
Asphaltic minerals	-----	-----	-----	17,941	----	-----
Coal	20,471	33,445	40,939	350,349	----	9,277
Geothermal resources	-----	-----	-----	98,180	----	2,684
Phosphate	1,620	4,625	390	30,531	2	40
Potash	9,411	-----	-----	80,928	114	309
Sodium	-----	-----	625	267,426	567	288
Sulphur	-----	-----	-----	5,593	----	-----

[1] These figures represent the total acreage for each leasable mineral commodity and do not reflect total Federal acreage prospectively valuable because some acreage contains more than one mineral commodity.

vents any further noncompetitive leasing of the area until such time as the boundaries of the Known Geologic Structure can be more accurately determined and published in the *Federal Register*.

The Survey recommends lands for leasing whenever there is reason to believe that sufficient competitive interest exists or that leasing would be in the best interests of the United States. With regard to Federal lands, the Survey: (1) recommends to the Bureau of Land Management the size of each parcel and special stipulations such as those pertaining to surface use or drilling requirements, (2) determines and recommends to the Bureau of Land Management a minimum acceptable bid for each parcel on the basis of current economic, geologic, and engineering data; and (3) recommends to the Bureau of Land Management whether the high bid submitted for each parcel should be accepted or rejected.

Most Indian lands are leased by competitive bidding methods, and the Bureau of Indian Affairs has usually relied on the Survey to parcel tracts for sale, to recommend stipulation to be included in the leases regarding other surface use and drilling requirements, and to recommend acceptance or rejection of high bids offered. Complete presale evaluations for Indian lease sales are only done when requested.

As noted above, oil and gas lands are leased competitively if they are located on Known Geologic Structures of producing oil and gas fields as defined from analysis of well logs, core sampling data, production records, and maps that are required to be submitted to the Geological Survey by lessees and operators. Lands not located on the Known Geologic Structure of a producing oil or gas field are leased by application to the Bureau of Land Management. During fiscal year 1975, the Survey identified 7,408 acres to be within Known Geologic Structures and classified 228,683 acres in 119 undefined Known Geologic Structures.

Coal is leased by competitive bidding when information available to the Government is adequate to prove existence of coal of workable quality and quantity. Alternatively, where prospecting or exploratory work is necessary to determine the existence or workability of deposits, coal may be leased noncompetitively by approval of a prospecting permit which can lead to a preference-right lease if prospecting discloses coal in commercial quantities.

During fiscal year 1975, field mapping for coal was in progress on 127 7.5-minute and 1 15-minute quadrangles and 3 coal-investigations maps were published. To date a total of 122 7.5-minute and 4 15-minute coal quadrangles have been published or released for open file as part of the coal program.

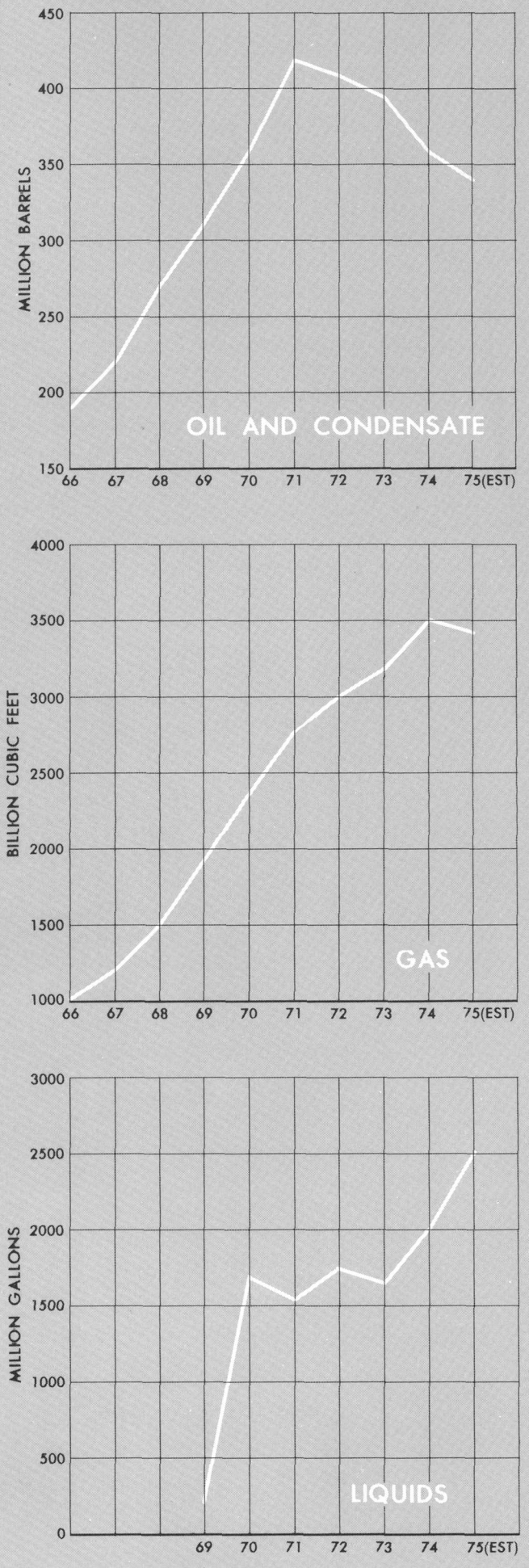


FIGURE 48.—Oil and gas production from Outer Continental Shelf lands, calendar years 1966–75. ▶

Drilling and coring were conducted in the States of Montana, North Dakota, Wyoming, Colorado, and Utah under grants and contracts. These data contributed to the definition of five new Known Coal Leasing Areas covering 910,000 acres (fig. 49). Coal on Federal lands in Known Coal Leasing Areas is subject to competitive leasing only.

Since the moratorium on coal leasing was imposed by the Secretary of the Interior in 1972, the coal-resource evaluation program has been concentrated on providing geologic and engineering data and analyses to the Bureau of Land Management's Energy Minerals Activity Recommendation System (EMARS). Twenty-nine coal-resource occurrence maps showing detailed coal geology and 19 coal-development-potential overlays showing relative coal values are scheduled to be submitted to the Bureau of Land Management in the fall of 1975 and to be open filed immediately thereafter.

Also, owing to the coal lease moratorium, tract evaluation has been limited to those tracts where immediate leasing is justified for continued operations or for efficient development. A total of five tracts were evaluated during the year, but only two leases were issued.

Twenty-five mineral and waterpower resource land classification maps at a scale of 1:250,000 were completed and open filed by the end of fiscal year 1975; ten additional maps are complete and will be released in fiscal year 1976; and 25 maps are in progress. All maps cover areas in the Rocky Mountain States (fig. 50). These maps provide an overall picture of land classification by the Geological Survey which is useful in showing resource relationships for land use planning.

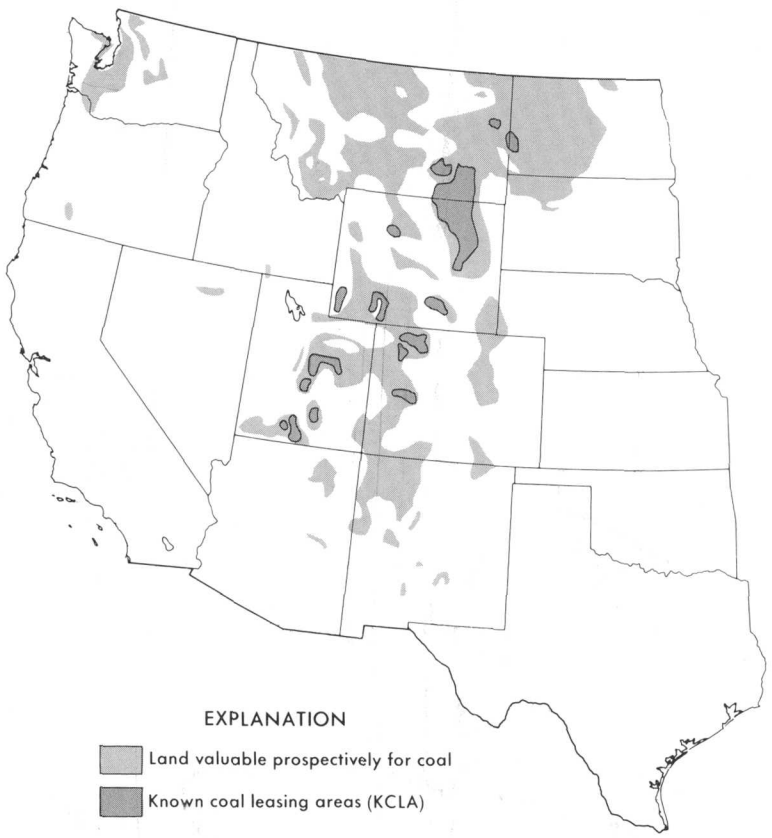


FIGURE 49.—Status of coal classification on Federal and Indian lands.

Resource-evaluation activities for *other leasable minerals* during the year included:

- Classification of about 3,120 acres in Known Potash Leasing Areas in New Mexico.
- Completion of seven 7.5-minute quadrangle maps of the geology of phosphate lands.

Regulation of Operations

The Geological Survey is responsible for supervising oil, gas, and mining operations on Federal and Indian lands and geothermal operations on Federal lands. In this regulatory program, oil, gas, geothermal, and mining operations are treated as separate units because of the different technologies and engineering disciplines used by each type of operation. The major program requirements, however, are basically the same: (1) review and approval of exploration and development plans; (2) supervision of exploration, development, and production operations; (3) computation and collection of royalties and certain rentals.

Other related activities such as unitization, method of production measurement, transportation allowances, commingling of products, off-lease storage, and sales contracts also require the prior approval or concurrence of the Survey.

Oil, gas, and geothermal operations

At the end of calendar year 1975, there were 126,718 oil and gas leases covering 93.6 million acres and 552 geothermal resources leases covering 1.3 million acres in effect (table 49). These leases were located in 33 States. During calendar year 1975, total oil and gas production from these leases amounted to 198 million barrels of oil, a decrease of nearly 5 percent from calendar year 1974, and 1,057 billion cubic feet of natural gas, a decrease of 14 percent from calendar year 1974. Survey personnel made over 18,000 inspections of oil and gas lease operations, prepared 1,078 environmental analyses of proposed new wells, approved 2,321 new wells (both exploratory and development wells), and processed 11,396 other types of applications.

At the end of fiscal year 1975, the Geological Survey was maintaining 15,398 producing oil and gas lease accounts, an increase of 3.3 percent over fiscal

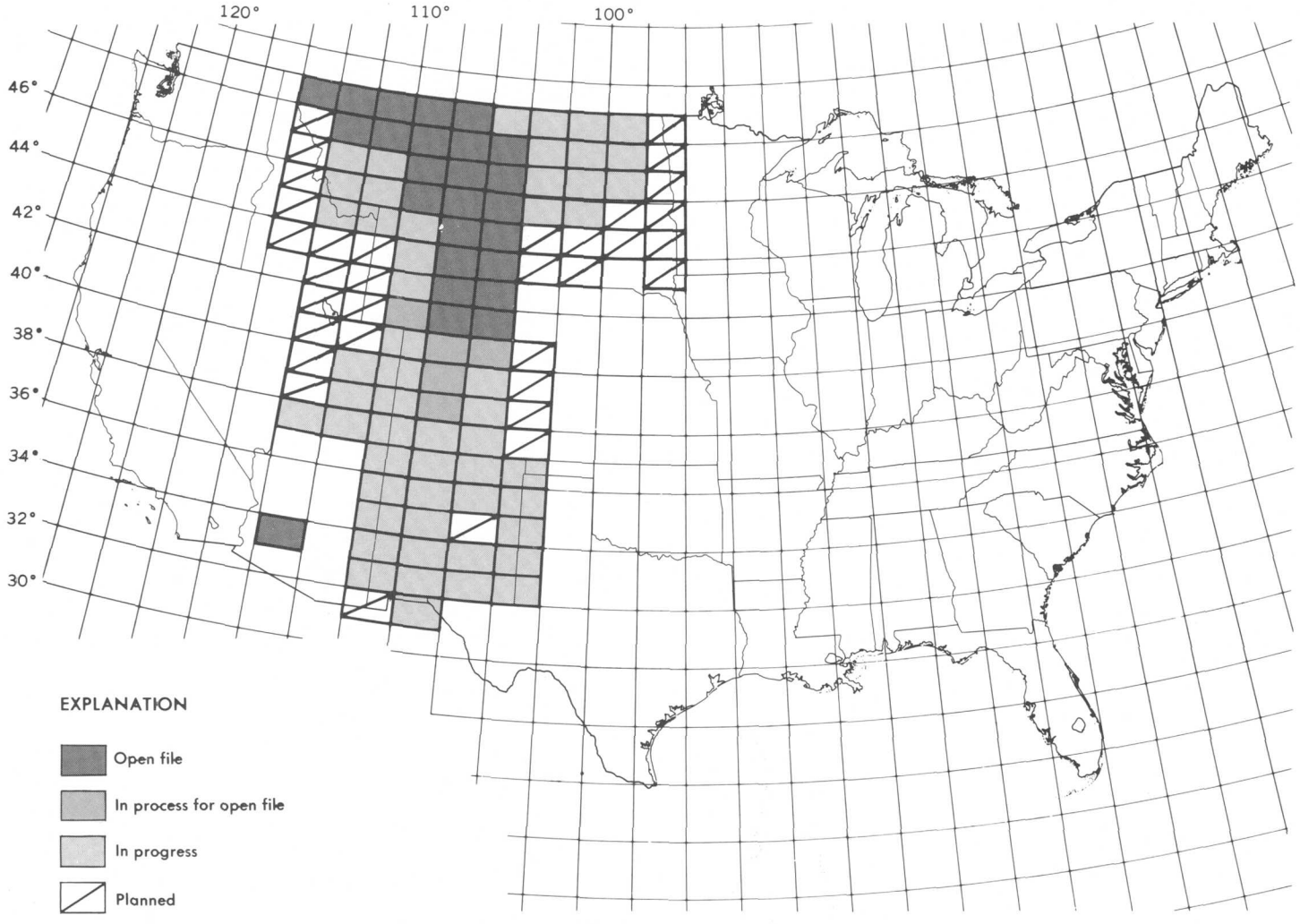


FIGURE 50.—Status of leasable mineral and waterpower resource land classification maps.

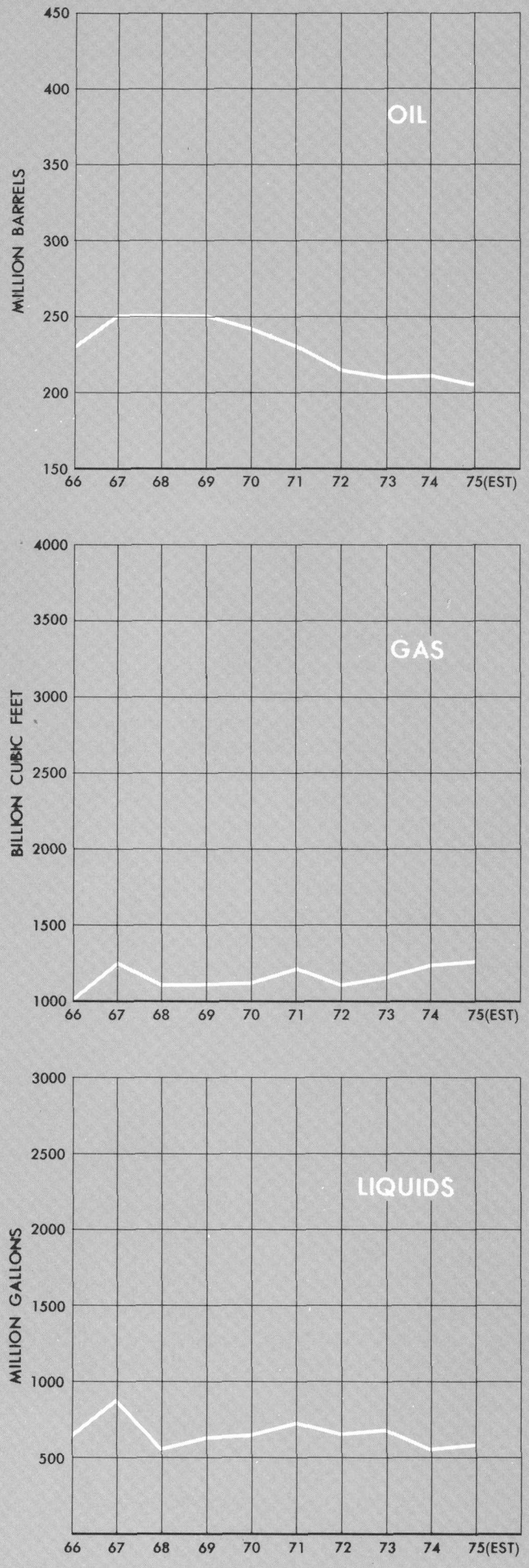
year 1974. At that time the Survey also had under its jurisdiction 1,670 rental accounts for Federal land leases. Total royalty revenue from the sale of oil, gas, and liquid products in calendar year 1975, amounted to $245 million dollars which was an increase of $26 million over calendar year 1974 owing to increased prices for those commodities.

About 6.5 percent of the Nation's domestic production of oil and 5.6 percent of its production of natural gas came from onshore Federal and Indian lands. Oil production from these lands, however, has been declining since 1968 (fig. 51) because new discoveries have not kept pace with the decline in production from older fields. The increasing demand for natural gas, which has caused greater effort to be directed toward finding new gas reserves, may account for some of the decline in oil production as well as the small increase in gas production. Liquid hydrocarbon products, which are extracted from natural gas produced from gas wells and from casinghead gas produced in association with oil, increased slightly during the year despite the decline in oil production.

The Geothermal Leasing program began in 1973 when the Department of the Interior published regulations governing the leasing of geothermal resources. By the end of calendar year 1975, 552 leases had been awarded. Although no geothermal leases are yet in a producing status, in May 1975 the first commercially producible geothermal well on Federal lands was successfully completed near the Castle Rock Springs area of the Geysers—Calistoga Known Geothermal Resources Area about 90 miles north of San Francisco.

Mining operations

During fiscal year 1975, the Survey supervised 2,479 mineral leases covering 8 million acres of Federal and Indian lands in 32 States. Although the number of leases under supervision has decreased from the previous fiscal year, prospecting and mining activities have sharply increased. Total production of solid



mineral commodities under lease during the year, for example, increased 34 percent to 88.3 million tons valued at $681 million as a result of continuing increases in demand for energy minerals, such as coal and uranium, fertilizer minerals, such as potash, and metallic minerals, such as lead, zinc, and copper.

Survey personnel made 2,100 producing lease and permit inspections, reviewed and approved 146 new or modified exploration and mining plans, prepared 146 environmental analyses, and assisted in the preparation of 26 environmental impact statements. Royalties from 180 producing lease accounts totaled $30.1 million, an increase over 1974 of 41.3 percent. Revenues from 803 rental accounts provided an additional $750,000.

The importance of Federal and Indian lands to the Nation's domestic production of solid minerals is illustrated in figure 46.

- *Coal*—Seven percent of the Nation's coal production in fiscal year 1975 came from leases on Federal and Indian lands in Montana, Wyoming, Colorado, Utah, New Mexico, and Arizona. It is estimated that production from existing leases could be increased from 44 million tons in 1975 to 213 million tons in 1980, an increase of nearly 384 percent. At the end of the fiscal year, 191 preference-right leases covering approximately 492,000 acres were pending a decision by the Secretary of the Interior on future coal leasing policy, and the coal leasing and operating regulations were being revised.

- *Oil Shale*—In 1971, the Department of the Interior initiated the Prototype Oil Shale Leasing program to encourage private industry to develop oil-shale mining and processing technology on a commercial scale, to insure the environmental integrity of the affected areas, to develop environmental safeguards and land-restoration techniques, and to develop management expertise in leasing and supervising oil-shale development. Following the preparation of an environmental impact statement, the Department competitively leased four tracts of land in Utah and Colorado embracing 20,400 acres for a bonus of $449 million. The lease terms require each lessee to file a detailed development plan with the Survey for review and approval on or before the third anniversary date of the lease. Furthermore, the lease terms require the bonus payments to be paid in five annual installments and permit the lessee to credit against the fourth and fifth payments any expenditures incurred prior

FIGURE 51.—Oil and gas production from Federal and Indian lands, calendar years 1966–75.

to the third anniversary of the lease that are directly attributable to operations for the development of the lease. The Survey's mining supervisor is responsible for determining that such expenditures credited by the lessee are properly attributable to development operations.

During 1975, four companies submitted their initial exploration plans for evaluation and approval by the Survey. Initial work also began on projects involving collecting baseline environmental data, monitoring air and water quality, and developing guidelines for future operations.

- *Fertilizer minerals*—A large increase in the demand for fertilizer minerals has accelerated the production and leasing activities for potash and phosphate during the past few years. Seventy-five percent of the Nation's potash is produced from Federal lands and 13 percent of phosphate comes from Federal and Indian lands. In Idaho, the principal western phosphate-producing State, there are 189 prospecting-permit applications pending.

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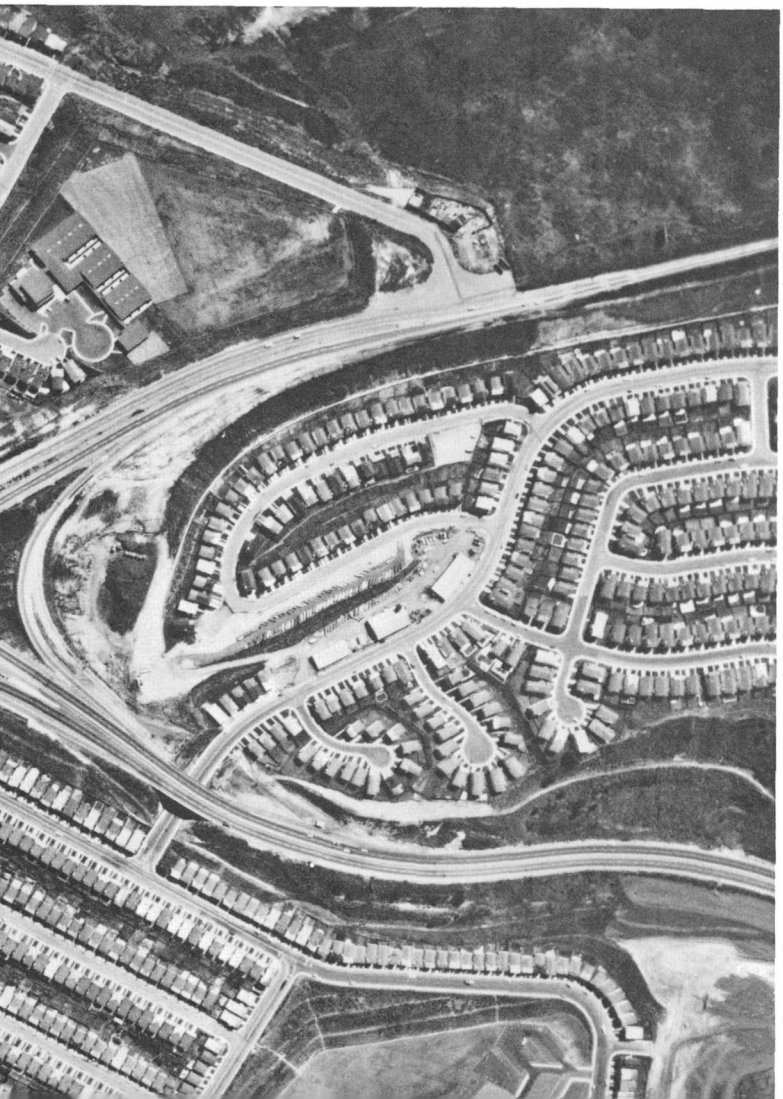
A coastal area of central California, subject to coastal erosion, landslides, and faulting, was nearly completely developed within a 10-year period. Application of earth-science information and proper land use controls could have mitigated the geologic hazards associated with this area.

Land Information and Analysis

OVERVIEW

In the past decade, conflicting uses of land resources have become one of the Nation's most critical problems. Too often, urbanization has encroached on land ill-suited for such development—houses, offices, and factories are built on or near active fault zones, on floodplains, or in areas prone to subsidence. Valuable mineral deposits, including building materials such as sand and gravel, have been paved or built over when prior planning could have achieved both the development of these resources and the use of the land for other purposes.

Serious concern over the environment is manifest in the enactment of the National Environmental Policy Act of 1969, recent State and local land use legislation, and intensive analyses of the implications of shortages of food, energy, and mineral resources. Consequently, there is an unprecedented need for information about our land for use in planning and decisionmaking. For example, recent moves to accelerate the development of energy resources, particularly the strip mining of Western coal deposits, demand greater knowledge of water supplies and of reclamation techniques to restore mined lands for future use.



Although the Geological Survey is the Nation's principal source of information about the character of the land surface and underlying resources, few Survey products have synthesized the results of the geologic, hydrologic, and topographic studies. Planners have had to seek the help of specialists to further analyze and interpret the information. The information base needed to resolve many of today's land use conflicts often reaches beyond the Survey's domain and includes the full range of concerns of the Department of the Interior.

In April 1975, the Department established the Land Information and Analysis Office within the Survey to consolidate several multidisciplinary land resource and environmental programs. This new office will interpret and display land resource information collected within the Department in ways that are readily accessible and understandable to a wide range of users, particularly land use planners and decisionmakers.

Programs

The Land Information and Analysis Office manages five multidisciplinary programs:

- The *Earth Sciences Applications* program (formerly the Urban Area Studies and the Land Resources and Analysis programs) is responsible for integrating the earth-science information collected by the Survey for use in analyzing land resource problems. The products, mainly thematic maps and reports, provide insight into the environmental consequences of land use decisions. For example, the San Francisco Bay region study has produced more than 70 geologic, hydrologic, and topographic maps and technical reports, plus 15 interpretive reports relating the data to land use planning and management alternatives and possible environmental impacts.
- The *Resource and Land Investigations* program encompasses the multidisciplinary, multibureau efforts of the Department of the Interior. The national problems addressed include, for example, the delineation of environmentally endangered areas, the development and application of land use inventory systems, and the siting of onshore facilities associated with Outer Continental Shelf energy resource development.
- The *Geography* program (formerly the Land Use Data and Analysis program) calls for the application of geographic analysis techniques to land and resource problems. Land use data are systematically collected, revised, and analyzed on a nationwide basis, and basic geographic research is conducted.

- The *Earth Resources Observation Systems* (EROS) program is the largest Departmental program to be managed by this new office. Since 1966, numerous experiments have been conducted applying remotely sensed data, primarily photographs and telecommunicated images obtained from satellites and high-altitude aircraft, to a wide variety of resource and environmental problems. The key facility of this program is the EROS Data Center in Sioux Falls, S. Dak., where the data are stored, reproduced, and distributed. The program includes research as well as user training in the interpretation and application of remotely sensed data and also includes the development of improved sensor and data processing systems.
- The *Environmental Impact Analysis* program (formerly the Energy Impact Evaluation program) directs the preparation and review of the environmental impact statements required of the Survey by the National Environmental Policy Act of 1969.

In addition, the Land Information and Analysis Office enters into cooperative projects with State, local, and other Federal agencies.

Budget and personnel

Obligations of Land Information and Analysis Office activity in 1975 amounted to $17.0 million, an increase of 31 percent over 1974 (table 23). The additional funds were used largely to undertake the Geography and Environmental Impact Analysis programs.

The work of the Land Information and Analysis Office is partly accomplished through private contracts and research grants. Of the fiscal year 1975 funds, $5 million (29.6 percent) was expended on contracts and $231,000 (1.4 percent) on research grants. This research centered on developing new methods of obtaining, interpreting, and displaying remotely sensed information. Contract services are also used to support the EROS Data Center.

The programs of the Land Information and Analysis Office were carried out by 191 full-time career employees in 1975; at the end of the year, 89 were assigned to the Office's programs (table 44), 10 were in the process of transferring to the Office, and 92 were assigned to other Survey offices to work on specific projects supported by the Land Information and Analysis Office. In addition, contract support services at the EROS Data Center amounted to 238 man-years. Personnel of the Topographic, Computer Center, and Administrative Divisions are also assigned to the Data Center.

TABLE 23.—*Land Information and Analysis Office activity obligations for fiscal year 1975, by program*

Program	Fiscal year 1975	Percent change relative to fiscal year 1974	
		Current dollars	Constant dollars
	(Dollars in millions)		
TOTAL	$16.99	+31	+18
Direct programs	15.46	+35	+22
Earth Sciences Applications program	1.60	+1	−9
Resource and Land Investigations program	.96	+5	−6
Geography program	2.01	—New Subactivity—	
Earth Resources Observation Systems program	8.28	−8	−17
Environmental Impact Analysis program	2.61	—New Subactivity—	
Reimbursable programs	1.53	−1	−10
States, counties, and municipalities	.03	—New Subactivity—	
Miscellaneous non-Federal sources	1.09	+84	+67
Other Federal agencies	.41	−57	−62

Highlights

The principal issues faced by the Land Information and Analysis Office in fiscal year 1975 concerned:

- Land use implications of energy and mineral resource development.
- Accelerated requests from State and local governments for information to support land use and resource planning and management (mainly for areas affected by the Coastal Zone Management Act of 1972 and by State and local land use legislation).
- Major Federal actions, especially related to energy resource development, that required environmental impact statements.

Consequently, new studies were undertaken to determine the onshore effects of oil and gas development along the Outer Continental Shelf off New England and the State of Washington, land use mapping of coastal States was accelerated, and environmental impact analysis task forces were formed. The analytical capability and user services associated with the remote sensing activities of the Office were also expanded.

The major events and accomplishments in fiscal year 1975 were:

- *Organization of the Land Information and Analysis Office* to address critical earth-science problems from a multidisciplinary perspective.
- *Successful launch of Landsat–2* and Congressional approval of a third Landsat to continue the global collection of valuable resource and environmental data.
- *Production of land use maps* for all of Louisiana and Arkansas and parts of Missouri, Kansas, Oklahoma, and Arizona to assist State and local planning and development activities.

EARTH SCIENCES APPLICATIONS PROGRAM

The Earth Sciences Applications program was established to provide a unit within the Geological Survey specifically concerned with making earth-science information available to land use planners and decisionmakers in directly usable form. Although the program's emphasis is chiefly upon geology, hydrology, and topography, many of its products eventually serve as Survey input to the Departmentwide Resource and Land Investigations program, which integrates earth-science information with natural-science information from other agencies.

The objectives of the Earth Sciences Applications program are threefold: (1) To interpret, demonstrate, and encourage the use of earth-science information for land use decisionmaking through demonstration projects, user interaction, technical assistance, publication of specially designed map and book reports, and project evaluations; (2) to stimulate development of multidisciplinary studies in the Survey through coordination and integration of activities; and (3) to serve as the focal point within the Survey for multidisciplinary studies to support the work of other Federal agencies. In accomplishing these objectives, the program has focused mainly on the interpretation and presentation of earth-science data bearing on land use conflicts in selected urban and adjoining areas throughout the United States. The location of these studies is shown in figure 52. These urban area studies

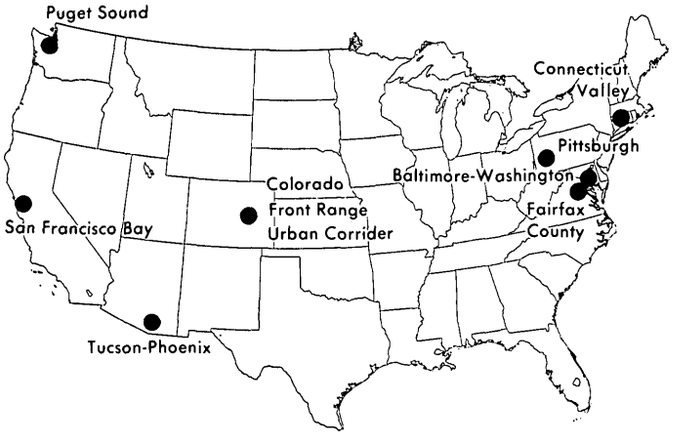


FIGURE 52.—Location of urban area studies in progress during fiscal year 1975.

are conducted by personnel from the Geologic, Water Resources, and Topographic Divisions supported by allocations of personnel and funds from the Earth Sciences Applications program. In fiscal year 1975, about $1.6 million was allocated to the urban area studies; however, about $5 million of related work coordinated with and ultimately contributing to the urban area studies was also conducted by the Topographic, Geologic, and Water Resources Divisions. An additional $505,000 was available to these Divisions from the Appalachian Regional Commission and the Department of Housing and Urban Development for work related to urban area studies.

The urban and adjoining areas under study in 1975 included Baltimore-Washington; Connecticut Valley; Denver, Colo.; Pittsburgh, Pa.; Puget Sound, Wash.; San Francisco, Calif.; Fairfax County, Va.; and Tucson-Phoenix, Ariz. (fig. 52). The Kentucky River Area Development District was also studied.

All of the urban areas under study in fiscal year 1975 have rapidly growing populations that impose severe demands on land and water resources. The types of earth-science information collected for land use and resource planners during these studies include character, thickness, and erodibility of soils; quantity and quality of surface water and ground water; definition of hazards associated with floods, earthquakes, landslides, subsidence, and poor foundation materials; and distribution of mineral resources, landforms, slopes, and watercourses. Without earth-science information to define the locations of natural resources and hazardous areas, land use managers run the risk of making decisions that may lead to substantial social and economic costs in future years.

Current urban area study projects were reviewed during fiscal year 1975, in terms of original objectives relative to past and likely future funding. Because of the lower-than-anticipated funding, the original objectives could not be achieved despite strong support from the other Divisions. It was decided to complete short-term goals of five urban area studies in fiscal year 1976, or early fiscal year 1977, and to concentrate funding in the other areas. The Puget Sound urban area study is being reoriented to consider the regional impacts of extensive oil and gas development in Alaska.

The Tucson-Phoenix urban area study, which began in July 1971 and carried through 1975, is an example of an ongoing study. This study area includes about 11,700 square kilometres (4,500 square miles) in three counties of Arizona. Reports published through fiscal year 1975 include 25 regional maps (scale 1:250,000) showing land status, distribution and thickness of alluvial deposits, recoverable ground water, vegetation, nonmetallic mineral deposits, chemical quality of ground water, and land subsidence and Earth fissures. An index to maps of flood-prone areas and a large-scale slope map were also published, and 90 1:24,000-scale slope maps were released to the open file.

The Arizona State Health and Land Departments use the regional scale maps to make decisions on water supply, sewage disposal, and use of State lands.

Engineers and supervisors of the Pima County Planning and Sanitation Departments use the various large- and regional-scale maps and reports to identify hazardous areas, plan major sewer lines, deny or alter construction plans in flood-prone or flood-erodible areas, and permit or deny real estate development in mineral deposit areas.

Accomplishments of the Earth Sciences Applications program in fiscal year 1975 included:

- Publication of "Seismic Hazard and Land-Use Planning" by Nichols and Buchanan-Banks (1974). An outgrowth of San Francisco Bay regional studies, the report summarizes and demonstrates the need for land use planning in areas of known seismic hazards.
- Publication of maps showing the potential sources of gravel and crushed-rock aggregate in certain areas of the Front Range Urban Corridor, Colo., specifically, (1) the Boulder-Fort Collins-Greeley, (2) Greater Denver, and (3) Colorado Springs-Castle Rock areas (Colton and Fitch, 1974; Trimble and Fitch, 1974a, b). These maps are the basis of local jurisdictions' preliminary evaluation of land development plans in response to State legislation that requires an evaluation of all mineral resources (metallic and nonmetallic) and geologic hazards before a real estate development is approved.
- Publication of "Relative Susceptibility of Lakes to Water-Quality Degradation in the Southern Hood Canal Area, Washington" by Bortleson and Foxworthy (1974). A result of early studies in the Puget Sound urban area, the report presents a method of evaluating future lake quality that has been adopted by State agencies.
- Completion of 23 open-file maps in Allegheny County, Pa., showing landslide susceptibility. An outgrowth of the Greater Pittsburgh region urban area study supported by the Appalachian Regional Commission, the maps are a valuable aid to land use planners, developers, and residents in avoiding the widespread natural hazard of landslides.
- Completion of six open-file, single-topic, earth-science maps of Montgomery County, Md. (Froelich, 1974a, b, c, d, e, f) and maps of the geology, mineral resources, and construction conditions of Prince Georges County, Md. (Hack, 1975a, b, c). The maps of the Baltimore-Washington urban area study are being widely used by regional planners, decisionmakers, and developers for land use management.
- Completion of about 33 single-topic earth-science maps in the Connecticut Valley urban area. These kinds of maps and their uses are explained in a report entitled "Geologic and hydrologic maps for land-use planning in the Connecticut Valley with examples from the folio of the Hartford North quadrangle, Connecticut" by Pessl and others (1972).

Evaluation of study results

The urban area projects are pilot studies to develop and demonstrate techniques of earth-science data collection and presentation that appear to be most useful to land use planners and decisionmakers. All the urban area studies have focused on regional planning and problems, yet local jurisdictions have been major users, perhaps because of the lack of essential earth-science data at larger map scales. At the urging of project personnel, some local governments have developed their own earth-science expertise to apply existing data to local needs. In the San Francisco Bay region, for example, four of the nine counties and one major city have established full-time geologist positions, and several other communities employ consultants or earth scientists part time, whereas none were employed in 1970 when the study began.

A survey was conducted to assess the extent to which maps and reports from the San Francisco Bay region study have been applied in land use decisions (Kockelman, 1975). The following applications identified during the survey are indicative of the widespread use of the study products at all levels of government:

Application	User
Bayland Development Policy Plan	Santa Clara County, Calif.
Building, grading, and subdivision regulations.	Santa Clara County.
Conservation and open-space plan	San Mateo County.
Dow petrochemical project environmental impact report.	Solano County.
Environmental analysis	Cities of El Cerrito, Richmond, and San Pablo.
Environmental hazards mitigation plan.	City of Oakland.
Fault trace development regulations	State of California.
Geology work prospectus	Sonoma County and State of California.
Land use plan element	Napa County.
Open-space plan	Sonoma County.
Resource conservation plan	Santa Clara County.
Resource management zoning district regulations.	San Mateo County.
Seismic and public safety plan elements.	San Mateo County.
Solid waste management site evaluation.	Contra Costa County.
Subdivision, grading, and timber ordinance administration.	San Mateo County.
Zoning district regulations	Napa County.

The Department of Housing and Urban Development, a principal cooperator in the San Francisco Bay region study, contracted with Arthur D. Little, Inc., to conduct an evaluation of the study. Although the report (Arthur D. Little, Inc., 1975) was prepared prior to the completion of many of the interpretive reports of the study, the findings were significant:

"The SFBRS Program has:

A. Raised the level of consciousness about natural hazards in the user community.
B. Begun to bridge the communication gap and improve information transfer among scientists, planners and decisionmakers.
C. Developed new, more detailed earth-science data for a complex geological area larger than Connecticut.
D. Expanded the focus and content of earth-science studies in other urban areas.
E. Strongly influenced the organizational structure of USGS, making it more responsive to data-application needs of others.
F. Strengthened the environmental requirements of and responses to HUD programs in the Bay area.
G. Improved the capability of ABAG (Association of Bay Area Governments) in environmental assessment, regional planning and decisionmaking.
H. Improved the capability of county and local planning agencies to perform environmental assessments and land use planning and to prepare codes and ordinances.
I. Experimented with new methods of data presentation and begun the development of a common language among scientists, planners, and users of resources."

The report also states that "Much still remains to be done to strengthen the fledgling impact of earth sciences in land use and environmental planning decisions." Perhaps the most valuable result of the continuing urban area studies will be the extension of effective communications between earth scientists, land use planners, and decisionmakers throughout the United States. If so, we may one day truly achieve a harmonious balance wherein man makes full use of land resources while he maintains esthetic and environmental values and avoids natural hazards.

RESOURCE AND LAND INVESTIGATIONS PROGRAM

The Department of the Interior established the Resource and Land Investigations program in September 1972 to mobilize more effectively its technological capacity and scientific competence for making objective analyses of land use alternatives. The Survey was assigned to take the lead in developing a technology and an information base for efficient and safe resource and land development in collaboration with other Interior agencies. The Survey's input to this program comes principally from the multidisciplinary studies conducted under the aegis of the Earth Sciences Applications program.

The purpose of the program is to improve technical communication between the collectors and analysts of resource and land information and the planners, managers, and decisionmakers in Government, industry, and the public sector. This goal is accomplished by coordinating the activities of the several Bureaus in those cases where a multidisciplinary perspective would improve the Department's ability to communicate with the planning community and by coordinating the Department's technical response to complex issues relating to land resource analysis. To improve the transfer of technical information in the planning community, directories, catalogs, and bibliographies are compiled and distributed that describe the information products, services, and research. The program also provides for technical assistance to aid planners in the acquisition and interpretation of information and in the development, selection, and application of planning tools.

The Resource and Land Investigations program in fiscal year 1975 included activities to:

- Identify and assess the utility of selected information products, geographic data systems, and data sources to State and local planning communities.
- Develop and distribute directories of data holdings and special information products of the Department of the Interior.
- Identify technical expertise in the Department that is needed by regional, State, and local planning communities and develop administrative procedures to make appropriate personnel available for consultation.
- Support and coordinate the preparation of guidebooks to planning methodologies.

Accomplishments during the year included the completion of guidebooks and other reports on:

- *Utility corridor siting*—A guidebook to methods for locating power transmission lines and pipelines and evaluating potential environmental impacts (Graf-Webster and others, 1974a).
- *Powerplant siting*—An annotated bibliography on factors influencing the location of thermal power generating facilities (Graf-Webster and others, 1974b).
- *State land use programs*—A series of background papers on land use planning and program analysis prepared by the Council of State Governments' Task Force on Natural Resources and Land Use Information and Technology (1974a, b, c, d, e; 1975a, b, c) as part of a grant from the Geological Survey.
- *Environmental analysis methodology*—A review and annotated bibliography of methodologies for evaluating environmental impacts (Bennington and others, 1974).

Evaluation

The reports, bibliographies, and assistance on planning techniques have been well received, and user responses have identified the need for more coordination between Federal and State data-collection and dissemination programs and for closer cooperation

within the planning community to provide specific information for land use information systems, critical environmental area planning, and assessment of the utility of information products for planning needs.

GEOGRAPHY PROGRAM

The Geography program links and integrates social science information and the techniques of geographic analysis with earth-science information collected by the Geological Survey. Activities of the program include:

- Mapping land use and land cover on a nationwide basis.
- Developing and demonstrating techniques of land use mapping using remote sensor data and a geographic information system for handling land use data.
- Conducting field investigations and participating in multidisciplinary studies that contribute to solutions of problems arising from interactions of land use practices and environmental factors.
- Contributing to the *National Atlas* project.

Planning and implementing programs designed to promote wise use of the land depend in part on a knowledge of the present distribution of and temporal changes in different types of land use and land cover and on a knowledge of where urbanization and other types of development are occurring. The location, area, and percentages of land use and land cover are among the types of statistical data used by Federal and State legislators and local officials to determine land use policy, to project demands for different types of land use, to predict where future development pressures will occur, and to formulate plans for regional development. Current land use and land cover data also support Federal and State planning for developing energy resources, managing public lands, siting public facilities, developing recreational areas, managing water resources, and assessing potential and actual natural disaster damages.

National land use and land cover mapping and data compilation

In fiscal year 1975, the Geological Survey established a Land Use Data and Analysis program to collect a comprehensive national baseline set of land use and land cover data that would alleviate or remedy many of the shortcomings of various types of existing data. Maps of current land use and land cover for the entire Nation are being prepared at 1:125,000 scale (1.25 kilometres to the centimetre, or 2 miles to the inch). Additional maps are being prepared in overlay format to relate current land use and land cover data to other sets of information such as: (1) resources on and ownership patterns pertaining to Federal lands; (2) certain resource management data, such as drainage-basin management; (3) political subdivisions, for example, counties and States; and (4) various types of census data.

The classification system being employed to map land use and land cover was developed in cooperation with many Federal and State agencies, employs common terminology, and is flexible (Anderson and others, 1976). Applied research has been conducted to assess the accuracy of the maps, as well as that of the data requirements and inventory methods, such as the application of Landsat digital data to land use and land cover mapping needs.

A computerized geographic information system has been developed to store and retrieve the data compiled under the national land use mapping program and other Survey land use and land cover research projects. The system includes: (1) entry of digitized land use and land cover maps and other related data; (2) editing and updating of the data base; and (3) retrieval and manipulation of the data for area measurement, comparative analysis with other data, and other analytic applications. Statistical reports are being prepared that present land use and land cover data for counties, watersheds, census county subdivisions, and federally owned land.

Experimental and demonstration land use and land cover maps are produced to test various mapping techniques, remote sensor applications, regional applications, classification variations, computer applications, and combinations of map scale and minimum area depicted.

Geography program personnel have provided technical assistance to users of Geological Survey land use and land cover data and maps and to those who desire to use the data in conjunction with computer software developed by the Geography program or who need the data converted to use with other systems. For example, the Geography program is cooperating with and assisting the U.S. Fish and Wildlife Service, the Bureau of Land Management, and the Soil Conservation Service to utilize the Survey's land use and land cover data in their resource management and planning. A cooperative Geological Survey and Forest Service test of the utility of the data in implementing requirements of the Forest and Rangeland Renewable Resource Planning Act of 1974 was started in fiscal year 1975.

Geography program accomplishments during the year included:

- *Compilation of land use and land cover data* for approximately 1,036,000 square kilometres (400,000

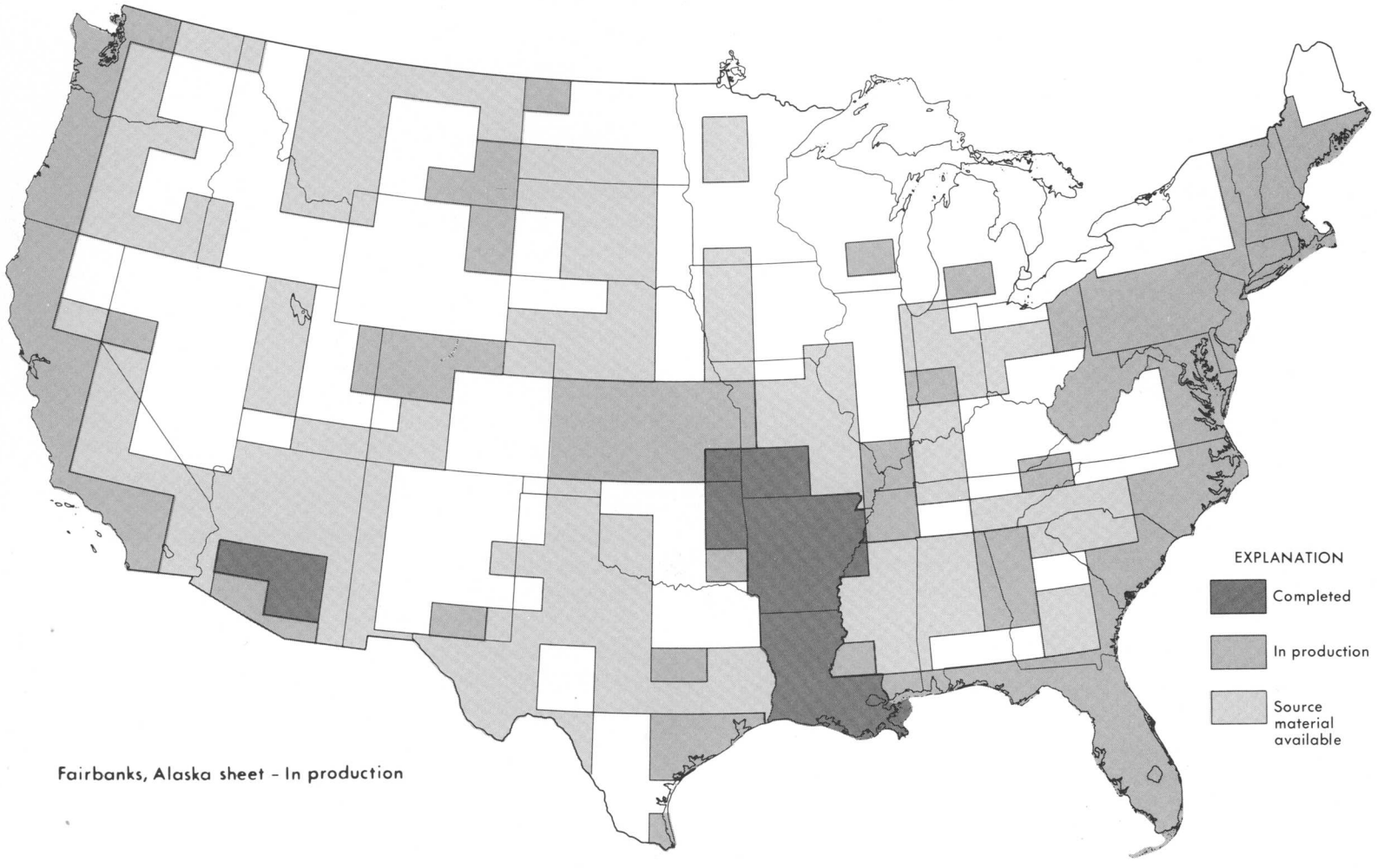


FIGURE 53. —Status of land use and land cover mapping, fiscal year 1975

square miles) during the first year of the national land use mapping effort (fig. 53). Emphasis was placed on mapping coastal areas, energy production areas, and areas covered by other Geological Survey program cooperative agreements such as the Greater Atlanta metropolitan area.

- *Compilation of regional and large-scale land use and land cover maps for the phosphate development area in southeastern Idaho* for use in the preparation of an environmental impact statement by the Environmental Impact Analysis program.
- *Completion of land use maps for the Greater Pittsburgh area, Pa., Lycoming County, Pa., and the Kentucky River Area Development District* for the Earth Science Applications program's urban area studies.
- *Completion of 85 percent of the Central Atlantic Regional Ecological Test Site (CARETS) Project final reports* for the National Aeronautics and Space Administration. These reports describe the results of studies of land use patterns and trends in the Norfolk, Va., area, image interpretation techniques, land use mapping accuracy, land use and air-quality planning, streamflow estimation using remotely sensed data, coastal ecosystems and environmental problems, environmental impact assessment, user evaluation, and geographic information system development.
- *Study of limitations on future resource development and urban expansion related to existing patterns of land use in the Little Rock, Ark., area* in cooperation with the Ozarks Regional Commission. Land use and land cover data were combined with soils data (such as permeability, structure, and agricultural potential), 100-year flood limits, mineral deposits data, and fish and wildlife information to produce a statistical data base that could be used in assessing limitations on future resource development and urban expansion.

Finally, Geography program personnel started a study of the development of the oil and gas industry on the Louisiana coast in fiscal year 1975 to determine the impact on land use and land cover of canal system expansion, maritime facilities siting, and changes in the labor force since 1947.

EARTH RESOURCES OBSERVATION SYSTEMS PROGRAM

In 1966, the Secretary of the Interior established the Earth Resources Observation Systems (EROS) program. The program, administered by the Geological Survey, provides for developing techniques to obtain and analyze remotely sensed data and for promoting the use of these techniques in fulfilling the resource and environmental inventory and management responsibilities of the Department. This objective is accomplished in cooperation with the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, and other Federal agencies.

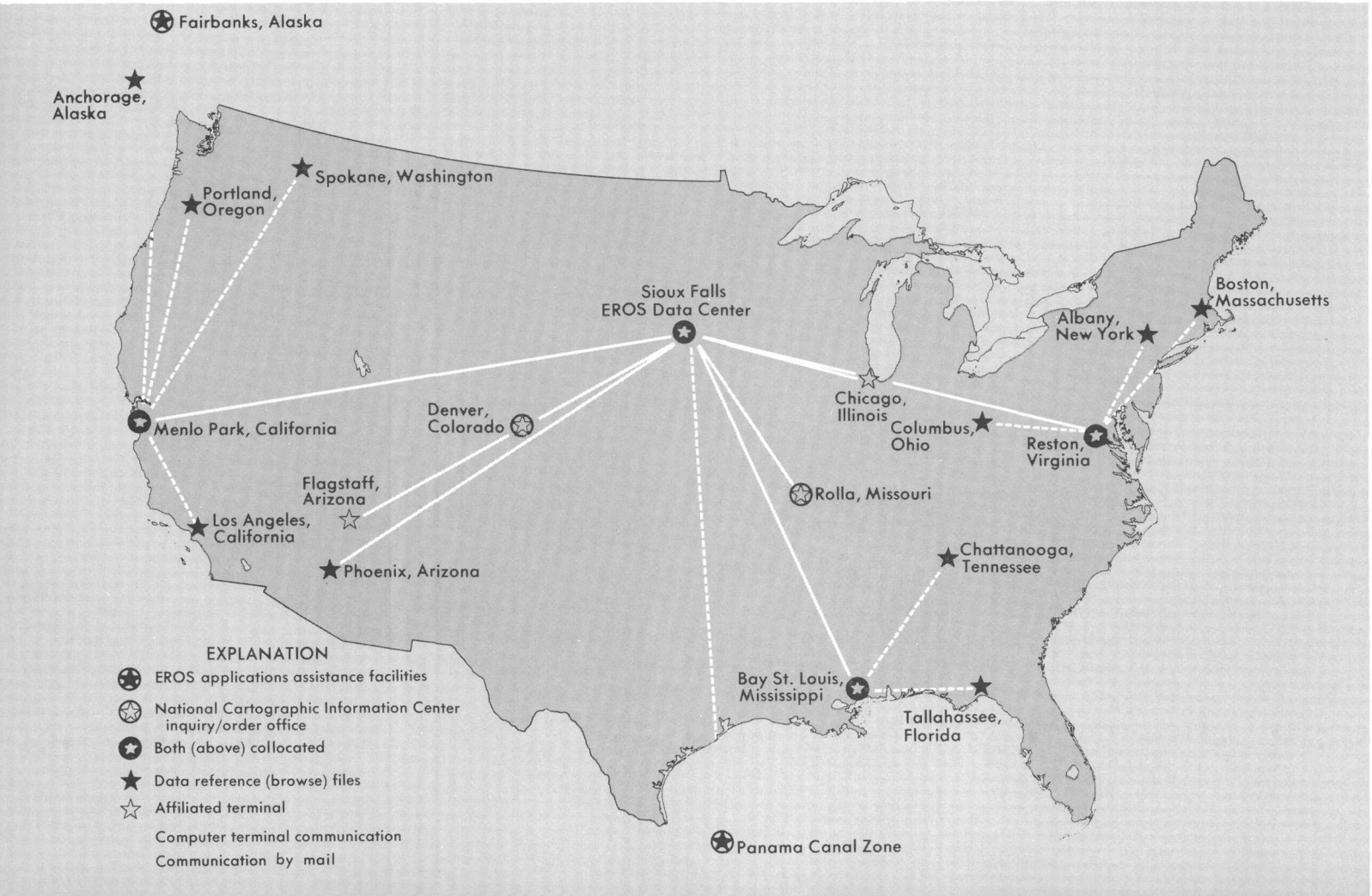
Program personnel work closely with representatives of the Department's Bureaus and Offices to coordinate and jointly sponsor applications of remote sensing technology. Much of the research, which has resulted in the demonstration of numerous new applications, has been made possible by the experimental data acquired through the National Aeronautics and Space Administration's Landsat and Skylab programs and their aerial remote sensing research program. Other research draws on data collected by other systems, such as the environmental satellites of the National Oceanic and Atmospheric Administration and aerial remote sensing activities sponsored by Department Bureaus and other Federal and State agencies.

EROS Data Center

The Earth Resources Observation Systems (EROS) Data Center in Sioux Falls, S. Dak., maintains an extensive archive of aerial and space photography, processes and distributes photographic and digital products, and provides extensive user training and assistance. The Data Center's archive is a major component of the Survey's National Cartographic Information Center.

Training and Assistance—A major function of the Data Center is to communicate the results of remote sensing research to potential users. Technical training programs, ranging in length from a few days to one month, stress the use of remotely sensed data to particular applications such as forest inventories or mineral exploration. During fiscal year 1975, the Data Center sponsored eight orientation courses, three discipline- or technique-oriented workshops, three training courses for people from other countries, and three technical symposia.

FIGURE 54.—Earth Resources Observation Systems and National Cartographic Information Center data inquiry and assistance network.



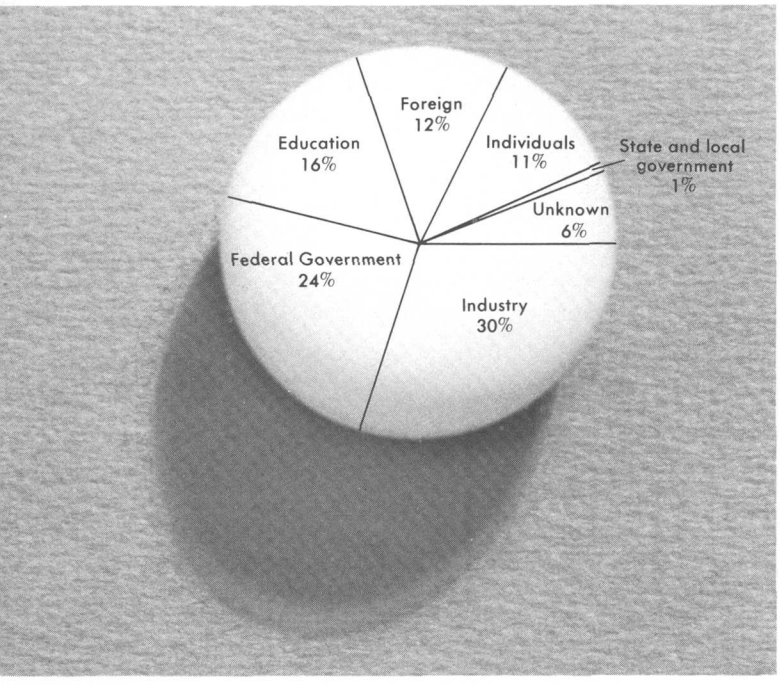


FIGURE 55.—Customer profile for purchase of all data from the EROS Data Center from April 1974 through March 1975.

In addition to formal courses, the Data Center operates a laboratory that provides visiting scientists with access to the latest equipment for processing digital imagery. This equipment is used for research, demonstration projects, and training. Data Center scientists also assist individual Federal, State, and local agencies in applying remotely sensed data to specific problems.

To encourage regional applications, the Earth Resources Observation Systems program includes eight applications assistance facilities (fig. 54) where the public can view microfilm copies of imagery available from the Data Center and order data. These facilities also offer assistance in techniques for applying the data to resource problems. In addition to these facilities, 12 Data Reference Files (fig. 54) are maintained for public use in Survey offices throughout the country; these files contain microfilm copies of the most frequently requested data available from the Center.

Data production and dissemination

The Data Center at Sioux Falls produces and distributes materials from data collected by satellites and aircraft (Watkins, 1975). Data archived at the Center total about 6 million images, including over 500,000 frames of Landsat imagery and Landsat electronic data in the form of computer-compatible tapes; over 40,000 photographs from Skylab, Apollo, and Gemini; more than 1.8 million photographs from the National Aeronautics and Space Administration Research Aircraft program; and almost 4 million aerial mapping photographs from the Department of the Interior.

The demand for reproductions of archival data continues to increase (table 53). In fiscal year 1975, the Data Center filled requests for over 400,000 frames of imagery, an increase of 46 percent over 1974, and the income amounted to $1.6 million (about 58 percent from the sale of Landsat data). A customer profile (fig. 55) shows that private industry is the largest single purchaser, accounting for 30 percent of total sales; Federal agencies account for 24 percent. A major application of the data is in mineral and petroleum exploration and related geologic base mapping by major petroleum and mining companies.

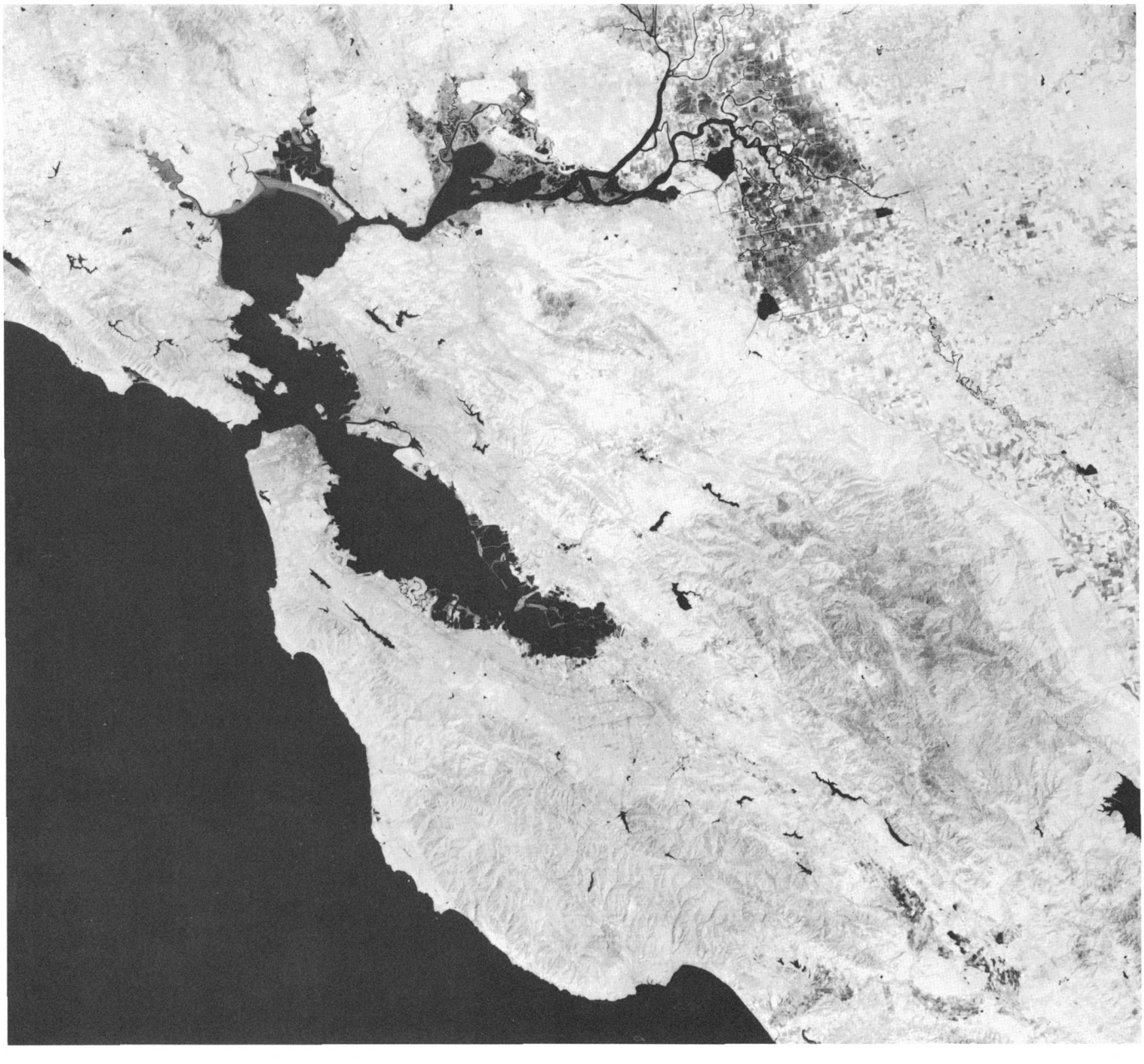
Applications and highlights

Several projects are described below to provide insight into the scope and applications of Landsat and aerial imagery to resource and land use planning and management.

- *Petroleum exploration*—Representatives from a number of petroleum and petroleum exploration companies have indicated in technical papers that they are routinely using Landsat data to improve their exploration and planning programs.
- *Environmental monitoring*—In response to the increase in coal mining in the Appalachians, the Geological Survey and other Federal and State agencies are jointly assessing the effect of coal mining on water quality, sedimentation, and streamflow in the Duncan Flats quadrangle of eastern Tennessee. Aerial thermal infrared imagery delinates groundwater outflow, ponding on strip mining benches, storm runoff, surface-water flow, and indications of acid mine drainage. Digitally processed Landsat imagery delineates land cover categories such as forest types, agricultural land, and bare earth caused by strip mining. Both the thermal infrared and the Landsat data provide a base on which to assess the dynamic environmental changes.
- *Hydrology*—A collaborative study of 1,930 river kilometres (1,200 miles) of a Mississippi River flood during the spring of 1973, conducted by the Survey, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, and the U.S. Army Corps of Engineers, demonstrated the potential of Landsat imagery for important engineering, economic, disaster-relief, and planning applications and provided the basis for a hydrologic atlas of the flood. Landsat–2 imagery was also used to map the extent of flooding of the lower Mississippi River and the Red, Ouachita, Black, and Atchafalaya Rivers during April 1975 at the request of the State of Louisiana. Analysis of the imagery was performed jointly by personnel of the Louisiana Office of State Planning, the Earth Resources Observation Systems program ap-

plications assistance facility at Bay St. Louis, Miss., and the Survey's Geography program. By comparing land use maps with Landsat imagery from the time of the flood, State officials determined that flood waters covered approximately 3,200 hectares (8,000 acres) of urban and other highly developed regions, 120,000 hectares (300,000 acres) of farmland, 44,100 hectares (109,000 acres) of upland forest, 282,500 hectares (698,000 acres) of wetland forest, and 1,130 hectares (2,800 acres) of sand and silt areas. Both the maps and statistics were used by the State for rapid analysis of flood damage and for immediate documentation of the need for Federal disaster-relief funds.

- *Other work*—In mineral exploration, Landsat images and aerial photography were used to study the structural and mineralization aspects of a number of regions (Sisselman, 1975; Rowan and others, 1974; Rowan, 1975; Albert, 1975; Richter and others, 1975; Schmidt, 1976; Carter, 1974; Williams and Carter, 1976). In environmental monitoring, Landsat images have been used to detect terrain changes (Lathram, 1973) and oil slicks (Svensson and others, 1975) and to assess the impacts of flood, fire, glacial movement, and drought (Robinove, 1975). Landsat imagery, aerial photography, and thermography have been used in studies of geothermal areas, glaciology, volcanology, cartography,



Landsat image of the San Francisco Bay region, California.

rangeland management, and environmental monitoring in Iceland (Williams and others, 1974; Williams and Thorarinsson, 1974; Thorarinsson and others, 1974). In cartography, Landsat images have been used to prepare planimetric maps of Antarctica and Arizona (State of Arizona, 1975) and to produce a false-color mosaic of Florida at 1:500,000 scale (U.S. Geological Survey, 1975).

U.S. Geological Survey Professional Paper 929 (Williams and Carter, 1976) is a compilation of 85 case histories of the applications of Landsat–1 data to global cartographic, geologic, hydrologic, geographic, and oceanographic problems. This report provides substantive documentation of applications of satellite remote sensing systems for operational programs.

Program highlights of the year included:

- *Distribution of over 400,000 frames of imagery* valued at over $1.6 million.
- *Reduction of product delivery time to an average of 12 days* by mid-1975.
- *Improvement of data quality* by applying recent advances in photographic processing methods and strict quality controls on both incoming reproducible materials and on outgoing data products.
- *Training courses and workshops attended by more than 150 scientists.* Formal courses on remote sensing techniques had 102 attendees representing 35 countries.
- *Successful launch of Landsat–2 by the National Aeronautics and Space Administration* and Congressional approval of Landsat–C made possible continued research and demonstration projects on the application of satellite images of the Earth.
- *Availability of cloud-free Landsat images for the entire United States.*
- *Preparation of a mosaic of 24 separate Landsat images of the State of Arizona.* This project demonstrated the usefulness of a gridded image as a base map for State and regional planning. A similar mosaic was also prepared for Florida.

Evaluation

Data production statistics, post card responses from people who purchase data, evaluation forms by participants in training courses, and interaction with Department coordinators provide a basis for evaluating the progress of the Earth Resources Observation Systems program.

The increasing demand for products is one indication of the success of the program. Each improvement in delivery time or data quality has been followed by an increase in demand for products. Another indication of success is the increasing number of requests for workshops and training in how to use the data. Perhaps the most important measure of success, however, is the increasing applications of the data to resource management, environmental protection, and scientific research.

Some agencies have expressed concern about becoming dependent on Landsat data, for several reasons:

1. Landsat is experimental. There is no assurance of program continuity beyond 1980, or even 1976, if a spacecraft or launch vehicle fails.
2. Data are not always available quickly enough to be used in making time-critical decisions.
3. Standard photographic products contain less than the complete data content of the original digital data and thereby preclude their use in some applications.

Continuation of the program beyond 1980 will, of course, depend upon Congressional appraisal of the costs and benefits of the Landsat system. The last two reasons for caution are technical, and their solutions are known. Within the resources available, the National Aeronautics and Space Administration and the Earth Resources Observation Systems program are augmenting their data processing and distribution systems to make the necessary improvements.

ENVIRONMENTAL IMPACT ANALYSIS PROGRAM

The Environmental Impact Analysis program provides an integrated Geological Survey response to the requirements of the National Environmental Policy Act with:

- Direction, coordination, and expertise in the preparation of environmental impact statements for which the Survey has lead or joint responsibility.
- Technical information and expertise in support of the preparation of statements for which the Survey has contributing responsibility.
- Technical analyses and review of statements and related documents prepared by other agencies.
- Manuals, guidelines, and training courses on the preparation and review of statements.
- Environmental research.

The National Environmental Policy Act requires that a Federal agency contemplating a major action that could significantly affect the quality of the environment must prepare a detailed statement of the possible environmental impacts. The Act further requires that statements must be reviewed by other Federal agencies having pertinent jurisdiction or expertise. In final form, the statement plays an essential role in an agency's decisionmaking process.

The Geological Survey becomes involved as a lead agency in the preparation of statements through the Conservation Division's supervision of mineral-resource exploration, development, extraction, and reclamation operations on Federal and Indian lands. During fiscal year 1975, approximately 80 percent of the environmental impact analysis involving the Geological Survey as the lead agency concerned the development of coal and oil and gas resources. The remaining 20 percent was mainly concerned with critical minerals, such as copper, nickel, and phosphate.

The Geological Survey becomes involved in the preparation of statements as a participating agency, in a nonlead role, both through its supervisory function, as described above, and through its special expertise in the areas of geology, hydrology, and mining and petroleum engineering. During fiscal year 1975, approximately 70 percent of this effort was energy related, involving principally coal and oil and gas leasing operations and projects involving minemouth electric generating plants, coal gasification plants, and related transmission lines, pipelines, and water supply. The remaining 30 percent was mainly concerned with critical minerals.

In accordance with guidelines set by the Council on Environmental Quality, Federal agencies submit environmental impact statements to the Department of the Interior for review. The statements are assigned by the Department to one or more Bureaus, primarily on the basis of legal jurisdiction or special expertise.

The principal objectives of the Environmental Impact Analysis program are to:

- Provide a core group of multidisciplinary specialists to assure the continuity of quality standards through acquired expertise in the preparation and review of environmental impact statements and through associated research and training.
- To reduce the time required for preparation and review of environmental impact statements.

During fiscal year 1975, the program assumed the direction and coordination of Geological Survey efforts to prepare and contribute to statements required by the Secretary of the Interior as background for decisions on leasing, mineral exploration and development, and powerplant construction; these decisions related directly to national issues of energy and critical minerals. The Survey efforts employed a task-force approach—assembling the expertise needed for an individual project from personnel in the Environmental Impact Analysis program, the operating Divisions of the Geological Survey, other Interior Bureaus, other Federal agencies, and contractors.

During the year, the Survey:

- *Took lead or joint-lead responsibility for the preparation of 10 environmental impact statements.* Eight statements concerned the development of onshore coal, oil and gas, and offshore oil and gas operations. The other two concerned critical minerals (fig. 56 and table 24). These statements are in preparation.
- *Participated in a nonlead capacity in the preparation of 15 impact statements* for which other Federal agencies had lead responsibility. Approximately 70 percent of these statements were energy-related. The remainder dealt with critical minerals. Two were completed during the year (fig. 56 and table 24).
- *Provided technical information,* gathered by other Survey programs, to the U.S. Forest Service for three impact statements on geothermal energy resources and to the Bureau of Land Management for seven impact statements on leasing of the Outer Continental Shelf.
- *Reviewed and commented* on 2,046 impact statements and related documents to assist other agencies in areas of Geological Survey jurisdiction and expertise.

Evaluation

The task-force approach to preparation of environmental impact statements has provided a centralized, effective, and flexible means of furnishing leadership and technical expertise. Management and review of work in progress are being accomplished more efficiently and with more in-depth probing.

The extensive procedures routinely employed for review and criticism of completed statements provide substantial feedback, which promotes rapid development of preparation expertise. These procedures include (1) internal reviews by the Department of the Interior and by agencies participating in the preparation effort, (2) external reviews by a broad spectrum of other Federal agencies, State and local agencies, and the public, and (3) application of the results of adjudications.

By the end of fiscal year 1975, the workload associated with preparing required environmental impact statements was increasing at a rate of about 30 percent per year. This rate reflects the critical problems that the statements address—problems that involve the balance between the environmental quality goals of the National Environmental Policy Act and the rapidly growing needs for development and use of the Nation's resources. The rate of increase is expected to continue or to accelerate owing to national efforts to decrease reliance on foreign sources of energy and critical minerals. Furthermore, the level of effort required to review environmental statements prepared by other agencies is increasing at a rate of about 10 percent per year.

FIGURE 56.—Sites for which environmental impact statements were in progress or completed during fiscal year 1975.

Farmlands and pond created through the reclamation of an area mine in Indiana. Techniques for such reclamation projects were developed during the 1930's.

TABLE 24.—*Environmental impact statements completed or in progress during fiscal year 1975 (locality numbers are keyed to figure 56)*

Title	State	Locality number	Project description
GEOLOGICAL SURVEY LEAD OR JOINT-LEAD RESPONSIBILITY			
Crow Shell (Youngs Creek) Coal Mine	Mont.	1	Evaluate impacts of coal mine and transportation system on Crow Indian Reservation.
East Decker Coal Mine	Mont.	2	Department of the Interior and State of Montana project to determine impact of proposed mining and reclamation plan.[1]
Belle Ayr North Coal Mine	Wyo.	3	Determine impacts of Amax Coal Co.'s proposed mine north of Gillette.
Belle Ayr South Coal Mine	Wyo.	4	Determine impacts of mining and reclamation plan for expanded Amax Coal Co.'s mine.
Cordero Coal Mine	Wyo.	5	Determine impacts of Sun Oil Co.'s proposed mining and reclamation plan south of Gillette.
Rochelle Coal Mine	Wyo.	6	Evaluate impacts of Peabody Coal Co.'s project in eastern Powder River Basin.
Phosphate resources development	Idaho	7	Determine separate and collective impacts of 16 mining plans on Federal leaseholds in southeastern Idaho.
Santa Barbara Channel development	Calif.	8	Examine impacts of further oil and gas development in channel.
Coal operating regulations (30 CFR, part 211).	Nationwide[2]		Examine impact of proposed revised regulations on lessees, permittees, and licensees during discovery, testing, development, mining, and reclamation.
Geological and geophysical regulations	Nationwide[2]		Examine impacts of proposed regulations governing Outer Continental Shelf geological and geophysical exploration.

Project	State	Locality number	Lead agency
GEOLOGICAL SURVEY PARTICIPATION			
Coal resources in eastern Powder River Basin—surface mines, generating and gasification plants, and railroad.[3]	Wyo.	9	Bureau of Land Management
Cholla project—additional power-generating units and transmission lines in Arizona and enlarged coal mine in New Mexico.[3]	Ariz.- N. Mex.	10	Forest Service.
INCO copper-nickel open-pit mine	Minn.	11	Do.
Crow Reservation coal program	Mont.	12	Bureau of Indian Affairs.
Coal resources	NW. Colo.	13	Bureau of Land Management.
North Emery powerplant and coal mine	Utah	14	Forest Service.
Kaiparowits power-generating plant and surface coal mine.	Utah	15	Bureau of Land Management.
Glen Canyon National Recreation Area master plan.	Utah	16	National Park Service.
Coronado power station and mine	Ariz.	17	Bureau of Reclamation.
El Paso gas coal-gasification plant and mine	N. Mex.	18	Do.
WESCO coal-gasification plants and mine	N. Mex.	19	Do.
Los Padres phosphate mining leases	Calif.	20	Bureau of Land Management.
Natural gas transportation system	Alaska[2]		Do.
Coal programmatic	Nationwide[2]		Do.
Oil and gas programmatic	Nationwide[2]		Do.

[1] Joint-lead responsibility with Bureau of Land Management.
[2] Not shown in figure 56.
[3] Completed.

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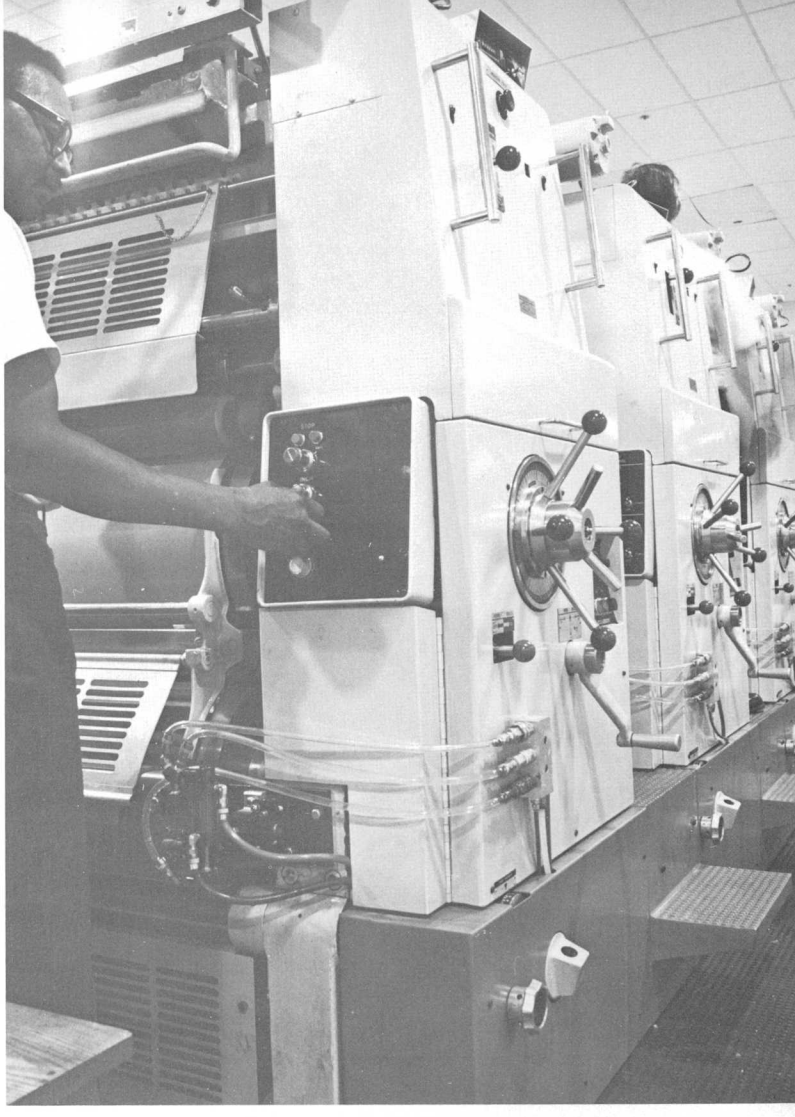

Program support activities at the National Center (clockwise from lower right): Computer Center, Personnel Office; Library; Printing Plant; Public Inquiries Office.

Program Support Activities

OVERVIEW

Four organizational units of the Geological Survey provide essential managerial, administrative, and technical services to support the Survey's scientific and regulatory programs:

- *Office of the Director,* through the Director, Associate Director, Assistant Directors, and their respective staffs (excluding the Land Information and Analysis Office), provides executive direction, coordinates interagency and intrabureau activities, and guides program development.
- *Administrative Division* supplies the Survey's programs with budgetary, financial, procurement, personnel, and other administrative services and manages the Survey's National Center facilities in Reston, Va.
- *Computer Center Division* operates a nationwide computing system and provides Survey scientists with a wide range of automatic data processing services.
- *Publications Division* edits the Survey's scientific and technical publications as well as nontechnical booklets, prints maps, distributes maps and monographs, and answers queries from the public about the Survey's work and reports.

Although operated and funded for the most part by the Geologic Division, the Geological Survey Library is also described in this section because of its importance to the research activities of all Survey programs.

Program support activities are financed by direct appropriations ("General Administration" and "Facilities" budget activities, table 26), assessments on direct and reimbursable program funds of other budget activities (table 43), and reimbursements from other agencies ("Miscellaneous Services to Other Accounts," table 26).

GENERAL ADMINISTRATION

General administrative expenses include the executive direction and coordination of Survey programs by the Director's Office and the provision of financial, procurement, personnel, and other administrative services by the Administrative Division.

During 1975, general administrative expenses (table 43) amounted to $10.8 million. These expenses were funded from three sources: the General Administration budget activity, about $3.7 million; assessments on the direct programs of other activities, $5.1 million; and assessments on the reimbursable programs, $2.0 million. No assessments are made on cooperative funds from State and local governments. Despite the bigger Geological Survey budget, more employees, and increased use of grants and contracts, general administrative expenses continued to represent only about 3.2 percent of the total Survey budget and have increased less than one half of a percent over the past five years (table 43).

Significant events and accomplishments during the year included:

- *Personnel recruiting*—More than 1,400 eligible candidates were evaluated in the course of filling some 700 positions, many in highly specialized scientific and engineering fields such as geology, exploration geophysics, and mining and petroleum engineering.
- *Minority group programs*—In 1971 the Director established the Minority Participation in the Earth Sciences program to encourage young people to

seek careers in the earth sciences. Under the auspices of this program, the Survey negotiated cooperative education agreements with eight colleges and, through the Government Employee's Training Act, provided tuition for eight minority-group students to pursue an education in the earth sciences. Under provisions of the Intergovernmental Personnel Act, three Survey scientists served as visiting professors in the earth sciences departments of three minority-group colleges. The Survey also employed 95 minority-group students in summer work programs to provide on-the-job experience.

- *Training*—Personnel training serves to strengthen on-the-job expertise as well as provide opportunities for career development. In fiscal year 1975, there were 4,995 instances in which employees received formal training, 67 percent more than in 1974.
- *Conflict of interest*—On March 3, 1975, the General Accounting Office reported on apparent conflicts of interest by Geological Survey employees (General Accounting Office, 1975). The report, part of a study of 49 Federal agencies, concluded:

  Many USGS employees have financial interests which appear to conflict with their Government duties. Many of these holdings violate the Organic Act of 1879. We believe that the ownership of these conflicting interests is due to deficiencies in the Department's financial disclosure system and that they will have to be corrected to prevent the situation that now exists from continuing.

  To resolve the issues raised by the General Accounting Office report, the Survey's Director took the following actions:

  1. On January 24, 1975, prior to the conclusion of the General Accounting Office study, the Director instructed the Personnel Officer to direct employees who had reported financial holdings in oil or mining enterprises to divest themselves of these holdings within 90 days.

  2. He issued a Survey Administrative Digest (March 5, 1975) to all employees, setting forth the provisions of the Organic Act of 1879 and reiterating the Survey's long-standing regulations prohibiting employees from owning any interest in oil or mining enterprises.

  3. He asked the Department Ethics Counselor to have the Department Solicitor review each case of conflict of interest identified in the General Accounting Office report.

  On July 3, 1975, the Department of the Interior issued new regulations governing employee responsibilities and conduct. In accordance with these new regulations, all employees were asked either to certify that they do not have holdings in violation of regulations or to come into compliance through divestiture.

  Of the 49 cases identified in the General Accounting Office report, 20 were found not to be in conflict, and the remainder divested themselves of all financial holdings which had the appearance of conflict of interest. No employee has been found to have an actual conflict of interest.
- *Freedom of Information Act*—Government agencies are now required to respond to Freedom of Information Act requests within ten days and to make available indexes of the types of agency information available. The Geological Survey has established strict procedures for handling these requests in accordance with the law. The impact of the new amendments on the Survey during the last 4 months of fiscal year 1975 was slight—only 30 formal requests for information were received.
- *Flexitime experiment*—On May 12, 1975, the Geological Survey began a 1-year experiment with flexible working hours for all employees in the Washington, D.C., area. Flexible hours, popularly known as "Flexitime," allow employees to vary their working hours around a "core time" (9:00 a.m. to 3:30 p.m.) when all employees must be present. An initial evaluation indicates that the experiment has been successful. A comprehensive evaluation will be conducted before deciding to continue or expand Flexitime within the Bureau.
- *Procurement and contracting activities*—Increases in the Survey's programs, especially those related to energy resources, and personnel ceilings have led the Survey to depend more and more on the private sector for services. Over the past five fiscal years the Survey's procurement and contracting program has increased tenfold, from $9 million in fiscal year 1970 to $97 million in fiscal year 1975 (fig. 57). During this period, personnel responsible for procurement and contracting increased from 34 to 55. To enable proportionately fewer personnel to handle this rapidly expanding workload and to improve the procurement process, the Survey awarded contracts for the design of an automated procurement information system and for the preparation of guides to the handling of small purchases, the writing of specifications, and the preparing and submitting of applications for scientific research grants.

FACILITIES

The Facilities activity covers the operation of the National Center, which consists of office, laboratory, industrial, and warehouse space in Reston, Va. Funds appropriated for facilities management for 1975 amounted to $10.8 million. These funds were maintained in a separate account under the control of the Assistant Director for Administration.

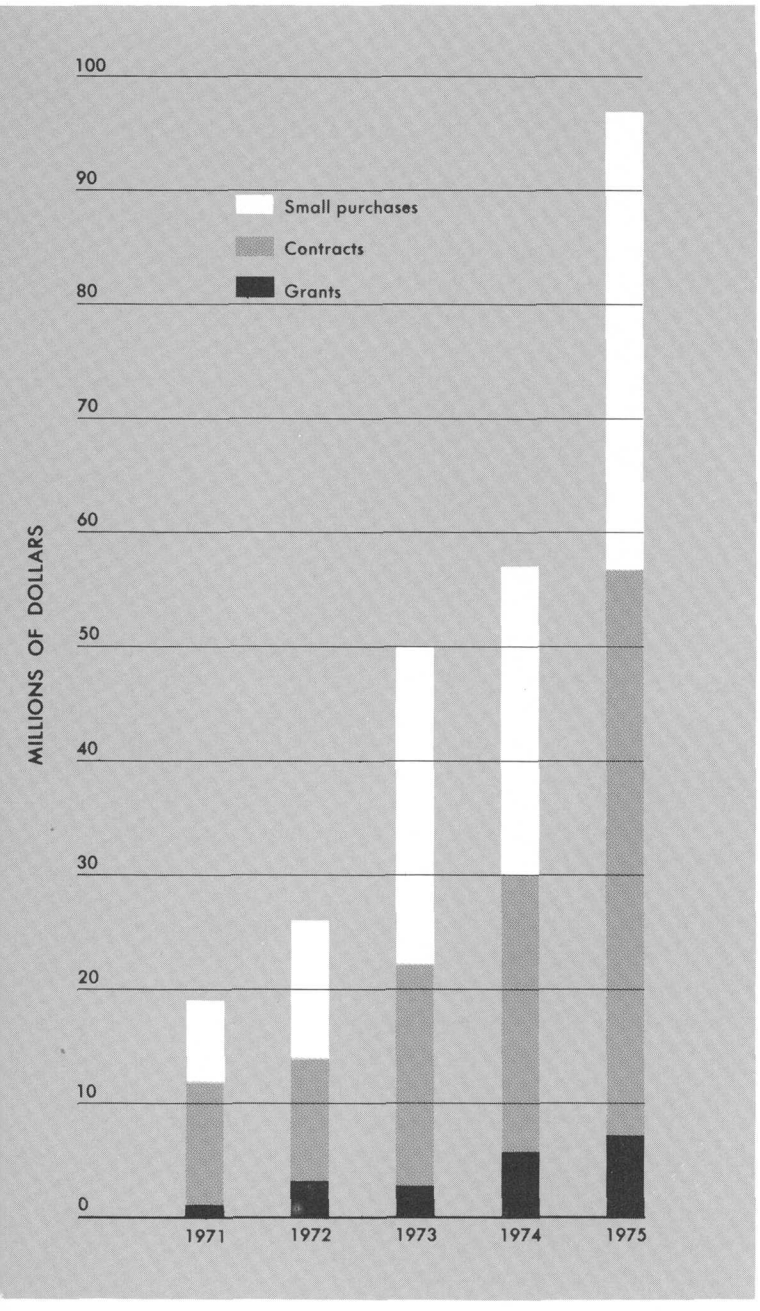

FIGURE 57.—Geological Survey expenditures on grants, contracts, and small purchases, fiscal years 1971–75.

In early March 1975 the Geological Survey completed the relocation of 2,300 employees to the National Center in Reston, Va., having thus consolidated 30 offices in 17 widely scattered locations throughout the Washington, D.C., area.

COMPUTER TECHNOLOGY

The Computer Center Division operates a nationwide system of computer facilities and terminals to provide automatic data processing services for the Geological Survey. The primary computer installation, located at the National Center, consists of two interconnected large-scale IBM 370/155 computers. Together, these computers provide high-speed magnetic core memory for 8 million characters of information and on-line magnetic disk storage for 5 billion characters of information. During 1975, more than 800 users from 77 remote locations submitted approximately 260,000 jobs to these computers (fig. 58).

In addition to the Reston computer facility, the Survey operates a number of other computers:

- Burroughs Corporation Model B–6700 computer at the Earth Resources Observation Systems Data Center, Sioux Falls, S. Dak.
- Digital Equipment Corporation Model 1070 computer at Denver, Colo.
- Systems Engineering Laboratories, Inc., Model 86 computer at Rolla, Mo.
- A number of special-purpose computers and minicomputers for use in field and laboratory investigations.

The growth of Survey computer use between 1974 and 1975 is reflected in the following statistics:

- During 1975, 260,000 jobs were submitted to the National Center computers, an increase of 39 percent (table 54).
- 70 terminals were connected to the National Center computers for remote entry and processing of batch-oriented tasks, an increase of 30 percent.
- $5.4 million was spent on in-house data processing and related services, an increase of 4 percent (table 55).
- $2.1 million was spent on contracts for commercial data processing services, an increase of 80 percent.

Much of this growth can be attributed to the expansion of Survey programs in energy research and development, resource evaluation, lease supervision, and information dissemination, and to the transition from routine batch-processing techniques to more sophisticated interactive processing methods which make use of time-sharing systems and software for data-base management. Program managers, faced with stringent personnel ceilings and increasing workloads, are using automatic data processing techniques to improve the productivity of their staffs. For example, remote terminals give Survey scientists rapid access to information about the availability of maps, aerial photographs, and space imagery; bibliographies of scientific literature; and a variety of data files. In many cases the time required to assemble data for research or to answer requests for information has been significantly shortened. While much still remains to be learned about how to use these tools to greatest advantage, their potential for improving the productivity and quality of Survey programs appears to be

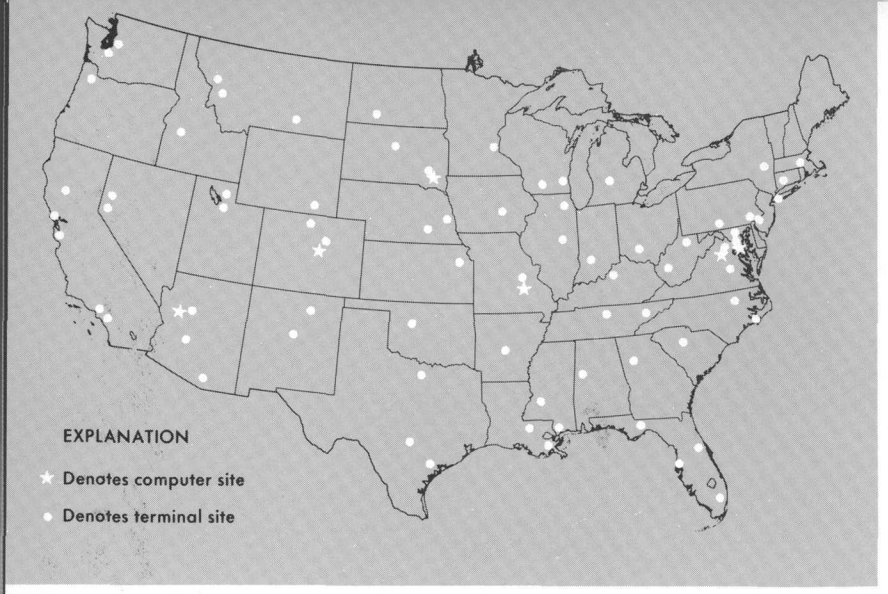

FIGURE 58.—Geological Survey computing network.

great. Projections by the Computer Center Division suggest that Survey scientists and engineers will be using approximately 600 terminal devices by 1980. Some examples of computer applications in operation or under development during 1975 are listed below:

- Development of a number of geologic data bases dealing with mineral resources, energy resources, and geochemical analyses.
- Operation of a real-time seismic monitoring and earthquake detection network.
- Expansion of the National Water Data Storage and Retrieval System (WATSTORE) to include ground-water data.
- Simulation of surface-water and ground-water behavior in areas expected to be mined for coal and oil shale.
- Development of automated cartographic methods to produce maps from spatial digital data.
- Royalty accounting.
- Tracking the development of Outer Continental Shelf oil and gas leases.
- Processing remote sensing data.

Highlights of computer support activities during fiscal year 1975 included:

- *The procurement of System 2000* provided Survey computer users with a comprehensive set of data-base management procedures for defining new data bases, modifying the definition of existing data bases, and retrieving and updating data.
- *Significant enhancements* were made to the control program of the IBM 370/155 when a performance analysis revealed that one control routine consumed an exorbitant amount of central-processing-unit time. This routine was modified to reduce processing time by one third; thus an additional 4 hours of computer time a day were made available to users. This enhancement deferred the acquisition of a second computer by almost one year.
- *The installation of a second IBM 370/155 computer* avoided complete saturation of the single system. The new configuration ensures that either processor can execute any current or future program designed to run on the previous system.

GEOLOGICAL SURVEY LIBRARY

The Geological Survey operates one of the largest earth-sciences libraries in the world. The main library is located at the Survey's National Center in Reston, Va., and branches are located at major research centers in Denver, Colo.; Menlo Park, Calif.; and Flagstaff, Ariz. These libraries collectively contain nearly 1.9 million books, monographs, serials, pamphlets, single-sheet maps, field records, photographs, and related material (table 56). Although these holdings are intended primarily to support the research of the Geological Survey, the library also serves other Government agencies, State geological surveys, academic institutions, and research organizations throughout the country.

The main library at Reston is now using a computer terminal to access the American Geological Institute's GEO-REF, the only broad-based, on-line, bibliographic search service presently available for the geosciences in the United States. This system is an efficient and economical means of furthering the use of the library's earth-science literature collection. Additional terminals are planned for the Denver and Menlo Park libraries. To benefit from the cataloging activities of more than 600 participating libraries, the Survey library has also joined with other Federal libraries in searching the Ohio College Library Center's on-line monograph catalog of more than 2 million entries. Terminal access to this information has significantly reduced the time required to catalog new acquisitions and to process catalog cards.

The demand for library services increased during the year partly because of the consolidation of research activities in the National Center and partly because of increases in energy, minerals, and environmental program activities. The growth in demand is reflected in the following statistics (table 56):

- 52,092 library visits, an increase of 18 percent.
- 80,991 items circulated, an increase of 31 percent.
- 16,965 items loaned to other libraries, an increase of 30 percent.
- 14,774 reference questions answered, an increase of 5 percent.

Acquisitions during 1975 included 49,800 issues of periodicals and serials, 12,900 books and monographs, and 21,800 maps.

PUBLICATIONS PROGRAM

Results of research and investigations conducted by the Geological Survey are made available to the public through increasingly diverse information services

and publications. Developing mechanisms to make the right piece of data, report, or map available at the right time is a formidable challenge.

The number of reports approved for publication by the Geological Survey has steadily increased during the past 5 years (fig. 59). About 63 percent of the 2,900 reports prepared in 1975 were designated for publication in professional journals and monographs

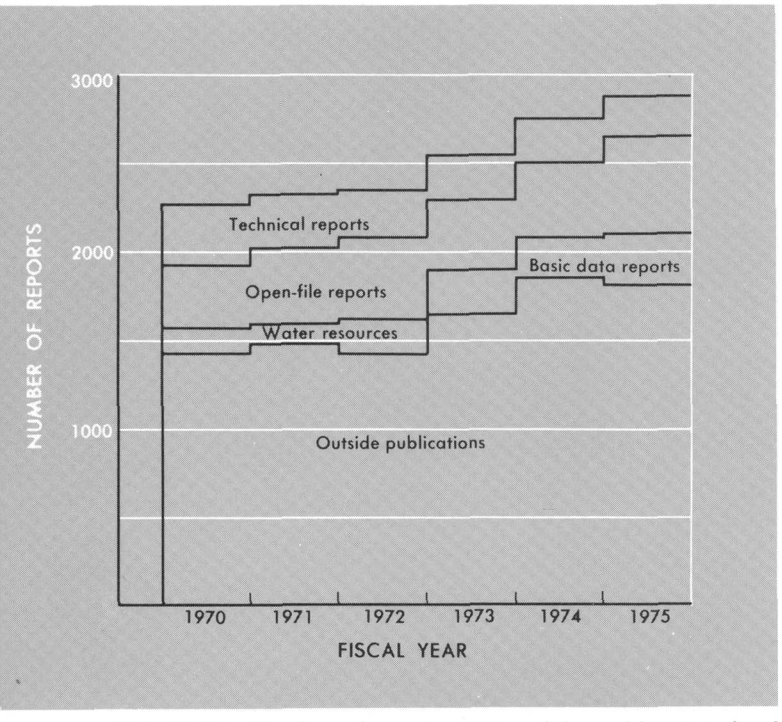

FIGURE 59.—Number of reports approved for publication, fiscal years 1970–75.

outside the Survey, about 20 percent were released to the open file, and the remainder were scheduled for publication by the Survey (table 45). The Survey also produced over 8,700 topographic, hydrologic, and geologic maps in 1975 (fig. 60 and table 46). A 47-percent increase in the production of topographic maps offset the slowing production of flood-prone area maps after completion of the first phase of the flood-hazards mapping program.

The Publications Division edits the Survey's scientific and technical publications printed by the Government Printing Office, prepares nontechnical booklets, produces reproduction manuscripts for geologic and hydrologic maps, and prints and distributes all Survey maps. Most of the maps are printed at the National Center, but in recent years a substantial number have been printed by commercial firms under contract.

The Publications Division also operates nine Public Inquiries Offices throughout the country that answer queries about the Survey's work and sell maps and books over the counter as agents of the Government Printing Office. Division operating statistics are summarized in table 57.

Highlights of the Publications Division's program in fiscal year 1975 included:

- *Acquisition of a 60-inch 5-color printing press* which will accommodate 80 percent of the maps to be printed with one pass through the press, as opposed to three passes (for 5-color maps) on the older 2-color presses.
- *Purchase of an automated imposition machine* to replace tedious manual methods of making printing plates.
- *Development of new map paper specifications,* with the approval of the Congressional Joint Committee on Printing, which reduced paper costs by 32 cents per pound. Applied to the purchase of 2.4 million pounds of paper during 1975, these new specifications saved the Survey more than $750,000.
- *Transmittal of 169 technical manuscripts* to the Government Printing Office for printing.
- *Distribution of 385,000 copies of technical reports.*
- *Printing of 18.3 million copies of 7,531 maps* including 2,575 flood-prone area leaflets and maps.
- *Distribution of 10.6 million copies of maps* of which 7.8 million copies were sold for $3.46 million.

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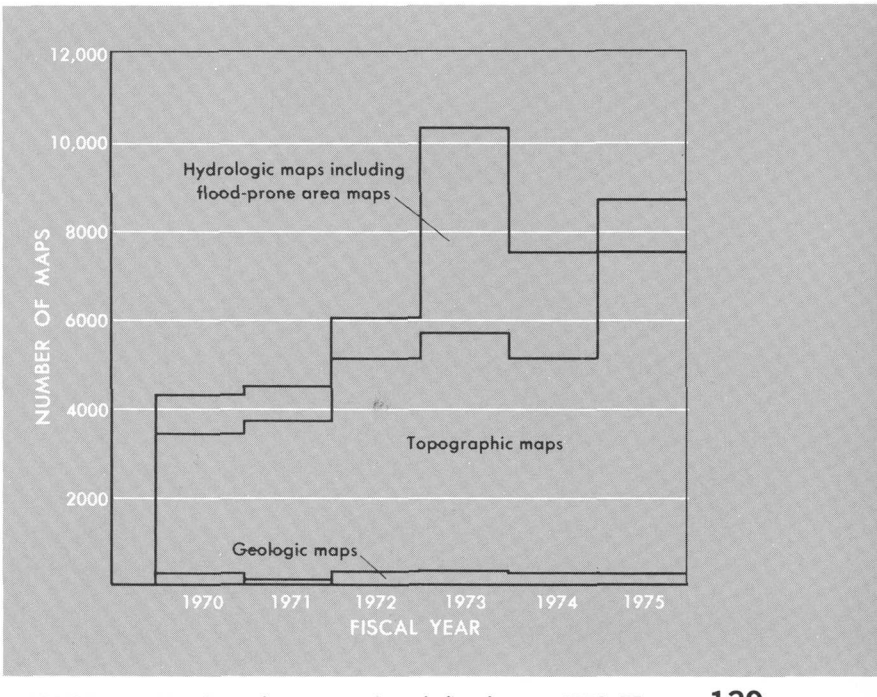
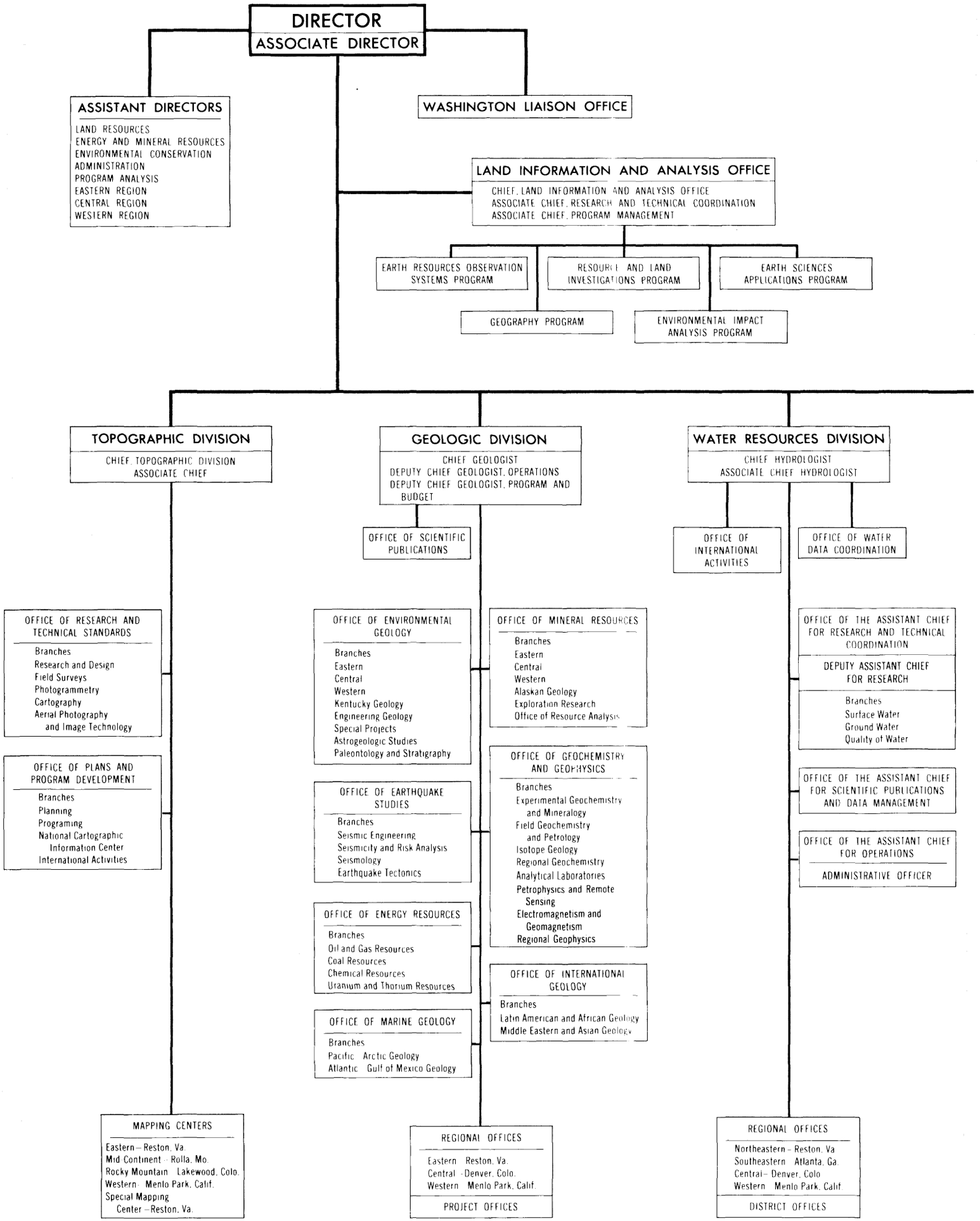
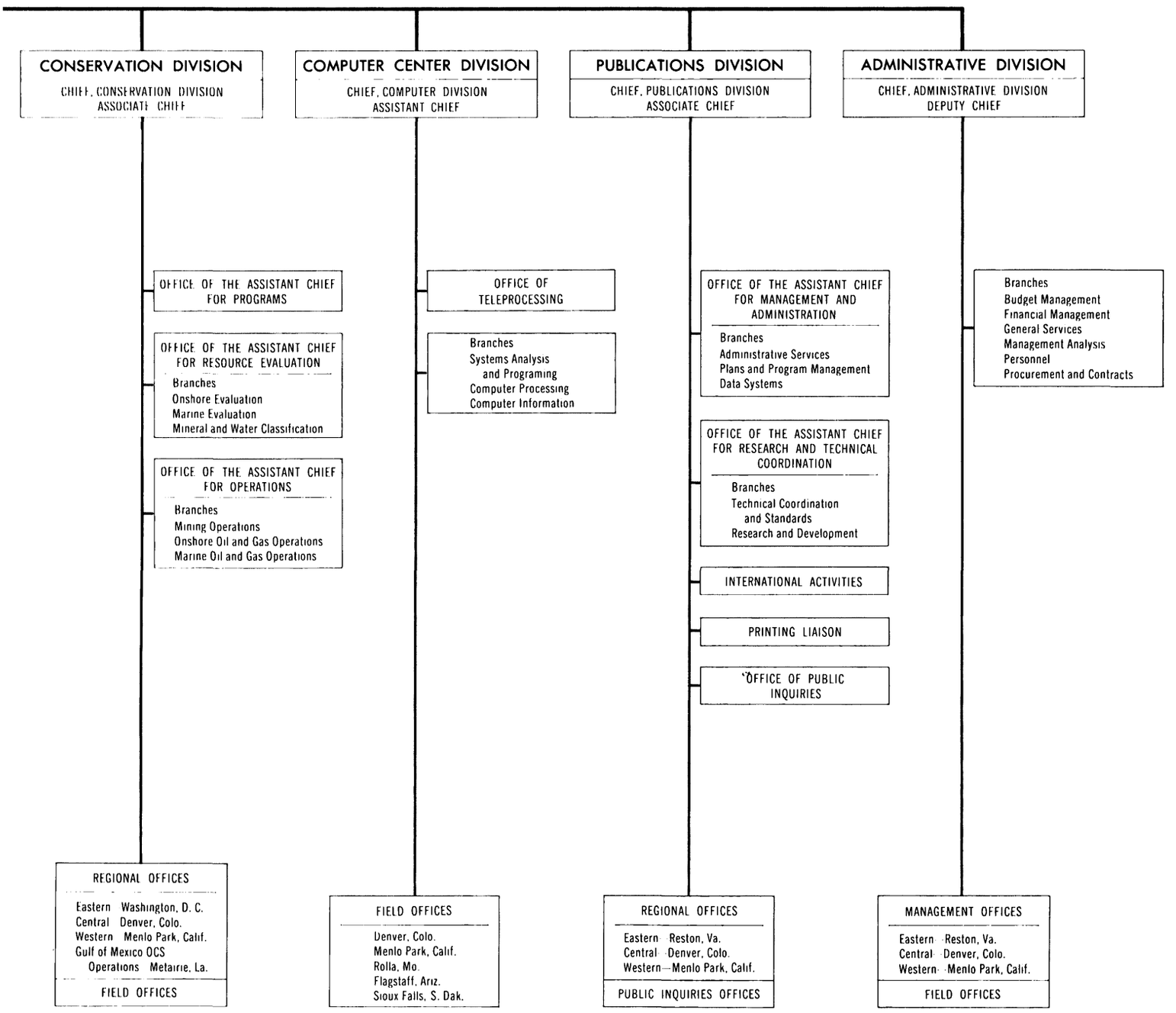
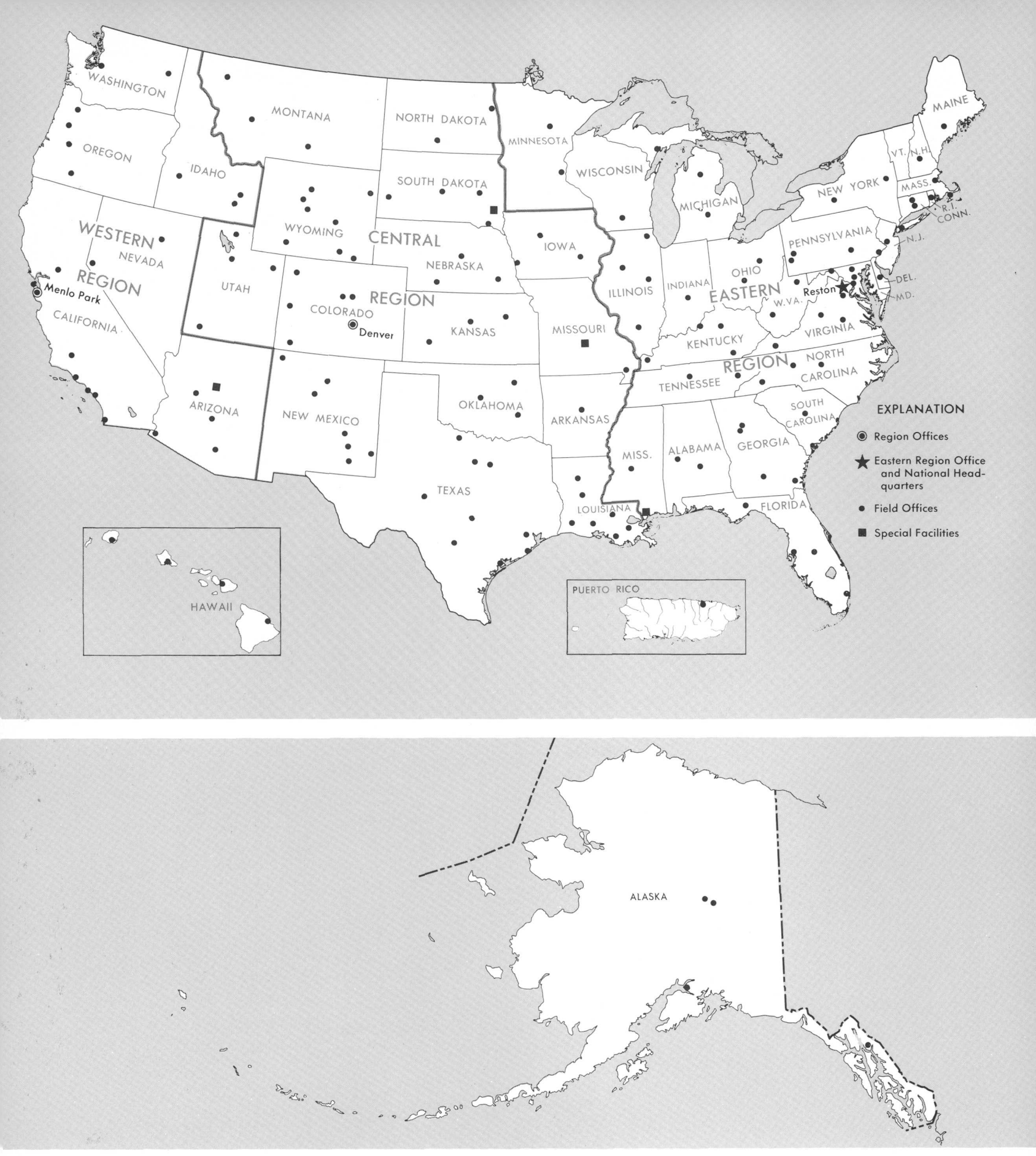


FIGURE 60.—Number of maps produced, fiscal years 1970–75.


DIRECTOR
ASSOCIATE DIRECTOR
ASSISTANT DIRECTORS
LAND RESOURCES
ENERGY AND MINERAL RESOURCES
ENVIRONMENTAL CONSERVATION
ADMINISTRATION
PROGRAM ANALYSIS
EASTERN REGION
CENTRAL REGION
WESTERN REGION
WASHINGTON LIAISON OFFICE
LAND INFORMATION AND ANALYSIS OFFICE
CHIEF, LAND INFORMATION AND ANALYSIS OFFICE
ASSOCIATE CHIEF, RESEARCH AND TECHNICAL COORDINATION
ASSOCIATE CHIEF, PROGRAM MANAGEMENT
EARTH RESOURCES OBSERVATION SYSTEMS PROGRAM
RESOURCE AND LAND INVESTIGATIONS PROGRAM
EARTH SCIENCES APPLICATIONS PROGRAM
GEOGRAPHY PROGRAM
ENVIRONMENTAL IMPACT ANALYSIS PROGRAM
TOPOGRAPHIC DIVISION
CHIEF, TOPOGRAPHIC DIVISION
ASSOCIATE CHIEF
GEOLOGIC DIVISION
CHIEF GEOLOGIST
DEPUTY CHIEF GEOLOGIST, OPERATIONS
DEPUTY CHIEF GEOLOGIST, PROGRAM AND BUDGET
WATER RESOURCES DIVISION
CHIEF HYDROLOGIST
ASSOCIATE CHIEF HYDROLOGIST
OFFICE OF SCIENTIFIC PUBLICATIONS
OFFICE OF INTERNATIONAL ACTIVITIES
OFFICE OF WATER DATA COORDINATION
OFFICE OF RESEARCH AND TECHNICAL STANDARDS
Branches
Research and Design
Field Surveys
Photogrammetry
Cartography
Aerial Photography and Image Technology
OFFICE OF PLANS AND PROGRAM DEVELOPMENT
Branches
Planning
Programing
National Cartographic Information Center
International Activities
OFFICE OF ENVIRONMENTAL GEOLOGY
Branches
Eastern
Central
Western
Kentucky Geology
Engineering Geology
Special Projects
Astrogeologic Studies
Paleontology and Stratigraphy
OFFICE OF EARTHQUAKE STUDIES
Branches
Seismic Engineering
Seismicity and Risk Analysis
Seismology
Earthquake Tectonics
OFFICE OF ENERGY RESOURCES
Branches
Oil and Gas Resources
Coal Resources
Chemical Resources
Uranium and Thorium Resources
OFFICE OF MARINE GEOLOGY
Branches
Pacific Arctic Geology
Atlantic Gulf of Mexico Geology
OFFICE OF MINERAL RESOURCES
Branches
Eastern
Central
Western
Alaskan Geology
Exploration Research
Office of Resource Analysis
OFFICE OF GEOCHEMISTRY AND GEOPHYSICS
Branches
Experimental Geochemistry and Mineralogy
Field Geochemistry and Petrology
Isotope Geology
Regional Geochemistry
Analytical Laboratories
Petrophysics and Remote Sensing
Electromagnetism and Geomagnetism
Regional Geophysics
OFFICE OF INTERNATIONAL GEOLOGY
Branches
Latin American and African Geology
Middle Eastern and Asian Geology
OFFICE OF THE ASSISTANT CHIEF FOR RESEARCH AND TECHNICAL COORDINATION
DEPUTY ASSISTANT CHIEF FOR RESEARCH
Branches
Surface Water
Ground Water
Quality of Water
OFFICE OF THE ASSISTANT CHIEF FOR SCIENTIFIC PUBLICATIONS AND DATA MANAGEMENT
OFFICE OF THE ASSISTANT CHIEF FOR OPERATIONS
ADMINISTRATIVE OFFICER
MAPPING CENTERS
Eastern – Reston, Va.
Mid Continent – Rolla, Mo.
Rocky Mountain – Lakewood, Colo.
Western – Menlo Park, Calif.
Special Mapping Center – Reston, Va.
REGIONAL OFFICES
Eastern – Reston, Va.
Central – Denver, Colo.
Western – Menlo Park, Calif.
PROJECT OFFICES
REGIONAL OFFICES
Northeastern – Reston, Va
Southeastern – Atlanta, Ga.
Central – Denver, Colo
Western – Menlo Park, Calif.
DISTRICT OFFICES

Organizational and Statistical Data





Maps showing location of selected major U.S. Geological Survey Offices. See the directory for exact locations of offices.

U.S. GEOLOGICAL SURVEY OFFICES
HEADQUARTERS OFFICES

12201 Sunrise Valley Drive
National Center, Reston, VA 22092

OFFICE OF THE DIRECTOR

Official	Name	Telephone number	Address
Director	V. E. McKelvey	(703)860–7411	National Center, STOP 101.
Associate Director	W. A. Radlinski	(703)860-7412	National Center, STOP 102.
Washington Liaison Officer	Frank E. Clarke	(202)343-3888	National Center, STOP 103. Room 4441, Interior Bldg., Washington, D.C. 20240.
Assistant Director—Land Resources	James R. Balsley	(703)860–7488	National Center, STOP 104.
Assistant Director—Energy and Mineral Resources	Montis R. Klepper	(703)860–7481	National Center, STOP 171.
Assistant Director—Environmental Conservation	Henry W. Coulter	(703)860–7491	National Center, STOP 106.
Assistant Director—Administration	Edmund J. Grant	(703)860–7201	National Center, STOP 201.
Assistant Director—Program Analysis	Dale D. Bajema	(703)860–7435	National Center, STOP 105.
Assistant Director—Eastern Region	William B. Overstreet	(703)860–7414	National Center, STOP 109.
Assistant Director—Central Region	Albert E. Letey, Acting	(303)234–4630	Box 25046, STOP 101, Denver Federal Center, Denver, CO 80225.
Assistant Director—Western Region	George E. Robinson, Acting	(415)323–8111 ext. 2711	345 Middlefield Road Menlo Park, CA 94025.
Information Officer	Frank H. Forrester	(703)860–7444	National Center, STOP 119.

LAND INFORMATION AND ANALYSIS OFFICE

Chief	James R. Balsley	(703)860–7488	National Center, STOP 104.
Associate Chief, Research and Technical Coordination	Philip Cohen, Acting	(703)860–7471	National Center, STOP 703.
Associate Chief, Program Management	Winston Sibert, Acting	(703)860–6855	National Center, STOP 702.
Earth Resources Observation System Program, Chief	John M. DeNoyer	(703)860–7881	National Center, STOP 730.
Geography Program, Chief	James R. Anderson	(703)860–6344	National Center, STOP 710.
Resource and Land Investigations Program, Chief	J. Ronald Jones	(703)860–6717	National Center, STOP 750.
Environmental Impact Analysis Program, Chief	Daniel B. Krinsley, Acting	(703)860–7455	National Center, STOP 760.
Earth Sciences Applications Program, Chief	Donald R. Nichols, Acting	(703)860–6961	National Center, STOP 720.

TOPOGRAPHIC DIVISION

Chief	Robert H. Lyddan	(703)860–6231	National Center, STOP 516.
Associate Chief	Rupert B. Southard	(703)860–6232	National Center, STOP 516.
Office of Research and Technical Standards, Chief	Hugh B. Loving, Acting	(703)860–6291	National Center, STOP 519.
Office of Plans and Program Development, Chief	Doyle G. Frederick	(703)860–6281	National Center, STOP 514.
National Cartographic Information Center, Chief	John R. Swinnerton	(703)860–6187	National Center, STOP 507.
Special Mapping Center, Chief	Roy E. Fordham	(703)860–7760	National Center, STOP 560. 1925 Newton Square East Reston, VA 22090.

GEOLOGIC DIVISION

Chief Geologist	Richard P. Sheldon	(703)860–6531	National Center, STOP 911.
Deputy Chief Geologist, Operations	Robert E. Davis	(703)860–6532	National Center, STOP 911.
Deputy Chief Geologist, Program and Budget	Donald H. Dow	(703)860–6544	National Center, STOP 910.
Office of Scientific Publications, Chief	George E. Becraft	(703)860–6575	National Center, STOP 904.
Office of Environmental Geology, Chief	John C. Reed, Jr.	(703)860–6411	National Center, STOP 908.
Office of Earthquake Studies, Chief	Robert M. Hamilton	(703)860–6471	National Center, STOP 905.
Office of Energy Resources, Chief	Charles Masters	(703)860–6431	National Center, STOP 915.
Office of Marine Geology, Chief	Charles Masters, Acting	(703)860–6431	National Center, STOP 915.
Office of Mineral Resources, Chief	Edwin W. Tooker	(703)860–6562	National Center, STOP 913.
Office of Geochemistry and Geophysics, Chief	Richard S. Fiske	(703)860–6584	National Center, STOP 906.
Office of International Geology, Chief	John A. Reinemund	(703)860–6418	National Center, STOP 917.

WATER RESOURCES DIVISION

Official	Name	Telephone number	Address
Chief Hydrologist	Joseph S. Cragwall, Jr.	(703)860–6921	National Center, STOP 409.
Associate Chief Hydrologist	O. Milton Hackett	(703)860–6921	National Center, STOP 408.
Assistant Chief Hydrologist, Scientific Publications and Data Management	George W. Whetstone	(703)860–6877	National Center, STOP 440.
Assistant Chief Hydrologist, Operations	Vacant	(703)860–6801	National Center, STOP 441.
Assistant Chief Hydrologist, Research and Technical Coordination	Edward A. Moulder	(703)860–6971	National Center, STOP 414.
Office of Water Data Coordination, Chief	R. H. Langford	(703)860–6931	National Center, STOP 417.
Office of International Activities, Chief	James R. Jones	(703)860–6548	National Center, STOP 470.

CONSERVATION DIVISION

Chief	Russell G. Wayland	(703)860–7524	National Center, STOP 600.
Associate Chief	Robert F. Evans	(703)860–7524	National Center, STOP 600.
Assistant Chief, Resources Evaluation	Robert L. Rioux	(703)860–7571	National Center, STOP 640.
Assistant Chief, Operations	John Duletsky	(703)860–7515	National Center, STOP 620.
Assistant Chief, Programs	Harold L. Pumphrey	(703)860–7581	National Center, STOP 630.

COMPUTER CENTER DIVISION

Chief	Carl E. Diesen	(703)860–7106	National Center, STOP 801.
Assistant Chief	Charles H. Tyler	(703)860–7109	National Center, STOP 801.
Office of Teleprocessing	Ralph N. Eicher	(703)860–7119	National Center, STOP 805.

PUBLICATIONS DIVISION

Chief	Harry D. Wilson, Jr.	(703)860–7181	National Center, STOP 341.
Associate Chief	John H. Eric	(703)860–7181	National Center, STOP 341.
Assistant Chief, Management and Administration	Melvin E. Hanes	(703)860–7188	National Center, STOP 341.
Assistant Chief, Research and Technical Coordination	Bernard J. Thien	(703)860–7183	National Center, STOP 341.
Office of Public Inquiries, Chief	Robbie S. Ritchey	(703)860–7185	National Center, STOP 341.
Printing Liaison Officer	Jesse R. Upperco	(703)860–7622	National Center, STOP 330.
International Activities	A. L. Dilonardo	(703)860–6791	National Center, STOP 328.

ADMINISTRATIVE DIVISION

Chief	Edmund J. Grant	(703)860–7201	National Center, STOP 201.
Deputy Chief	Lewis Menen	(703)860–7203	National Center, STOP 202.
Personnel Officer	Maxine C. Millard	(703)860–6127	National Center, STOP 215.
Contracts Officer	William Burk	(703)860–7261	National Center, STOP 205.

SELECTED FIELD OFFICES

LAND INFORMATION AND ANALYSIS OFFICE

EARTH RESOURCES OBSERVATION SYSTEMS DATA CENTER

Location	Official in charge	Telephone number	Address
South Dakota	Allen H. Watkins	(605)594–6123	EROS Data Center, Sioux Falls, SD 57198.

TOPOGRAPHIC DIVISION

REGIONAL MAPPING CENTERS

Mapping Center	Chief	Telephone number	Address
Eastern	Peter F. Bermel	(703)860–6352	National Center, STOP 567, Reston, VA 22092.
Midcontinent	A. Carroll McCutchen	(314)364–3680 ext. 111	1400 Independence Rd., Rolla, MO 65401.

SELECTED FIELD OFFICES—CONTINUED

Mapping Center	Chief	Telephone number	Address
Rocky Mountain	Albert E. Letey	(303)234–2351	Box 25046, STOP 510, Denver Federal Center, Denver, CO 80225.
Western	Roy R. Mullen	(415)323–8111 ext. 2411	345 Middlefield Road, Menlo Park, CA 94025.

GEOLOGIC DIVISION
REGIONAL OFFICES

Region	Regional Geologist	Telephone number	Address
Eastern	Eugene H. Roseboom, Jr.	(703)860–6631	National Center, STOP 953, Reston, VA 22092.
Central	Ralph L. Erickson	(303)234–3625	Box 25046, STOP 911, Denver Federal Center, Denver, CO 80225.
Western	George Gryc	(415)323–8111 ext. 2214	345 Middlefield Road, Menlo Park, CA 94025.

WATER RESOURCES DIVISION
REGIONAL OFFICES

Region	Regional Hydrologist	Telephone number	Address
Northeastern	Joseph T. Callahan	(703)860–6985	National Center, STOP 433, Reston, VA 22092.
Southeastern	Leslie B. Laird	(404)526–5395	1459 Peachtree St. NE., Suite 200, Atlanta, GA 30309.
Central	Alfred Clebsch, Jr.	(303)234–3661	Box 25046, STOP 406, Denver Federal Center, Denver, CO 80225.
Western	William H. Robinson, Acting	(415)323–8111 ext. 2337	345 Middlefield Road, Menlo Park, CA 94025.

DISTRICT OFFICES

State	District Chief	Telephone number	Address
Alabama	William J. Powell	(205)752–8104	P.O. Box V, 202 Oil and Gas Board Bldg., University of Alabama, University, AL 35486.
Alaska	Harry Hulsing	(907)277–5526	Skyline Bldg., 218 E St., Anchorage, AK 99501.
Arizona	Horace M. Babcock	(602)792–6671	Federal Bldg., 301 W. Congress St., Tucson, AZ 85701.
Arkansas	Richard T. Sniegocki	(501)378–5246	2301 Federal Office Bldg., 700 W. Capital Ave., Little Rock, AR 72201.
California	Lee R. Peterson	(415)323–8111 ext. 2326	855 Oak Grove Avenue, Menlo Park, CA 94025.
Colorado	James E. Biesecker	(303)234–5092	Box 25046, STOP 415, Denver Federal Center, Denver, CO 80225.
Connecticut	Frederick H. Ruggles, Jr.	(203)244–2528	P.O. Box 715, 235 Post Office Bldg., 135 High Street, Hartford, CT 06101.
Delaware	Walter F. White, Jr.	(301)661–4664	See Maryland District Office.
District of Columbia	Walter F. White, Jr.	(301)661–4664	See Maryland District Office.
Florida	Clyde S. Conover	(904)386–1118	325 John Knox Road, Suite F–240, Tallahassee, FL 32303.
Georgia	John R. George	(404)526–4858	6481 Peachtree Industrial Blvd., Doraville, GA 30340.
Hawaii	Frank T. Hidaka	(808)955–0251	1833 Kalakaua Ave., 5th Floor, Honolulu, HI 96815.
Idaho	Edwin E. Harris	(208)342–2711 ext. 2537.	Box 036, 365 Federal Bldg., 550 W. Fort Street, Boise, ID 83724.
Illinois	Lawrence A. Martens	(217)359–3918	P.O. Box 1026, 605 N. Neil St., Champaign, IL 61820.
Indiana	James L. Cook	(317)269–7101	1819 N. Meridian St., Indianapolis, IN 46202.
Iowa	Sulo W. Wiitala	(319)338–0581 ext. 521	P.O. Box 1230, 269 Federal Bldg., Iowa City, IA 52240.
Kansas	J. S. Rosenhein	(913)864–4321	1950 Avenue A—Campus West, University of Kansas, Lawrence, KS 66045.
Kentucky	Philip A. Emery	(502)582–5241	572 Federal Bldg., 600 Federal Place, Louisville, KY 40202.
Louisiana	Albert N. Cameron	(504)387–0181 ext. 281.	P.O. Box 66492, 6554 Florida Blvd., Baton Rouge, LA 70896.
Maine	John A. Baker	(617)223–2822	See Massachusetts District Office.

WATER RESOURCES DIVISION DISTRICT OFFICES—CONTINUED

State	District Chief	Telephone number	Address
Maryland	Walter F. White, Jr.	(301)661–4664	8809 Satyr Hill Road, Parkville, MD 21234.
Massachusetts	John A. Baker	(617)223–2822	150 Causeway St., Suite 1001, Boston, MA 02114.
Michigan	T. Ray Cummings	(517)372–1910 ext. 561	2400 Science Parkway, Red Cedar Research Park, Okemos, MI 48864.
Minnesota	Charles R. Collier	(612)725–7841	1033 Post Office Bldg., St. Paul, MN 55101.
Mississippi	Lamar E. Carroon	(601)969–4600	430 Bounds Street, Jackson, MS 39206.
Missouri	Anthony Homyk	(314)364–3680 ext. 185	1400 Independence Rd., Rolla, MO 65401.
Montana	George M. Pike	(406)449–5263	P.O. Box 1696, 421 Federal Bldg., Helena, MT 59601.
Nebraska	Kenneth A. Mac Kichan	(402)471–5082	406 Federal Bldg. and U.S. Courthouse, 100 Centennial Mall North, Lincoln, NE 68508.
Nevada	John P. Monis	(702)882–1388	227 Federal Bldg., 705 N. Plaza St., Carson, City, NV 89701.
New Hampshire	John A. Baker	(617)223–2822	See Massachusetts District Office.
New Jersey	Harold Meisler	(609)599–3511	P.O. Box 1238, 420 Federal Bldg., 402 East State Street, Trenton, NJ 08607.
New Mexico	William E. Hale	(505)766–2246	P.O. Box 4369, Geology Bldg., University of New Mexico, Albuquerque, NM 87106.
New York	Robert J. Dingman	(518)472–3107	P.O. Box 1350, 343 U.S. Post Office and Courthouse Bldg., Albany, NY 12201.
North Carolina	Ralph C. Heath	(919)755–4510	P.O. Box 2857, 436 Century Sta. P.O. Bldg., Raleigh, NC 27602.
North Dakota	Walter R. Scott	(701)255–4011 ext. 227	P.O. Box 778, 332 New Federal Bldg., 3rd St. and Rosser Avenue, Bismarck, ND 58501.
Ohio	James F. Blakey	(614)469–5553	975 West Third Avenue, Columbus, OH 43212.
Oklahoma	James H. Irwin	(405)231–4256	201 NW. 3rd St., Rm. 621, Oklahoma City, OK 73102.
Oregon	Stanley F. Kapustka	(503)234–3361 ext. 4776	P.O. Box 3202, 830 NE. Holladay St., Portland, OR 97208.
Pennsylvania	Norman H. Beamer	(717)782–3468	P.O. Box 1107, 4th Floor, Federal Bldg., 228 Walnut St., Harrisburg, PA 17108.
Puerto Rico	Ernest D. Cobb	(809)783–4660	P.O. Box 34168, Bldg. 652, Ft. Buchanan, PR 00934.
Rhode Island	John A. Baker	(617)223–2822	See Massachusetts District Office.
South Carolina	John S. Stallings	(803)765–5966	2001 Assembly St., Suite 200, Columbia, SC 29201.
South Dakota	John E. Powell	(605)352–8651 ext. 258	P.O. Box 1412, 231 Federal Bldg., Huron, SD 57350.
Tennessee	Stanley P. Sauer	(615)749–5424	A–413 Federal Bldg., U.S. Courthouse, Nashville, TN 37203.
Texas	I. Dale Yost	(512)397–5766	649 Federal Bldg., 300 East 8th St., Austin, TX 78701.
Utah	Theodore Arnow	(801)524–5663	8002 Federal Bldg., 125 S. State St., Salt Lake City, UT 84138.
Vermont	John A. Baker	(617)223–2822	See Massachusetts District Office.
Virginia	William E. Forrest	(804)782–2427	200 W. Grace St., Rm. 304, Richmond, VA 23220.
Washington	John E. McCall	(206)593–6510	1305 Tacoma Avenue South, Rm. 300, Tacoma, WA 98402.
West Virginia	Vacant	(304)343–6181 ext. 310.	3303 Federal Bldg. and U.S. Courthouse, 500 Quarrier Street East, Charleston, WV 25301.
Wisconsin	William W. Barnwell	(608)262–2488	1815 University Avenue, Rm. 200, Madison, WI 53706.
Wyoming	Samuel W. West	(307)778–2220 ext. 2111	P.O. Box 2087, 4015 Warren Ave., Cheyenne, WY 82001.

CONSERVATION DIVISION
REGIONAL OFFICES

Region	Conservation Manager	Telephone number	Address
Eastern	George Brown	(202)254–3137	1725 K St., NW., Suite 213, Washington, DC 20244.
Central	George H. Horn	(303)234–2855	Box 25046, STOP 609, Denver Federal Center, Denver, CO 80225.

CONSERVATION DIVISION REGIONAL OFFICES—CONTINUED

Region	Conservation Manager	Telephone number	Address
Gulf of Mexico Outer Continental Shelf Operations	A. Dewey Acuff	(504)837–4720 ext. 381	P.O. Box 7944, 434 Imperial Office Bldg., 3301 N. Causeway Blvd., Metarie, LA 70011.
Western	Willard C. Gere	(415)323–8111 ext. 2563	345 Middlefield Road, Menlo Park, CA 94025.

PUBLICATIONS DIVISION
REGIONAL OFFICES

Region	Official in charge	Telephone number	Address
Eastern	Lewis D. Brown	(703)860–6761	National Center, STOP 328, Reston, VA 22092.
Central	John L. Heller	(303)234–4974	Box 25046, STOP 303, Denver Federal Center, Denver, CO 80225.
Western	Fred Kunkel	(415)323–8111 ext. 2537	345 Middlefield Road, Menlo Park, CA 94025.

PUBLIC INQUIRIES OFFICES

Location	Official in charge	Telephone number	Address
Alaska	Margaret I. Erwin	(907)277–0577	108 Skyline Bldg., 502 2nd Ave., Anchorage, AK 99501.
California:			
Los Angeles	Lucy E. Birdsall	(213)688–2850	7638 Federal Bldg., 300 N. Los Angeles Street, Los Angeles, CA 90012.
San Francisco	Jean V. Molleskog	(415)556–5627	504 Custom House, 555 Battery Street, San Francisco, CA 94111.
Colorado	Sylvia T. Huhta	(303)837–4169	1012 Federal Bldg., 1961 Stout St., Denver, CO 80202.
District of Columbia	Bruce A. Hubbard	(202)343–8073	1028 GSA Bldg., 19th and F Sts., NW., Washington, DC 20244.
Texas	Mildred V. Smith	(214)749–3230	1C45 Federal Bldg., 1100 Commerce Street, Dallas, TX 75202.
Utah	Wendy R. Hassibe	(801)524–5652	8102 Federal Bldg., 125 South State Street, Salt Lake City, UT 84138.
Virginia	A. Ernestine Jones	(703)860–6167	1C402 National Center, STOP 302, 12201 Sunrise Valley Drive, Reston, VA 22092.
Washington	Eula Thune	(509)456–2524	678 U.S. Court House, West 920 Riverside Avenue, Spokane, WA 99201.

BRANCH OF DISTRIBUTION OFFICES

Location	Official in charge	Telephone number	Address
Alaska	Natalie Cornforth	(907)452–1951	310 First Avenue, Fairbanks, AK 99701.
Colorado	Dwight F. Canfield	(303)234–3832	Box 25286, STOP 306, Denver Federal Center, Denver, CO 80225.
Virginia	John J. Curry	(703)557–2751	1200 South Eads Street, Arlington, VA 22202.

ADMINISTRATIVE DIVISION
REGIONAL MANAGEMENT OFFICES

Region	Regional Management Officers	Telephone number	Address
Eastern	Roy Heinbuch	(703)860–7691	National Center, STOP 290, Reston, VA 22092.
Central	Thomas J. Lyons	(303)234–3736	Box 25046, STOP 202, Denver Federal Center, Denver, CO 80225.
Western	Avery W. Rogers	(415)323–2211	345 Middlefield Road, Menlo Park, CA 94025.

COOPERATORS AND OTHER FINANCIAL CONTRIBUTORS DURING FISCAL FINANCIAL YEAR 1975

[Cooperators listed are those with whom the U.S. Geological Survey had a written agreement for fiscal cooperation in fiscal year 1975, cosigned by responsible officials of the Geological Survey and the cooperating agency. Agencies with whom the Geological Survey had research contracts and to whom it supplied funds for such research are not listed. Parent agencies are listed separately from their subdivisions where separate cooperative agreements for different projects were made with the parent agency and with a subdivision of the parent agency]

FEDERAL COOPERATORS

Department of Agriculture:
- Agriculture Research Service
- Forest Service
- Soil Conservation Service
- Statistical Reporting Service

Department of the Air Force:
- AFWL/PRP Kirtland AFB
- Air Force Academy
- Air Force Headquarters, Washington, D.C.
- Air Force Systems Command
- Air Force Weapons Laboratory (PRP)
- Alaskan Air Command
- Edwards Air Force Base
- Eglin Air Force Base
- Headquarters (AF-SC)
- Headquarters (AFTAC/AC)
- Headquarters Pacific Air Forces
- Headquarters 321st Combat Support Group (SAC)
- Homestead Air Force Base
- Office of Scientific Research
- Rocket Propulsion Laboratory
- Vandenburg Air Force Base

Department of the Army:
- Army Electronics Command
- Army Research Office
- Cold Regions Research and Engineering Laboratory
- Construction Engineering Research Laboratory
- Corps of Engineers
- White Sands Missile Range

Department of Commerce, National Oceanic and Atmospheric Administration:
- Buoy Office
- Environmental Data Service
- Environmental Research Laboratories
- National Environmental Satellite Service
- National Marine Fisheries Service
- National Ocean Survey
- National Weather Service

Department of Defense:
- Advanced Research Projects Agency
- Defense Intelligence Agency
- Defense Mapping Agency (IAGS)
- Defense Nuclear Agency
- U.S. Arms Control and Disarmament Agency

Department of Health, Education, and Welfare, Public Health Service

Department of Housing and Urban Development

Department of the Interior:
- Alaska Power Administration
- Bonneville Power Administration
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Mines
- Bureau of Outdoor Recreation
- Bureau of Reclamation
- Fish and Wildlife Service
- National Park Service
- Office of Land Use and Water Planning
- Office of Saline Water
- Office of Water Resources Research
- U.N. Geothermal Symposium
- Water Resources Council

Department of Justice

Department of the Navy:
- Key West Naval Station
- Marine Corps, Camp Pendleton
- Naval Air Development Center
- Naval Facilities Engineering Command
- Naval Weapons Center
- Office of Naval Petroleum and Oil Shale Reserves
- Office of Naval Research
- Public Works Center, Guam

Department of State:
- Agency for International Development
- International Boundary and Water Commission
- International Joint Commission

Department of Transportation:
- Federal Highway Administration
- Office of the Secretary

Energy Research and Development Administration:
- Albuquerque Operations Office
- Division of Applied Technology
- Division of Administrative Services
- Division of Reactor Research and Development
- Idaho Operations Office
- Nevada Operations Office
- Oak Ridge Operations Office
- Office of the Director of Regulation
- Richland Operations Office
- Rocky Flats Division
- San Francisco Operations Office
- Savannah River Operations Office

FEDERAL COOPERATORS—CONTINUED

Environmental Protection Agency:
- Management Division
- National Environmental Research Center
- Office of Radiation Programs
- Office of Research and Development
- Office of Solid Waste
- Office of Water Programs
- Pacific Northwest Environmental Research Laboratory
- Water and Hazardous Materials

Federal Energy Administration

General Services Administration

National Academy of Sciences

National Aeronautics and Space Administration

National Science Foundation

Nuclear Regulatory Commission

Office of Emergency Preparedness
- Pacific Northwest River Basins Commission

Tennessee Valley Authority

Veterans Administration

STATE, COUNTY, AND LOCAL COOPERATORS

Alabama:
- Alabama Forestry Commission
- Alabama Highway Department
- City of Mobile
- County of Jefferson
- Geological Survey of Alabama

Alaska:
- Alaska Department of Aviation
- Alaska Department of Fish and Game
- Alaska Department of Highways
- Alaska Department of Natural Resources
- Alaska Geological Survey
- City and Borough of Juneau
- City of Anchorage
- City of Cordova
- City of Kenai
- City of Kodiak
- City of Seward
- Department of Environmental Conservation
- Greater Anchorage Area Borough
- Kenai Borough
- North Star Borough
- University of Alaska

Arizona:
- Arizona Game and Fish Department
- Arizona Highway Department
- Arizona Water Commission
- City of Flagstaff
- City of Nogales
- City of Safford
- City of Tucson
- City of Williams
- Department of Health Services
- Flood Control District of Maricopa County
- Gila Valley Irrigation District
- Lyman Water Company
- Maricopa County Municipal Water Conservation District No. 1
- Office of the Governor
- Pima County Board of Supervisors
- Salt River Valley Water User's Association
- San Carlos Irrigation and Drainage District
- Show Low Irrigation Company
- University of Arizona

Arkansas:
- Arkansas Department of Pollution Control and Ecology
- Arkansas Division of Soil and Water Resources
- Arkansas Geological Commission
- Arkansas State Highway Commission

California:
- Alameda County Flood Control and Water Conservation District.
- Alameda County Water District
- Antelope Valley-East Kern Water Agency
- Berrenda Mesa Water District
- Big Bear Lake Pest Abatement District
- California Department of Conservation, Division of Mines and Geology
- California Department of Fish and Game
- California Department of Water Resources
- California Division of Highways, Materials and Research Department
- California Water Resources Control Board
- Casitas Municipal Water District
- Chino Basin Municipal Water District
- City and County of San Francisco:
  - Hetch Hetchy Water Supply
  - Water Department
- City of Modesto, Public Works Department
- City of Redding
- City of San Diego
- City of San Jose
- City of San Rafael
- City of Santa Barbara
- City of Santa Cruz
- Coachella Valley County Water District
- Contra Costa County Flood Control and Water Conservation District
- County of Fresno
- County of Madera
- County of Modoc
- County of Sacramento, Department of Public Works
- County of San Diego, Board of Supervisors
- County of San Mateo
- Department of Transportation, Office of Structures
- Desert Water Agency
- East Bay Municipal Utility District

California—Continued
- Fern Valley Water District
- Georgetown Divide Public Utility District
- Goleta County Water District
- Hoopa Valley Tribe
- Imperial County Department of Public Works
- Imperial Irrigation District
- Indian Wells Valley County Water District
- Kern County
- Kern County Water Agency
- Lake County Flood Control and Water Conservation District
- Livermore Amador Valley Water Management Agency
- Los Angeles County, Department of County Engineers
- Los Angeles County Flood Control District
- Los Angeles Department of Water and Power
- Madera Irrigation District
- Marin Municipal Water District
- Merced Irrigation District
- Metropolitan Water District of Southern California
- Mojave Water Agency
- Montecito County Water District
- Monterey County Flood Control and Water Conservation District
- Napa County Flood Control and Water Conservation District
- North Marin County Water District
- Orange County Flood Control District
- Orange County Water District
- Oroville-Wyandotte Irrigation District
- Pacheco Pass Water District
- Paradise Irrigation District
- Placer County Department of Public Works
- Riverside County Flood Control and Water Conservation District
- San Benito County Water Conservation and Flood Control District
- San Bernardino County Flood Control District
- San Bernardino Valley Municipal Water District
- San Luis Obispo County and Cities Area Planning Coordinating Council
- San Luis Obispo County Flood Control and Water Conservation District
- Santa Ana Watershed Planning Agency
- Santa Barbara County Flood Control and Water Conservation District
- Santa Barbara County Water Agency
- Santa Clara County Flood Control and Water District
- Santa Cruz County Flood Control and Water Conservation District
- Santa Cruz County Planning Department
- Santa Margarita and San Luis Rey Watershed Planning Agencies
- Santa Maria Valley Water Conservation District
- Santa Ynez River Water Conservation District
- Siskiyou County Flood Control and Water Conservation District
- Solano Irrigation District
- Tehachapi-Cummings County Water District
- Terra Bella Irrigation District
- Tulare County Flood Control District
- Turlock Irrigation District
- United Water Conservation District
- University of California:
  - Department of Engineering
  - School of Forestry and Conservation
  - Scripps Institute of Oceanography

California—Continued
- Valley Community Services District
- Valley Sanitary District
- Ventura County Flood Control District, Riverside County
- Western Municipal Water District
- Woodbridge Irrigation District
- Yolo County Flood Control and Water Conservation District

Colorado:
- Arkansas River Compact Administration
- Cherokee Water District
- City and County of Denver, Board of Water Commissioners
- City of Aspen
- City of Aurora, Department of Public Utilities
- City of Colorado Springs, Department of Public Utilities
- City of Fort Collins
- City of Pueblo
- Colorado City Water and Sanitation District
- Colorado Department of Local Affairs
- Colorado Department of Natural Resources:
  - Division of Water Resources
  - Division of Wildlife
  - Geological Survey
- Colorado Department of Public Health, Water Pollution Control Commission
- Colorado River Water Conservation District
- Colorado Water Conservation Board
- Eagle County Commissioners
- El Paso County Board of Commissioners
- El Paso County Water Association
- Huerfano County Conservation District
- Jefferson County Health Department
- Kiowa-Bijou Groundwater Management District
- Larimer County Planning Office
- Lower South Platte Water Conservation District
- Metro Denver Sewage Disposal District No. 1
- Northern Colorado Water Conservation District
- Pikes Peak Area Council of Governments
- Pitkin County Board of County Commissioners
- Rio Grande Water Conservation District
- San Luis Valley Water Conservation District
- Southeastern Colorado Water Conservancy District
- Southern Ute Indian Tribe
- Southwestern Water Conservation District
- State of Colorado, Department of Highways
- Teller County
- Urban Drainage and Flood Control District

Connecticut:
- City of Hartford, Department of Public Works
- City of New Britain, Board of Water Commissioners
- City of Torrington
- Connecticut Geological and Natural History Survey
- Department of Environmental Protection
- Department of Transportation
- State of Connecticut, Office of State Planning
- Town of Fairfield

Delaware:
- Delaware Geological Survey, University of Delaware
- Department of Highways and Transportation, Division of Highways

District of Columbia:
- Department of Environmental Services

STATE, COUNTY, AND LOCAL COOPERATORS—CONTINUED

Florida:
- Brevard County
- Broward County
- Broward County Air and Water Pollution Control Board
- Central and Southern Florida Flood Control District
- City of Boca Raton
- City of Clearwater
- City of Cocoa
- City of Deerfield Beach
- City of Fort Lauderdale
- City of Fort Myers
- City of Gainesville
- City of Hallandale
- City of Hollywood
- City of Jacksonville
- City of Juno Beach
- City of Miami, Department of Water and Sewers
- City of Pensacola
- City of Perry
- City of Pompano Beach
- City of Riviera Beach
- City of St. Petersburg
- City of Sarasota
- City of Tallahassee
- City of Tampa
- City of Temple Terrace
- City of West Palm Beach
- Collier County
- Collier County Water Management District No. 1
- Collier County Water Management District No. 7
- Department of Pollution Control
- Division of State Planning
- East Central Florida Regional Planning Council
- Englewood Water District
- Escambia County
- Florida Department of Natural Resources:
  - Bureau of Geology
  - Division of Parks and Recreation
- Florida Department of Transportation
- Game and Fresh Water Fish Commission
- Hendry County
- Hillsborough County
- Jacksonville Area Planning Board
- Jacksonville Recreation and Public Area
- Lake County
- Lake Worth Drainage District
- Lee County
- Loxahatchee River Environmental Control District
- Manasota Basin Board
- Manatee County, Board of County Commissioners
- Marion County
- Martin County
- Metropolitan Dade County
- Northwest Florida Water Management District
- Orange County
- Osceola County
- Palm Beach County
- Pinellas County
- Reedy Creek Improvement District
- Sarasota County
- School of Marine and Atmospheric Science, University of Miami Division of Planning
- Seminole County
- Southwest Water Management District
- St. Johns River Water Management

Florida—Continued
- Suwanee River Authority
- Suwanee River Water Management District
- Tampa Bay Regional Planning Commission
- Tampa Port Authority
- Village of Tequesta
- Volusia County
- Walton County

Georgia:
- Chatham County
- City of Brunswick
- Dekalb County
- Department of Natural Resources:
  - Earth and Water Division
  - Environmental Protection Division
- Department of Transportation

Hawaii:
- City and County of Honolulu
- Honolulu Board of Water Supply
- State Department of Health
- State Department of Land and Natural Resources
- State Department of Transportation

Idaho:
- City of Kellogg
- Idaho Bureau of Mines and Geology
- Idaho Department of Health and Welfare
- Idaho Department of Highways
- Idaho Department of Transportation
- Idaho Department of Water Administration
- Idaho State University
- Idaho Water Resources Board
- Southeast Idaho Council of Governments

Illinois:
- Bloomington and Normal Sanitary District
- City of Springfield
- Cook County, Forest Preserve District
- Du Page County
- Environmental Protection Agency
- Fountain Head Drainage District
- Fulton County
- Illinois Institute of Environmental Quality
- Kane County
- Lake County
- McHenry County Regional Planning Commission
- Sanitary District of Bloom Township
- State Department of Registration and Education:
  - Illinois State Geological Survey
  - Illinois State Water Survey
- State Department of Transportation:
  - Division of Highways
  - Division of Water Resources Management
- The Metropolitan Sanitary District of Greater Chicago
- University of Illinois at Urbana-Champaign

Indiana:
- City of Indianapolis
- Indiana Board of Health
- Indiana Department of Natural Resources
- Indiana Highway Commission
- Town of Carmel

STATE, COUNTY, AND LOCAL COOPERATORS—CONTINUED

Iowa:
- City of Cedar Rapids
- City of Des Moines
- City of Fort Dodge
- Iowa Geological Survey
- Iowa Natural Resources Council
- Iowa State Highway Commission, Highway Research Board
- Iowa State University
- Iowa State University, Agricultural and Home Economics Experiment Station
- Linn County
- University of Iowa, Institute of Hydraulic Research

Kansas:
- City of Wichita
- Kansas State Department of Health
- Kansas State Water Resources Board
- Kansas-Oklahoma Arkansas River Commission
- State Geological Survey of Kansas
- State Highway Commission of Kansas

Kentucky:
- Bureau of Highways, Department of Transportation
- Department of Natural Resources
- Kentucky Geological Survey, University of Kentucky
- University of Kentucky Research Foundation

Louisiana:
- Louisiana Department of Highways
- Louisiana Department of Public Works
- Louisiana Office of State Planning
- Louisiana State University
- Sabine River Authority of Louisiana
- Sabine River Compact Administration

Maine:
- Department of Environmental Protection
- Maine Department of Economic Development
- Maine Department of Transportation
- Maine Geological Survey
- Maine Public Utilities Commission

Maryland:
- City of Baltimore, Water Division
- Department of Natural Resources, Water Resources Administration
- Maryland Department of Health and Mental Hygiene
- Maryland Department of Transportation, The State Highway Administration
- Maryland Geological Survey
- Maryland National Capital Park and Planning Commission
- Montgomery County
- Washington Suburban Sanitary Commission

Massachusetts:
- Department of Natural Resources, Division of Mineral Resources
- Department of Public Works:
  - Division of Highways
  - Division of Waterways
- Metropolitan District Commission

Massachusetts—Continued
- State Water Resources Commission:
  - Division of Water Pollution Control
  - Division of Water Resources

Michigan:
- Michigan Department of Agriculture, Soil and Water Conservation Division
- Michigan Department of Natural Resources:
  - Geological Survey Division
  - Water Resources Commission

Minnesota:
- Metropolitan Council of the Twin Cities Area
- Metropolitan Sewer Board of the Twin Cities Area
- Minnesota Department of Highways
- Minnesota Department of Natural Resources, Division of Waters, Soils, and Minerals
- Minnesota Pollution Control Agency
- Minnesota State Planning Agency
- Pelican River Watershed District

Mississippi:
- City of Jackson
- Harrison County Development Commission
- Jackson County Board of Supervisors
- Jackson County Port Authority
- Mississippi Air and Water Pollution Control Commission
- Mississippi Board of Water Commissioners
- Mississippi Geological Survey
- Mississippi Research and Development Center
- Mississippi State Highway Department
- Mississippi State University
- Pat Harrison Waterway District
- Pearl River Basin Development District
- Pearl River Valley Water Supply District
- Yellow Creek Port Authority

Missouri:
- Curators of the University of Missouri
- Department of Natural Resources:
  - Division of Environmental Quality, Clean Water Commission
  - Research Technical Information
- Metropolitan St. Louis Sewer District
- Missouri Department of Business and Administration, Division of Geological Surveys and Water Resources
- Missouri State Highway Commission
- Missouri Water Pollution Board
- St. Louis County

Montana:
- Endowment and Research Foundation—Montana State University
- Lewis and Clark County, Board of County Commissioners
- Montana Bureau of Mines and Geology
- Montana Department of Health and Environmental Sciences
- Montana Department of Intergovernmental Relations
- Montana Department of Natural Resources
- Montana State Fish and Game Department
- Montana State Highway Commission
- Old West Regional Commission

STATE, COUNTY, AND LOCAL COOPERATORS—CONTINUED

Nebraska:
- Clay County Ground Water Conservation District
- Filmore County Ground Water Conservation District
- Hamilton County Ground Water Conservation District
- Kansas-Nebraska Big Blue River Compact Administration
- Lower Loup Natural Resources District
- Lower Platte South Natural Resources District
- Nebraska Department of Environmental Control
- Nebraska Department of Water Resources
- Nebraska Game and Parks Commission
- Nebraska Natural Resources Commission
- Seward County Ground Water Conservation District
- State Department of Roads
- University of Nebraska, Conservation and Survey Division
- Upper Big Blue Natural Resources District
- York County Ground Water Conservation District

Nevada:
- Nevada Bureau of Mines and Geology
- Nevada Department of Conservation and Natural Resources
- Nevada State Highway Department

New Hampshire:
- New Hampshire Department of Resources and Economic Development
- New Hampshire Water Resources Board
- New Hampshire Water Supply and Pollution Control Commission

New Jersey:
- Bergen County
- Camden County Board of Freeholders
- Delaware River Basin Commission
- New Jersey Department of Agriculture, State Soil Conservation Committee
- New Jersey Department of Environmental Protection
- New Jersey Department of Transportation
- North Jersey District Water Supply Commission
- Passaic Valley Water Commission
- Rutgers State University
- Township of Cranford

New Mexico:
- Albuquerque Metropolitan Arroyo Flood Control Authority
- City of Las Cruces
- Costilla Creek Compact Commission
- Elephant Butte Irrigation District
- Interstate Stream Commission
- New Mexico Bureau of Mines and Mineral Resources
- New Mexico State Engineer
- New Mexico State Highway Department
- Pecos River Commission
- Rio Grande Compact Commission
- University of New Mexico

New York:
- Board of Hudson River—Black River Regulating District
- Central New York State Parks Commission
- City of Albany
- City of Auburn
- City of New York:
  - Board of Water Supply
  - Environmental Protection Agency
- County of Chautauqua
- County of Cortland

New York—Continued
- County of Dutchess:
  - Board of Supervisors
  - Department of Public Works
- County of Nassau, Department of Public Works
- County of Onondaga:
  - Department of Public Works
  - Water Authority
- County of Orange
- County of Putnam
- County of Rockland Drainage Agency
- County of Suffolk:
  - Department of Environmental Control
  - Water Authority
- County of Ulster, Ulster County Legislature
- County of Westchester, Department of Public Works
- County of Wyoming
- Department of Environmental Conservation:
  - Environmental Management
  - Environmental Quality
  - Environmental Research
  - Facilities and Construction Management
- Department of Transportation
- Monroe County Water Authority
- New York State College of Agriculture and Life Sciences
- New York State Department of Health
- New York State Education Department, Museum and Science Service
- Oswegatchie-Cranberry Reservoir Commission
- Power Authority of the State of New York
- State University of New York, College of Environmental Science and Forestry
- Town of Brighton
- Town of Clarkstown
- Town of Middlebury
- Town of Warwick
- Village of Nyack

North Carolina:
- City of Asheville, Public Works Department
- City of Burlington
- City of Charlotte
- City of Durham, Department of Water Resources
- City of Greensboro
- City of Winston-Salem
- North Carolina Department of Conservation and Development, Division of Mineral Resources
- North Carolina Department of Natural and Economic Resources, Office of Earth Resources
- North Carolina Department of Water and Air Resources
- State Department of Transportation
- Triangle "J" Council of Governments
- Water Research Institute
- Wilson County

North Dakota:
- North Dakota Geological Survey
- Oliver County, Board of County Commissioners
- State Highway Department
- State Water Commission

Ohio:
- City of Canton
- City of Columbus, Department of Public Service
- Miami Conservancy District

Ohio—Continued
- Ohio Department of Natural Resources
- Ohio Department of Transportation
- Ohio Department of Transportation, Division of Highways
- Ohio Environmental Protection Agency
- Three Rivers Watershed District

Oklahoma:
- City of Oklahoma City, Water Department
- Oklahoma Department of Highways
- Oklahoma Geologic Survey
- Oklahoma Soil Conservation Board
- Oklahoma Water Resources Board
- State Department of Health, Environmental Health Service

Oregon:
- Burnt River Irrigation District
- City of Astoria
- City of Corvallis
- City of Eugene, Water and Electric Board
- City of McMinnville, Water and Light Department
- City of Portland, Bureau of Water Works
- City of The Dalles
- Confederated Tribes of the Umatilla Indian Reservation
- Confederated Tribes of the Warm Springs Reservation
- Coos Bay-North Bend Water Board
- Coos County, Board of Commissioners
- Cowlitz County
- Douglas County
- Lakeside Water District
- Lane County, Department of General Administration
- Oregon State Board of Higher Education
- Oregon State Game Commission
- Oregon State Highway Commission
- Oregon State Water Resources Department

Pennsylvania:
- Chester County Commissioners
- Chester County Health Department
- Chester County Water Resources Authority
- City of Bethlehem
- City of Easton
- City of Harrisburg
- City of Philadelphia, Water Department
- Department of Environmental Management
- Pennsylvania Department of Environmental Resources:
  - Bureau of Topographic and Geologic Survey
  - Bureau of Water Quality Management
  - Office of Engineering and Construction
  - State Soil and Water Conservation Commission
- Pennsylvania Department of Transportation

Pennsylvania—Continued
- Pennsylvania Office of State Planning and Development
- Susquehanna River Basin Commission

Rhode Island:
- City of Providence, Department of Public Works
- State Department of Natural Resources:
  - Division of Fish and Wildlife
  - Division of Planning and Development
- State Department of Transportation, Division of Roads and Bridges
- State Water Resources Board

South Carolina:
- Commissioners of Public Works, Spartanburg Water Works
- South Carolina State Development Board
- State Development Board, Division of Geology
- State Highway Department
- State Land Resources Conservation Commission
- State Pollution Control Authority
- State Public Service Authority
- State Water Resources Commission

South Dakota:
- Black Hills Conservancy Subdistrict
- City of Sioux Falls
- City of Watertown
- East Dakota Conservancy Subdistrict
- South Dakota Department of Natural Resource Development
- South Dakota Department of Transportation and State Geological Survey

Tennessee:
- Chickasaw Basin Authority
- City of Chattanooga
- City of Franklin
- City of Lawrenceburg
- City of Manchester
- City of Memphis, Board of Light, Gas, and Water Commissioners
- Lincoln County
- Metropolitan Government of Nashville and Davidson County
- Murfreesboro Water and Sewer Department
- Tennessee Department of Conservation:
  - Division of Geology
  - Division of Water Resources
- Tennessee Department of Highways
- Tennessee Department of Public Health, Division of Water Quality Control
- Tennessee Department of Transportation
- Tennessee Game and Fish Commission

STATE, COUNTY, AND LOCAL COOPERATORS—CONTINUED

Tennessee—Continued
- Tennessee State Planning Office
- University of Tennessee

Texas:
- City of Austin
- City of Dallas, Public Works Department
- City of Fort Worth
- City of Houston
- County of Dallas
- Sabine River Compact Administration
- Texas Highway Department
- Texas Water Development Board

Utah:
- Bear River Commission
- Salt Lake County
- State Department of Highways
- State Department of Natural Resources, Division of Water Rights
- Utah Geological and Mineralogical Survey
- Utah Legislative Council

Vermont:
- State Department of Highways
- State Department of Water Resources, Planning and Development Division
- Vermont Geological Survey

Virginia:
- City of Alexandria
- City of Newport News, Department of Public Utilities
- City of Norfolk:
  - Department of Utilities
  - Division of Water Supply
- City of Roanoke
- City of Staunton
- County of Chesterfield
- County of Fairfax
- Virginia Department of Conservation and Economic Development, Division of Mineral Resources
- Virginia Department of Highways
- Virginia Polytechnic Institute and State University
- Virginia State Water Control Board

Washington:
- Chehalis Tribal Council
- City of Port Angeles
- City of Seattle, Department of Lighting
- City of Tacoma:
  - Department of Public Utilities

Washington—Continued
- Department of Public Works
- Clark County Public Utility District
- Coleville Business Council
- Cowlitz County Public Utility District
- Municipality of Metropolitan Seattle
- Pacific County
- Quinault Business Committee
- Squaxin Indian Tribe
- Swinomish Tribal Council
- The Evergreen State College
- Tulalip Tribal Council
- University of Washington
- Washington State Department of Ecology
- Washington State Department of Fisheries
- Washington State Department of Game
- Washington State Department of Highways
- Washington State Department of Natural Resources, Division of Mines and Geology
- Yakima Tribal Council

West Virginia:
- Clarksburg Water Board
- Morgantown Water Commission
- West Virginia Department of Highways
- West Virginia Department of Natural Resources, Division of Water Resources
- West Virginia Geological and Economic Survey

Wisconsin:
- City of Madison
- City of Middleton
- Dane County
- Douglas County
- Madison Metropolitan Sewerage District
- Southeastern Wisconsin Regional Planning Commission
- State Department of Natural Resources
- State Department of Transportation, Division of Highways
- The University of Wisconsin-Extension, Geological and Natural History Survey
- Town of Kronenwetter

Wyoming:
- City of Cheyenne, Board of Public Utilities
- State Highway Commission of Wyoming
- Wyoming Department of Economic Planning and Development
- Wyoming Game and Fish Commission
- Wyoming State Agriculture Commission
- Wyoming State Department of Environmental Quality
- Wyoming State Engineer

OTHER COOPERATORS AND CONTRIBUTORS

Appalachian Regional Commission

Coastal Plains Regional Commission

Government of Algeria

Government of American Samoa

Government of Brazil

Government of Burma

Government of Colombia

Government of Guam

Government of Iran

Government of Jordan

Government of Nepal

Government of Nicaragua

Government of Oman

Government of Peru

Government of the Philippines

Government of Saudi Arabia

Government of Thailand

Government of Turkey

Government of Yemen

Northern Great Plains Resources Programs

Ozarks Regional Commission

Permittees and licensees of the Federal Power Commission

Puerto Rico:
- Gobierno Municipal De Bayamón
- Puerto Rico Department of Natural Resources
- Puerto Rico Environmental Quality Board
- Puerto Rico Water Resources Authority

Trust Territory of the Pacific Islands

United Nations

Virgin Islands, Department of Public Works

STATISTICAL DATA

TABLE 25.—*Original and revised budget structure of the Surveys, Investigations, and Research appropriation for 1975*

Budget activity	Organizational unit
ORIGINAL STRUCTURE	
Special Resource and Environmental Projects: Urban Area Studies. Mineral Policy. Geothermal Investigations. Energy Impact Evaluations. Arctic Environmental Studies.	Office of Land Information and Analysis, Geologic Division, and Conservation Division.
Alaska Pipeline Related Investigations.	Geologic Division.
Topographic Surveys and Mapping.	Topographic Division.
Geologic and Mineral Resource Surveys and Mapping.	Geologic Division.
Mineral Discovery Loan Program.	Geologic Division.
Water Resources Investigations.	Water Resources Division.
Conservation of Lands and Minerals.	Conservation Division.
General Administration.	Office of the Director and Administrative Division.
Facilities.	Administrative Division.
Earth Resources Observation Systems.	Office of Land Information and Analysis.
Resource and Land Investigations.	Office of Land Information and Analysis.
Land Use Data and Analysis.	Office of Land Information and Analysis.
REVISED STRUCTURE	
Alaska Pipeline Related Investigations.	Geologic Division.
Topographic Surveys and Mapping.	Topographic Division.
Geologic and Mineral Resources Surveys and Mapping.	Geologic Division.
Water Resources Investigations.	Water Resources Division.
Conservation of Lands and Minerals.	Conservation Division.
General Administration.	Office of the Director and Administrative Division.
Facilities.	Administrative Division.
Land Information and Analysis.	Land Information and Analysis Office.

TABLE 26.—*Geological Survey budget, by activity and sources of funds, fiscal years 1970–75*

[In thousands of dollars. Detail may not add to totals because of rounding]

Budget activity	1970	1971	1972	1973	1974	1975
	CURRENT DOLLARS					
Total	$157,387	$173,243	$188,996	$211,944	$249,437	$338,764
Direct program	103,308	114,080	130,951	149,971	171,983	253,605
Reimbursable program	54,079	59,163	58,045	61,973	77,454	85,159
States, counties, and municipalities	23,098	24,687	25,857	28,011	32,443	35,124
Miscellaneous non-Federal sources	3,135	3,240	3,383	3,620	4,695	6,399
Other Federal agencies	27,846	31,236	28,805	30,342	40,316	43,636
Alaska Pipeline Related Investigations	739	1,401	1,401	1,239	890	344
Direct program	709	1,336	1,339	1,239	890	344
Reimbursable program	30	65	62	--	--	--
Other Federal agencies	30	65	62	--	--	--
Topographic Surveys and Mapping	35,695	37,426	38,737	40,271	43,664	52,597
Direct program	28,493	31,153	34,545	35,172	37,161	45,350
Reimbursable program	7,202	6,273	4,192	5,099	6,503	7,247
States, counties, and municipalities	4,526	3,901	3,204	3,719	4,942	4,995
Miscellaneous non-Federal sources	286	355	357	600	643	594
Other Federal agencies	2,390	2,017	631	780	918	1,658
Geologic and Mineral Resource Surveys and Mapping [1]	46,796	49,015	51,529	57,979	73,563	114,477
Direct program	31,056	31,919	34,244	42,895	49,877	89,018
Reimbursable program	15,740	17,096	17,285	15,084	23,686	25,459
States, counties, and municipalities	1,292	1,322	1,359	1,556	1,681	1,550
Miscellaneous non-Federal sources	2,260	2,280	2,317	2,306	2,684	3,751
Other Federal agencies	12,188	13,494	13,609	11,222	19,321	20,158
Water Resources Investigations [2]	59,607	66,084	71,324	78,103	88,352	101,437
Direct program	31,585	34,581	37,446	40,185	45,433	53,420
Reimbursable program	28,022	31,503	33,878	37,918	42,919	48,017
States, counties, and municipalities	17,280	19,464	21,294	22,736	25,820	28,546
Miscellaneous non-Federal sources	559	571	679	664	721	901
Other Federal agencies	10,183	11,468	11,905	14,518	16,378	18,570
Conservation of Lands and Minerals [3]	7,527	9,704	13,467	14,748	18,213	36,082
Direct program	7,497	9,670	13,441	14,700	18,172	36,032
Reimbursable program	30	34	26	48	41	50
Miscellaneous non-Federal sources	2	2	1	3	--	4
Other Federal agencies	28	32	25	45	41	46
Land Information and Analysis [4]	1,967	3,539	7,289	13,125	13,003	16,994
Direct program	1,101	2,373	6,714	11,876	11,458	15,461
Reimbursable program	866	1,166	575	1,249	1,545	1,533
States, counties, and municipalities	--	--	--	--	--	33
Miscellaneous non-Federal sources	--	--	--	--	593	1,093
Other Federal agencies	866	1,166	575	1,249	952	407
General administration [5]	2,867	3,048	3,187	3,217	3,517	3,671
Direct program	2,867	3,048	3,187	3,217	3,517	3,671
Facilities [6]	--	--	35	687	5,475	10,309
Direct program	--	--	35	687	5,475	10,309
Miscellaneous services to other accounts	2,189	3,026	2,027	2,575	2,760	2,853
Reimbursable program	2,189	3,026	2,027	2,575	2,760	2,853
Miscellaneous non-Federal sources	28	32	29	47	54	56
Other Federal agencies	2,161	2,994	1,998	2,528	2,706	2,797

See footnotes at end of table.

TABLE 26.—*Geological Survey budget, by activity and sources of funds, fiscal years 1970–75*—Continued

[In thousands of dollars. Detail may not add to totals because of rounding]

Budget activity	1970	1971	1972	1973	1974	1975
CONSTANT 1967 DOLLARS [7]						
Total	$138,180	$144,610	$152,171	$164,298	$178,936	$219,265
Direct program	90,701	95,225	105,436	116,257	123,374	164,146
Reimbursable program	47,479	49,385	46,735	48,041	55,562	55,119
States, counties, and municipalities	20,279	20,607	20,819	21,714	23,273	22,734
Miscellaneous non-Federal sources	2,752	2,705	2,724	2,806	3,368	4,142
Other Federal agencies	24,448	26,073	23,192	23,521	28,921	28,243
Alaska Pipeline Related Investigations	649	1,169	1,128	960	638	223
Direct program	623	1,115	1,078	960	638	223
Reimbursable program	26	54	50	--	--	--
Other Federal agencies	26	54	50	--	--	--
Topographic Surveys and Mapping	31,339	31,240	31,189	31,218	31,323	34,043
Direct program	25,016	26,004	27,814	27,265	26,658	29,353
Reimbursable program	6,323	5,236	3,375	3,953	4,665	4,690
States, counties, and municipalities	3,974	3,256	2,580	2,883	3,545	3,233
Miscellaneous non-Federal sources	251	296	287	465	461	384
Other Federal agencies	2,098	1,684	508	605	659	1,073
Geologic and Mineral Resource Surveys and Mapping [1]	41,085	40,914	41,489	44,945	52,771	74,095
Direct program	27,266	26,644	27,572	33,252	35,780	57,617
Reimbursable program	13,819	14,270	13,917	11,693	16,991	16,478
States, counties, and municipalities	1,134	1,103	1,094	1,206	1,206	1,003
Miscellaneous non-Federal sources	1,984	1,903	1,866	1,788	1,925	2,428
Other Federal agencies	10,701	11,264	10,957	8,699	13,860	13,047
Water Resources Investigations [2]	52,333	55,162	57,427	60,545	63,380	65,655
Direct program	27,731	28,866	30,150	31,151	32,592	34,576
Reimbursable program	24,602	26,296	27,277	29,394	30,788	31,079
States, counties, and municipalities	15,171	16,247	17,145	17,625	18,522	18,477
Miscellaneous non-Federal sources	491	477	547	515	517	583
Other Federal agencies	8,940	9,572	9,585	11,254	11,749	12,019
Conservation of Lands and Minerals [3]	6,608	8,100	10,843	11,432	13,065	23,354
Direct program	6,582	8,072	10,822	11,395	13,036	23,322
Reimbursable program	26	28	21	37	29	32
Miscellaneous non-Federal sources	2	2	1	2	--	2
Other Federal agencies	24	26	20	35	29	30
Land Information and Analysis [4]	1,727	2,954	5,869	10,174	9,328	10,999
Direct program	967	1,981	5,406	9,206	8,220	10,007
Reimbursable program	760	973	463	968	1,108	992
States, counties, and municipalities	--	--	--	--	--	21
Miscellaneous non-Federal sources	--	--	--	--	425	708
Other Federal agencies	760	973	463	968	683	263
General administration [5]	2,517	2,544	2,566	2,494	2,523	2,376
Direct program	2,517	2,544	2,566	2,494	2,523	2,376
Facilities [6]	--	--	28	532	3,928	6,672
Direct program	--	--	28	532	3,928	6,672
Miscellaneous services to other accounts	1,922	2,526	1,632	1,996	1,980	1,847
Reimbursable program	1,922	2,526	1,632	1,996	1,980	1,847
Miscellaneous non-Federal sources	25	27	23	36	39	37
Other Federal agencies	1,897	2,499	1,609	1,960	1,941	1,810

[1] Funds include: Mineral Discovery Loan Program activity for fiscal years 1970–75; and parts of Geothermal Investigations, Minerals Policy, and Arctic Environmental Studies components of the Special Resource and Environmental Projects activity for fiscal years 1971–75. Funds exclude the Land Resource Analysis program for fiscal years 1973–75.

[2] Funds exclude Employee Compensation Payments subactivity for fiscal years 1970–75.

[3] Funds include parts of Geothermal Investigations component of the Special Resource and Environmental Projects activity for fiscal years 1972–75.

[4] Budget activity funds are reconstructed for fiscal years 1970–75 and include: Earth Resources Observation System activity for fiscal years 1970–75; Urban Area Studies and Energy Impact Evaluation components of the Special Resource and Environmental Projects activity for fiscal years 1970–75; Land Resources Analysis program of the Geologic and Mineral Resource Surveys and Mapping activity for fiscal years 1974–75; and the Land Use Data and Analysis activity for fiscal year 1975.

[5] Funds include Employee Compensation Payments subactivity of the Water Resources Investigations activity for fiscal years 1970–75.

[6] Budget activity began in fiscal year 1972.

[7] Gross National Product implicit price deflater was used to convert current to constant 1967 dollars.

TABLE 27.—*Geological Survey Federal-State Cooperative program funds, by State, fiscal years 1970–75*

[In thousands of dollars]

State	1970	1971	1972	1973	1974	1975
Total [1]	$46,399	$49,274	$50,651	$55,633	$65,256	$70,151
Total State share [2]	23,098	24,687	25,857	28,011	32,443	35,124
Alabama	826	846	839	928	1,094	1,212
State share	435	467	461	514	554	623
Alaska	417	411	619	838	897	1,162
State share	258	203	330	399	410	410
Arizona	819	869	1,021	1,001	1,144	1,248
State share	412	444	540	510	576	646
Arkansas	464	492	506	596	857	887
State share	222	239	250	288	455	410
California	3,474	4,014	3,893	4,115	4,789	4,690
State share	1,677	1,951	1,936	2,053	2,280	2,337
Colorado	951	944	995	1,128	1,484	2,445
State share	464	477	507	575	837	1,324
Connecticut	585	619	617	687	814	1,069
State share	277	302	304	292	374	523
Delaware	88	112	111	121	130	194
State share	52	73	75	81	74	106
District of Columbia	12	12	2	3	3	3
State share	6	6	1	1	1	1
Florida	2,959	3,119	3,398	3,643	5,083	5,575
State share	1,456	1,539	1,719	1,858	2,552	2,781
Georgia	652	751	799	2,008	3,239	3,083
State share	354	400	437	1,041	1,611	1,531
Hawaii	598	649	622	653	691	697
State share	284	334	314	337	339	341
Idaho	546	633	619	675	718	749
State share	261	308	307	344	353	366
Illinois	549	650	653	646	544	645
State share	263	316	341	333	277	323
Indiana	895	906	994	1,107	1,363	1,288
State share	428	439	491	590	678	632
Iowa	457	442	517	525	608	617
State share	218	214	255	259	299	302
Kansas	1,286	1,324	1,362	1,358	1,402	1,424
State share	619	645	675	676	686	716
Kentucky	1,738	1,900	2,033	2,212	2,451	2,728
State share	842	939	1,008	1,039	1,122	1,229
Louisiana	1,071	1,167	1,212	1,240	1,900	1,740
State share	567	621	655	674	980	902
Maine	151	158	163	168	175	248
State share	80	84	89	91	96	127
Maryland	594	580	620	695	851	1,011
State share	296	295	321	356	435	530
Massachusetts	946	1,126	1,159	1,379	1,346	1,618
State share	463	595	614	625	656	810
Michigan	993	865	859	947	930	1,054
State share	473	407	417	425	436	505
Minnesota	1,369	1,434	1,369	1,420	1,903	1,639
State share	673	707	681	727	966	817
Mississippi	444	551	592	593	645	743
State share	275	316	357	340	325	415
Missouri	776	863	792	732	657	678
State share	374	420	413	375	322	337
Montana	318	393	401	402	505	587
State share	172	212	221	223	255	287
Nebraska	440	502	553	588	705	731
State share	211	246	274	298	344	358

See footnotes at end of table.

TABLE 27.—*Geological Survey Federal-State Cooperative program funds, by State, fiscal years 1970–75*—Continued

[In thousands of dollars]

State	1970	1971	1972	1973	1974	1975
Nevada	482	513	578	640	689	846
State share	225	234	271	288	304	332
New Hampshire	116	113	100	139	177	172
State share	56	55	50	67	97	73
New Jersey	735	785	822	856	1,051	977
State share	363	390	418	433	530	501
New Mexico	842	888	963	1,107	1,332	1,439
State share	432	462	509	601	662	714
New York	1,800	1,989	2,224	2,395	2,796	2,977
State share	866	973	1,111	1,229	1,415	1,585
North Carolina	883	938	946	1,038	1,586	1,885
State share	419	437	457	492	771	942
North Dakota	689	661	714	899	763	998
State share	337	325	361	461	369	489
Ohio	912	979	990	1,028	978	1,093
State share	486	521	518	520	481	563
Oklahoma	579	664	614	634	702	748
State share	312	359	333	340	344	368
Oregon	625	606	727	828	896	902
State share	312	307	372	432	439	443
Pennsylvania	2,322	2,178	2,167	2,047	2,357	2,415
State share	1,164	1,088	1,092	1,042	1,195	1,209
Rhode Island	91	97	92	90	97	110
State share	48	52	50	50	52	54
South Carolina	340	374	403	574	546	574
State share	178	196	212	301	279	284
South Dakota	399	409	424	423	471	515
State share	219	226	236	230	227	251
Tennessee	535	546	538	589	851	952
State share	284	292	294	321	422	470
Texas	3,103	3,835	3,717	3,794	4,046	4,261
State share	1,545	1,922	1,925	1,949	2,027	2,100
Utah	852	868	967	1,069	1,068	1,361
State share	407	421	486	530	534	838
Vermont	121	124	125	129	144	130
State share	72	62	64	66	73	64
Virginia	1,675	1,119	797	793	905	858
State share	850	577	420	421	466	442
Washington	1,686	1,774	1,800	1,988	2,121	2,208
State share	801	856	881	962	1,037	1,104
West Virginia	386	457	482	620	946	775
State share	213	249	263	332	521	448
Wisconsin	1,162	1,229	1,285	1,354	1,563	1,706
State share	556	584	619	638	775	883
Wyoming	588	626	589	612	698	853
State share	297	315	316	310	328	514
American Samoa	42	65	72	64	63	70
State share	20	32	36	32	31	32
Guam	21	25	36	43	62	65
State share	10	12	18	21	31	32
Puerto Rico	902	964	1,042	1,347	1,303	1,293
State share	470	484	494	557	682	585
Trust Territories	74	93	105	125	117	170
State share	35	45	52	62	58	84
Virgin Islands	19	23	12	[3]	[3]	33
State share	9	12	6	[3]	[3]	31

[1] Includes Federal funds from direct program.
[2] Reimbursable program funds from States, counties, and municipalities.
municipalities.
[3] Included with Puerto Rico funds.

TABLE 28.—*Geological Survey reimbursable program funds from other Federal agencies, by agency, fiscal years 1970–75*

[In thousands of dollars]

Agency	1970	1971	1972	1973	1974	1975
Total	$27,846	$31,236	$28,805	$30,342	$40,316	$43,636
Appalachian Regional Commission	--	--	--	--	189	179
Department of Agriculture	290	310	268	273	356	891
Department of Commerce	--	233	85	73	[1]	154
Department of Defense	6,303	7,863	9,123	8,443	13,351	11,247
Department of Housing and Urban Development	182	713	1,202	2,095	3,581	3,069
Department of the Interior	3,584	3,408	1,714	2,208	2,312	9,361
Bonneville Power Administration	--	--	101	118	136	105
Bureau of Commercial Fisheries	4	--	--	--	--	--
Bureau of Indian Affairs	--	--	--	149	340	697
Bureau of Land Management	120	166	205	207	251	5,114
Bureau of Mines	--	--	80	--	--	1,735
Bureau of Reclamation	2,517	2,358	656	855	676	721
Bureau of Sports Fisheries	4	12	11	--	--	--
Fish and Wildlife Service	--	--	101	256	380	372
National Park Service	414	647	508	459	529	617
Office of Saline Water	--	--	31	156	--	--
Office of the Secretary	117	--	--	--	--	--
Office of Territories	408	225	21	8	--	--
Department of State	2,271	2,697	2,789	2,756	2,177	1,698
Department of Transportation	--	--	--	--	--	4
Energy Research and Development Administration [2]	3,400	3,072	3,112	3,011	4,029	3,501
Environmental Protection Agency	570	579	627	916	1,127	1,389
Federal Energy Administration	--	--	--	--	--	353
National Aeronautics and Space Administration	7,347	7,029	6,017	6,507	5,672	3,449
National Oceanic and Atmospheric Administration	--	--	--	--	2,001	434
National Science Foundation	483	1,279	906	333	1,375	1,928
Nuclear Regulatory Commission	--	--	--	--	--	1,195
Ozark Regional Commission	--	--	--	--	60	49
Tennessee Valley Authority	160	204	198	255	212	252
Miscellaneous Federal agencies	1,095	855	766	944	1,168	1,686
Miscellaneous services to other accounts	2,161	2,994	1,998	2,528	2,706	2,797

[1] Included in miscellaneous Federal agencies.
[2] Includes Atomic Energy Commission funds for fiscal years 1970–74. See also funds from the Nuclear Regulatory Commission in fiscal year 1975.

TABLE 29.—*Alaska Pipeline Related Investigations, reimbursable program funds from other Federal agencies, by agency, fiscal years 1970–75*

[In thousands of dollars]

Agency	1970	1971	1972	1973	1974	1975
Total	$30	$65	$62	--	--	--
Department of the Interior	$30	$65	$65	--	--	--
Bureau of Commercial Fisheries	4	--	--	--	--	--
Bureau of Land Management	22	53	51	--	--	--
Bureau of Sports Fisheries	4	12	11	--	--	--

TABLE 30.—*Topographic Surveys and Mapping direct program funds, by subactivity, fiscal years 1970–75*

[In thousands of dollars]

Subactivity	1970	1971	1972	1973	1974	1975
CURRENT DOLLARS						
Total direct program	$28,493	$31,153	$34,545	$35,172	$37,161	$45,350
Quadrangle Mapping and Revision [1]	26,219	29,090	32,710	33,433	35,046	41,148
Small Scale and Special Mapping	2,274	2,063	1,835	1,739	2,115	2,661
National Cartographic Information Center [2]	--	(150)	(300)	(675)	(1,043)	1,541
CONSTANT 1967 DOLLARS [3]						
Total direct program	25,016	26,004	27,814	27,265	26,658	29,353
Quadrangle Mapping and Revision [1]	23,019	24,282	26,337	25,917	25,141	26,633
Small Scale and Special Mapping	1,997	1,722	1,477	1,348	1,517	1,722
National Cartographic Information Center [2]	--	(125)	(242)	(523)	(748)	998

[1] Funds are reconstructed for fiscal years 1970–72 and include the Map Revision and Maintenance subactivity.
[2] National Cartographic Information Center funds included in the Quadrangle Mapping and Revision subactivity prior to fiscal year 1975.
[3] Gross National Product implicit price deflator was used to convert current to constant 1967 dollars.

TABLE 31.—*Topographic Surveys and Mapping Federal-State Cooperative program funds, by State, fiscal years 1970–75*

[In thousands of dollars]

State	1970	1971	1972	1973	1974	1975
Total [1]	$9,052	$7,802	$6,408	$7,438	$9,884	$9,990
Total State share [2]	4,526	3,901	3,204	3,719	4,942	4,995
Alabama	56	50	50	50	40	62
State share	28	25	25	25	20	31
Arkansas	40	50	46	54	58	72
State share	20	25	23	27	29	36
California	554	432	186	186	198	252
State share	277	216	93	93	99	126
Colorado	--	--	--	--	4	830
State share	--	--	--	--	2	415
Connecticut	56	40	40	40	120	124
State share	28	20	20	20	60	62
Florida	988	580	580	572	578	454
State share	494	290	290	286	289	227
Georgia	16	40	56	1,218	2,294	1,992
State share	8	20	28	609	1,147	996
Illinois	100	168	150	120	30	70
State share	50	84	75	60	15	35
Indiana	138	136	136	134	136	136
State share	69	68	68	67	68	68
Iowa	46	44	--	--	--	--
State share	23	22	--	--	--	--
Kansas	268	266	266	248	286	268
State share	134	133	133	124	143	134
Kentucky	178	200	210	182	278	254
State share	89	100	105	91	139	127
Louisiana	62	60	60	50	152	120
State share	31	30	30	25	76	60
Maine	40	40	40	40	40	40
State share	20	20	20	20	20	20
Maryland	--	--	20	22	20	20
State share	--	--	10	11	10	10

See footnotes at end of table.

TABLE 31.—*Topographic Surveys and Mapping Federal-State Cooperative program funds, by State, fiscal years 1970–75*—Continued

[In thousands of dollars]

State	1970	1971	1972	1973	1974	1975
Massachusetts	150	200	200	196	190	250
State share	75	100	100	98	95	125
Michigan	306	100	100	100	100	100
State share	153	50	50	50	50	50
Minnesota	856	884	734	708	1,092	840
State share	428	442	367	354	546	420
Missouri	242	226	184	130	134	134
State share	121	113	92	65	67	67
Nevada	34	36	40	40	58	54
State share	17	18	20	20	29	27
New Mexico	--	--	--	--	--	16
State share	--	--	--	--	--	8
New York	338	272	380	234	366	226
State share	169	136	190	117	183	113
North Carolina	216	220	220	172	670	890
State share	108	110	110	86	335	445
North Dakota	156	100	112	242	88	222
State share	78	50	56	121	44	111
Ohio	150	150	150	150	150	150
State share	75	75	75	75	75	75
Oklahoma	152	166	126	112	110	110
State share	76	83	63	56	55	55
Oregon	60	60	60	78	44	92
State share	30	30	30	39	22	46
Pennsylvania	904	700	550	326	392	312
State share	452	350	275	163	196	156
South Carolina	--	--	--	120	--	36
State share	--	--	--	60	--	18
South Dakota	34	38	50	50	50	50
State share	17	19	25	25	25	25
Tennessee	40	42	12	38	50	44
State share	20	21	6	19	25	22
Texas	864	1,162	694	742	726	686
State share	432	581	347	371	363	343
Utah	96	104	72	114	120	100
State share	48	52	36	57	60	50
Vermont	20	20	20	20	40	34
State share	10	10	10	10	20	17
Virginia	1,160	510	166	132	232	218
State share	580	255	83	66	116	109
Washington	50	50	32	32	34	6
State share	25	25	16	16	17	3
West Virginia	220	198	206	298	506	228
State share	110	99	103	149	253	114
Wisconsin	402	398	400	402	412	414
State share	201	199	200	201	206	207
Wyoming	10	10	10	10	10	10
State share	5	5	5	5	5	5
Puerto Rico	50	50	50	76	76	74
State share	25	25	25	38	38	37

[1] Includes Federal funds from direct program.
[2] Reimbursable program funds from States, counties, and municipalities.

TABLE 32.—*Topographic Surveys and Mapping reimbursable program funds from other Federal agencies, by agency, fiscal years 1970–75*

[In thousands of dollars]

Agency	1970	1971	1972	1973	1974	1975
Total	$2,390	$2,017	$631	$780	$918	$1,658
Department of Agriculture	--	--	--	--	95	326
Department of Commerce	--	181	--	--	--	--
Department of Defense	--	--	--	35	92	183
Department of the Interior	1,497	1,125	21	68	238	441
Bureau of Indian Affairs	--	--	--	60	165	198
Bureau of Land Management	--	--	--	--	73	243
Bureau of Reclaimation	1,089	900	--	--	--	--
Office of Territories	408	225	21	8	--	--
Department of Transportation	--	--	--	--	--	4
National Aeronautics and Space Administration	246	326	138	207	235	97
National Science Foundation	356	202	256	198	46	257
Miscellaneous Federal agencies	291	183	216	272	212	350

TABLE 33.—*Geologic and Mineral Resource Surveys and Mapping direct program funds, by subactivity, fiscal years 1970–75*

[In thousands of dollars]

Subactivity	1970	1971	1972	1973	1974	1975
CURRENT DOLLARS						
Total direct program	$31,056	$31,919	$34,244	$42,895	$49,877	$89,018
Land Resource Surveys [1]	13,675	14,519	15,154	19,246	23,077	33,385
Mineral Resource Surveys [2]	13,548	13,424	13,524	14,026	14,971	18,017
Energy Resource Surveys	2,578	2,639	3,144	5,197	6,696	22,376
Offshore Geologic Surveys	1,255	1,337	2,422	4,426	5,133	15,240
CONSTANT DOLLARS [3]						
Total direct program	27,266	26,643	27,572	33,252	35,780	57,617
Land Resource Surveys [1]	12,006	12,119	12,201	14,919	16,555	21,608
Mineral Resource Surveys [2]	11,895	11,205	10,889	10,873	10,740	11,662
Energy Resource Surveys	2,263	2,203	2,532	4,029	4,803	14,483
Offshore Geologic Surveys	1,102	1,116	1,950	3,431	3,682	9,864

[1] Funds adjusted for fiscal years 1970–73 to include geologic mapping in support of Mineral Resource Surveys.
[2] Funds adjusted for fiscal years 1970–73 to exclude geologic mapping and to include the Mineral Discovery Loan Program activity for fiscal years 1970–73.
[3] Gross National Product implicit price deflator was used to convert current to constant 1967 dollars.

TABLE 34.—*Geologic and Mineral Resource Surveys and Mapping Federal-State Cooperative funds, by State, fiscal years 1970–75*

[In thousands of dollars]

State	1970	1971	1972	1973	1974	1975
Total [1]	$2,766	$2,825	$2,941	$4,270	$4,254	$4,541
State share [2]	1,292	1,322	1,359	1,556	1,681	1,550
Alabama	--	--	--	10	10	15
State share	--	--	--	10	5	5
Alaska	--	--	160	332	238	476
State share	--	--	80	135	93	75
Arkansas	51	50	51	85	125	165
State share	25	25	25	36	27	27
California	86	127	71	79	362	57
State share	39	63	33	22	80	21
Colorado	101	74	42	50	--	--
State share	45	41	20	30	--	--
Connecticut	162	150	141	235	208	258
State share	75	75	69	69	75	75
Georgia	--	--	2	--	6	10
State share	--	--	1	--	3	5
Hawaii	--	--	--	--	--	--
State share	--	--	--	--	--	--
Idaho	23	--	--	--	--	--
State share	12	--	--	--	--	--
Iowa	--	--	--	--	16	--
State share	--	--	--	--	8	--
Kansas	--	--	--	--	--	--
State share	--	--	--	--	--	--
Kentucky	1,048	1,100	1,158	1,332	1,454	1,599
State share	510	550	575	600	630	675
Maryland	58	45	20	27	14	19
State share	28	23	10	10	7	9
Massachusetts	355	410	417	633	563	581
State share	164	205	205	205	228	205
Michigan	150	166	153	216	178	158
State share	65	68	65	65	65	65
Minnesota	--	--	--	--	--	--
State share	--	--	--	--	--	--
Nevada	158	173	192	249	254	384
State share	70	70	80	90	90	105
New Hampshire	26	24	25	31	59	50
State share	13	12	13	13	39	13
New Mexico	--	--	--	20	40	11
State share	--	--	--	10	20	--
New York	--	--	--	--	20	21
State share	--	--	--	--	10	10
North Carolina	25	51	35	99	40	18
State share	6	6	6	12	6	18
Pennsylvania	93	19	15	30	10	--
State share	30	8	8	15	5	--
South Carolina	--	--	--	--	--	5
State share	--	--	--	--	--	5
Texas	--	--	--	3	--	--
State share	--	--	--	3	--	--
Utah	--	--	11	18	7	6
State share	--	--	3	7	7	4
Washington	58	53	58	122	67	134
State share	25	25	20	30	20	30
West Virginia	--	--	--	20	20	21
State share	--	--	--	10	10	10
Wisconsin	48	50	55	82	76	68
State share	17	8	8	8	8	8
Wyoming	29	48	15	27	26	11
State share	2	4	2	2	2	2
Puerto Rico	295	270	320	570	461	474
State share	166	131	136	174	243	183
Virgin Islands	--	15	--	--	--	--
State share	--	8	--	--	--	--

[1] Includes Federal funds from direct program.
[2] Reimbursable program funds from States, counties, and municipalities.

TABLE 35.—*Geologic and Mineral Resource Surveys and Mapping reimbursable program funds from other Federal agencies, by agency, fiscal years 1970–75*

[In thousands of dollars]

Agency	1970	1971	1972	1973	1974	1975
Total	$12,188	$13,494	$13,609	$11,222	$19,321	$20,158
Appalachian Regional Commission	--	--	--	--	189	179
Department of Defense	2,344	3,179	3,219	1,431	5,670	2,648
Department of Housing and Urban Development	--	--	281	294	224	817
Department of the Interior	--	--	134	156	--	5,719
Bureau of Indian Affairs	--	--	--	--	--	243
Bureau of Land Management	--	--	--	--	--	3,741
Bureau of Mines	--	--	80	--	--	1,735
Bureau of Reclamation	--	--	23	--	--	--
Office of Saline Water	--	--	31	156	--	--
Department of State	1,555	1,711	1,987	1,975	1,510	1,056
Energy Research and Development Administration [1]	1,945	1,858	2,090	2,134	3,125	2,542
Federal Energy Administration	--	--	--	--	--	353
National Aeronautics and Space Administration	5,924	5,454	5,038	4,708	4,745	2,938
National Oceanic and Atmospheric Administration	--	--	--	--	2,001	434
National Science Foundation	127	1,077	650	135	1,329	1,604
Nuclear Regulatory Commission	--	--	--	--	--	1,195
Miscellaneous Federal agencies	293	215	210	389	528	673

[1] Includes Atomic Energy Commission funds for fiscal years 1970–74. See also funds from the Nuclear Regulatory Commission in fiscal year 1975.

TABLE 36.—*Water Resources Investigations direct program funds, by subactivity, fiscal years 1970–75*

[In thousands of dollars]

Subactivity	1970	1971	1972	1973	1974	1975
CURRENT DOLLARS						
Total direct program [1]	$31,585	$34,581	$37,446	$40,185	$45,433	$53,420
National Water Data System	29,876	32,360	34,849	37,523	42,993	48,191
Federal program	12,575	13,177	14,841	16,334	17,695	21,183
Federal-State program [2]	17,301	19,183	20,008	21,189	25,298	27,008
Critical National water problems	1,709	2,221	2,597	2,662	2,440	5,229
CONSTANT 1967 DOLLARS [3]						
Total direct program [1]	27,731	28,866	30,150	31,151	32,592	34,576
National Water Data System	26,230	27,012	28,059	29,088	30,842	31,192
Federal program	11,040	10,999	11,949	12,662	12,694	13,711
Federal-State program [2]	15,190	16,013	16,110	16,426	18,148	17,481
Critical National water problems	1,501	1,854	2,091	2,063	1,750	3,384

[1] Direct program funds exclude the Employee Compensation Payments subactivity for fiscal years 1970–75.
[2] Federal share of Federal-State cooperative program.
[3] Gross National Product implicit price deflator was used to convert current to constant 1967 dollars.

TABLE 37.—*Water Resources Investigations Federal-State Cooperative program funds, by State, fiscal years 1970–75*

[In thousands of dollars]

State	1970	1971	1972	1973	1974	1975
Total [1]	$34,581	$38,647	$41,302	$43,925	$51,118	$55,554
State share [2]	17,280	19,464	21,294	22,736	25,820	28,546
Alabama	770	796	789	868	1,044	1,135
State share	407	442	436	479	529	587
Alaska	417	411	459	506	659	686
State share	258	203	250	264	317	335
Arizona	819	869	1,021	1,001	1,144	1,248
State share	412	444	540	510	576	646
Arkansas	373	392	409	457	674	650
State share	177	189	202	225	399	347
California	2,834	3,455	3,636	3,850	4,229	4,381
State share	1,361	1,672	1,810	1,938	2,101	2,190
Colorado	850	870	953	1,078	1,480	1,615
State share	419	436	487	545	835	909
Connecticut	367	429	436	412	486	687
State share	174	207	215	203	239	386
Delaware	88	112	111	121	130	194
State share	52	73	75	81	74	106
District of Columbia	12	12	2	3	3	3
State share	6	6	1	1	1	1
Florida	1,971	2,539	2,818	3,071	4,505	5,055
State share	962	1,249	1,429	1,572	2,263	2,521
Georgia	636	711	741	790	939	1,081
State share	346	380	408	432	461	530
Hawaii	598	649	622	653	691	697
State share	284	334	314	337	339	341
Idaho	523	633	619	675	718	749
State share	249	308	307	344	353	366
Illinois	449	482	503	526	514	575
State share	213	232	266	273	262	288
Indiana	757	770	858	973	1,227	1,152
State share	359	371	423	523	610	564
Iowa	411	398	517	525	592	617
State share	195	192	255	259	291	302
Kansas	1,018	1,058	1,096	1,110	1,116	1,156
State share	485	512	542	552	543	582
Kentucky	512	600	665	698	719	875
State share	243	289	328	348	353	427
Louisiana	1,009	1,107	1,152	1,190	1,748	1,620
State share	536	591	625	649	904	842
Maine	111	118	123	128	135	208
State share	60	64	69	71	76	107
Maryland	536	535	580	646	817	972
State share	268	272	301	335	418	511
Massachusetts	441	516	542	550	593	787
State share	224	290	309	322	333	480
Michigan	537	599	606	631	652	796
State share	255	289	302	310	321	390
Minnesota	513	550	635	712	811	799
State share	245	265	314	373	420	397
Mississippi	444	551	592	593	645	743
State share	275	316	357	340	325	415
Missouri	534	637	608	602	523	544
State share	253	307	321	310	255	270
Montana	318	393	401	402	505	587
State share	172	212	221	223	255	287
Nebraska	440	502	553	588	705	731
State share	211	246	274	298	344	358

See footnotes at end of table.

TABLE 37.—*Water Resources Investigations Federal-State Cooperative program funds, by State, fiscal years 1970–75*—Continued

[In thousands of dollars]

State	1970	1971	1972	1973	1974	1975
Nevada	290	304	346	351	377	408
State share	138	146	171	178	185	200
New Hampshire	90	89	75	108	118	122
State share	43	43	37	54	58	60
New Jersey	735	785	822	856	1,051	977
State share	363	390	418	433	530	501
New Mexico	842	888	963	1,087	1,292	1,412
State share	432	462	509	591	642	706
New York	1,462	1,717	1,844	2,161	2,410	2,730
State share	697	837	921	1,112	1,222	1,462
North Carolina	642	667	691	767	876	977
State share	305	321	341	394	430	479
North Dakota	533	561	602	657	675	776
State share	259	275	305	340	325	378
Ohio	762	829	840	878	828	943
State share	411	446	443	445	406	488
Oklahoma	427	498	488	522	592	638
State share	236	276	270	284	289	313
Oregon	565	546	667	750	852	810
State share	282	277	342	393	417	397
Pennsylvania	1,325	1,459	1,602	1,691	1,955	2,103
State share	682	730	809	864	994	1,053
Rhode Island	91	97	92	90	97	110
State share	48	52	50	50	52	54
South Carolina	340	374	403	454	546	533
State share	178	196	212	241	279	261
South Dakota	365	371	374	373	421	465
State share	202	207	211	205	202	226
Tennessee	495	504	526	551	801	908
State share	264	271	288	302	397	448
Texas	2,239	2,673	3,023	3,049	3,320	3,575
State share	1,113	1,341	1,578	1,575	1,664	1,757
Utah	756	764	884	937	941	1,255
State share	359	369	447	466	467	784
Vermont	101	104	105	109	104	96
State share	62	52	54	56	53	47
Virginia	515	609	631	661	673	640
State share	270	322	337	355	350	333
Washington	1,578	1,671	1,710	1,834	2,020	2,068
State share	751	806	845	916	1,000	1,071
West Virginia	166	259	276	302	420	526
State share	103	150	160	173	258	324
Wisconsin	712	781	830	870	1,075	1,224
State share	338	377	411	429	561	668
Wyoming	549	568	564	575	662	832
State share	290	306	309	303	321	507
American Samoa	42	65	72	64	63	70
State share	20	32	36	32	31	32
Guam	21	25	36	43	62	65
State share	10	12	18	21	31	32
Puerto Rico	557	644	672	701	766	745
State share	279	328	333	345	401	365
Trust Territories	74	93	105	125	117	170
State share	35	45	52	62	58	84
Virgin Islands	19	8	12	[3]	[3]	33
State share	9	4	6	--	--	31

[1] Includes Federal funds from direct program.
[2] Reimbursable program funds from States, counties, and municipalities.
[3] Included with Puerto Rico funds.

TABLE 38.—*Water Resources Investigations reimbursable program funds from other Federal agencies, by agency, fiscal years 1970–75*

[In thousands of dollars]

Agency	1970	1971	1972	1973	1974	1975
Total	$10,183	$11,468	$11,905	$14,518	$16,378	$18,570
Department of Agriculture	290	310	268	273	261	565
Department of Commerce	--	52	85	73	[1]	154
Department of Defense	3,934	4,659	5,879	6,953	7,554	8,391
Department of Housing and Urban Development	--	358	921	1,801	3,018	2,252
Department of the Interior	2,057	2,218	1,497	1,984	2,026	3,190
Bonneville Power Administration	--	--	101	118	101	105
Bureau of Indian Affairs	--	--	--	89	175	256
Bureau of Land Management	98	113	154	207	178	1,130
Bureau of Reclamation	1,428	1,458	633	855	676	721
Fish and Wildlife Service	--	--	101	256	367	361
National Park Service	414	647	508	459	529	617
Office of the Secretary	117	--	--	--	--	--
Department of State	716	986	802	781	667	642
Energy Research and Development Administration [2]	1,455	1,214	1,022	877	904	959
Environmental Protection Agency	570	579	627	916	1,127	1,389
National Aeronautics and Space Administration	493	438	266	343	284	235
National Science Foundation	--	--	--	--	--	67
Tennessee Valley Authority	160	204	198	255	212	252
Miscellaneous Federal agencies	508	450	340	262	325	474

[1] Included with miscellaneous Federal agencies funds.
[2] Includes Atomic Energy Commission funds for fiscal years 1970–74.

TABLE 39.—*Conservation of Lands and Minerals direct program funds, by subactivity, fiscal years 1970–75*

[In thousands of dollars]

Subactivity	1970	1971	1972	1973	1974	1975
	CURRENT DOLLARS					
Total direct program	$7,497	$9,670	$13,441	$14,700	$18,172	$36,032
Outer Continental Shelf Lands	2,594	4,234	7,626	8,114	10,957	23,196
Regulation of OCS Oil and Gas Operations	1,599	3,104	4,935	5,398	6,342	10,051
OCS Oil and Gas Tract Selection and Resource Evaluation	995	1,130	2,691	2,716	4,615	13,145
Federal and Indian Lands	4,903	5,436	5,815	6,586	7,215	12,836
Regulation of Operations on Leases	3,875	4,353	4,574	5,127	5,552	8,428
Oil and Gas	2,835	3,185	3,336	3,739	3,941	5,262
Energy Minerals (Coal and Uranium)	545	612	332	373	393	508
Oil Shale	--	--	--	--	--	315
Geothermal	--	--	--	--	148	1,012
Non-energy Minerals	495	556	906	1,015	1,070	1,331
Resource Classification and Evaluation	1,028	1,083	1,241	1,459	1,663	4,408
Oil and Gas	301	319	156	150	202	223
Coal	91	97	640	618	832	2,380
Oil Shale	--	--	--	--	--	295
Geothermal	--	--	48	281	138	961
Non-energy Minerals	294	312	55	53	71	81
Water Resources Development	342	355	342	357	420	468

TABLE 39.—*Conservation of Lands and Minerals direct program funds, by subactivity, fiscal years 1970–75*—Continued

Subactivity	1970	1971	1972	1973	1974	1975
CONSTANT 1967 DOLLARS [1]						
Total direct program	6,582	8,072	10,822	11,395	13,036	23,322
Outer Continental Shelf Lands	2,278	3,534	6,140	6,290	7,860	15,014
Regulation of OCS Oil and Gas Operations	1,404	2,591	3,973	4,185	4,549	6,506
Research on OCS Operational Safety Devices	--	--	--	--	--	--
OCS Oil and Gas Tract Selection and Resource Evaluation	874	943	2,167	2,105	3,311	8,508
Federal and Indian Lands	4,304	4,538	4,682	5,105	5,176	8,308
Regulation of Operations on Leases	3,402	3,634	3,683	3,974	3,983	5,455
Oil and Gas	2,489	2,659	2,686	2,898	2,827	3,406
Energy Minerals	478	511	267	289	282	329
Oil Shale	--	--	--	--	--	204
Geothermal	--	--	--	--	106	655
Non-energy Minerals	435	464	730	787	768	861
Resource Classification and Evaluation	902	904	999	1,131	1,193	2,853
Oil and Gas	264	266	126	116	145	144
Coal	80	81	515	479	597	1,541
Oil Shale	--	--	--	--	--	191
Geothermal	--	--	39	218	99	622
Non-energy Minerals	258	261	44	41	51	52
Water Resources Development	300	296	275	277	301	303

[1] Gross National Product implicit price deflator was used to convert current to constant 1967 dollars.

TABLE 40.—*Conservation of Lands and Minerals reimbursable program funds from other Federal agencies, fiscal years 1970–75*

[In thousands of dollars]

Agency	1970	1971	1972	1973	1974	1975
Total	$28	$32	$25	$45	$41	$46
Department of Defense	25	25	25	24	25	25
Miscellaneous Federal agencies	3	7	--	21	16	21

TABLE 41.—*Land Information and Analysis direct program funds, by subactivity, fiscal years 1970–75*

[In thousands of dollars]

Subactivity [1]	1970	1971	1972	1973	1974	1975
CURRENT DOLLARS						
Total direct program	$1,101	$2,373	$6,714	$11,876	$11,458	$15,461
Earth Sciences Applications	--	452	970	1,519	1,580	1,600
(Urban Area Studies) [2]	--	(452)	(970)	(987)	(1,020)	(1,020)
(Land Resource Surveys—Land Resource Analysis) [3]	--	--	--	(532)	(560)	(580)
Resource and Land Investigations [4]	--	--	--	--	916	959
Geography	--	--	--	--	--	2,013
(Land Use and Data Analysis) [5]	--	--	--	--	--	(2,013)
Earth Resources Observation Systems [6]	1,101	1,921	5,744	10,357	8,962	8,284
Environmental Impact Analysis [7]	--	--	--	--	--	2,605
(Energy Impact Evaluation)	--	--	--	--	--	(2,605)
CONSTANT 1967 DOLLARS						
Total direct program	967	1,981	5,406	9,206	8,220	10,007
Earth Sciences Applications	--	377	781	1,177	1,134	1,035
(Urban Area Studies) [2]	--	(377)	(781)	(765)	(732)	(660)
(Land Resource Surveys—Land Resource Analysis) [3]	--	--	--	(412)	(402)	(375)

See footnotes at end of table.

TABLE 41.—*Land Information and Analysis direct program funds, by subactivity, fiscal years 1970–75*—Continued

Subactivity [1]	1970	1971	1972	1973	1974	1975
CONSTANT 1967 DOLLARS [8]—Continued						
Resource and Land Investigations [4]	--	--	--	--	657	621
Geography	--	--	--	--	--	1,303
(Land Use and Data Analysis) [5]	--	--	--	--	--	(1,303)
Earth Resources Observation Systems [6]	967	1,604	4,625	8,029	6,429	5,362
Environmental Impact Analysis	--	--	--	--	--	1,686
(Energy Impact Evaluation) [7]	--	--	--	--	--	(1,686)

[1] All subactivities reconstructed through fiscal year 1975.
[2] Urban Area Studies, a subactivity of the Special Resource and Environmental Projects, began in fiscal year 1971.
[3] Land Resource Analysis program, a component of the Land Resource Surveys subactivity of Geologic and Mineral Resource Surveys and Mapping, began in fiscal year 1973.
[4] Resource and Land Investigations program was a separate budget activity in fiscal years 1974–75.
[5] Land Use and Data Analysis was a separate budget activity in fiscal year 1975.
[6] Earth Resources Observation Systems was a separate budget activity in fiscal years 1970–75.
[7] Energy Impact Evaluation was a subactivity of Special Resource and Environmental Projects activity during fiscal year 1975.
[8] Gross National Product implicit price deflator was used to convert current to constant 1967 dollars.

TABLE 42.—*Land Information and Analysis reimbursable program funds from other Federal agencies, by agency, fiscal years 1970–75*

[In thousands of dollars]

Agency	1970	1971	1972	1973	1974	1975
Total	$866	$1,166	$575	$1,249	$952	$407
Department of Defense	--	--	--	--	10	--
Department of Housing and Urban Development	182	355	--	--	339	--
Department of the Interior	--	--	--	--	48	11
Bonneville Power Administration	--	--	--	--	35	--
Fish and Wildlife Service	--	--	--	--	13	11
National Aeronautics and Space Administration	684	811	575	1,249	408	179
Ozark Regional Commission	--	--	--	--	60	49
Miscellaneous Federal agencies	--	--	--	--	87	168

TABLE 43.—*Program support funds, by activity, fiscal years 1970–75*

[In thousands of dollars]

Program support activity	1970	1971	1972	1973	1974	1975
CURRENT DOLLARS						
General Administrative Expenses [1]	$4,622	$5,335	$6,422	$7,173	$8,197	$10,806
General Administration [2]	2,867	3,048	3,187	3,217	3,517	3,671
Direct program assessments [3]	500	962	1,669	2,352	2,770	5,126
Reimbursable program assessments [4]	1,255	1,325	1,566	1,604	1,910	2,009
Electronic data processing and related services [5]	4,931	5,582	4,862	6,168	6,987	8,425
Funded by Survey programs [6]	3,239	3,068	3,351	4,177	4,828	6,129
Funded by miscellaneous accounts [7]	1,692	2,514	1,511	1,991	2,159	2,296
Publication services [8]	8,713	9,615	10,667	11,656	11,932	13,004
Funded by Survey programs [6]	8,370	9,248	10,297	11,147	11,432	12,488
Funded by miscellaneous accounts [7]	343	367	370	509	500	516
CONSTANT 1967 DOLLARS						
General Administrative Expenses [1]	4,058	4,453	5,171	5,560	5,880	6,994
General Administration [2]	2,517	2,544	2,566	2,494	2,523	2,376
Direct program assessments [3]	439	803	1,344	1,823	1,987	3,318
Reimbursable program assessments [4]	1,102	1,106	1,261	1,243	1,370	1,300
Electronic Data processing and related services [5]	4,566	4,659	3,915	4,781	5,012	5,453
Funded by Survey programs [6]	2,999	2,561	2,698	3,238	3,463	3,967
Funded by miscellaneous accounts [7]	1,567	2,098	1,217	1,543	1,549	1,486

See footnotes at end of table.

TABLE 43.—*Program support funds, by activity, fiscal years 1970–75*—Continued

Program support activity	1970	1971	1972	1973	1974	1975
CONSTANT 1967 DOLLARS [9]—Continued						
Publication services [8]	7,650	8,026	8,588	9,036	8,560	8,417
Funded by Survey programs [6]	7,349	7,720	8,291	8,641	8,201	8,083
Funded by miscellaneous accounts [7]	301	306	297	395	359	334
Ratio of General Administrative expenses to total bureau funds (percent)	2.9	3.1	3.4	3.4	3.3	3.2

[1] Obligations of the Director's Office for executive direction and of the Adminis.rative Division for management services.
[2] Direct program funds of the General Administration budget activity. Obligations reconstructed for fiscal years 1970–75 to include Employee Compensation Payments.
[3] Assessments made on direct program funds of other budget activities.
[4] Assessments made on reimbursable program funds of other budget activities. No assessments are made on cooperative funds from State and local governments.
[5] Obligations of the Computer Center Division.
[6] Obligations charged to Survey program activities.
[7] Obligations charged to the Miscellaneous Services to Other Accounts activity for reimbursable work done for other agencies.
[8] Obligations of the Publications Division.
[9] Gross National Product implicit price deflator was used to convert current to constant 1967 dollars.

TABLE 44.—*Geological Survey end-of-year employment, by organizational unit, fiscal years 1970–75*

Organizational unit	1970	1971	1972	1973	1974	1975
Total	9,134	9,192	9,224	9,387	9,921	10,435
Permanent employment	8,098	8,173	8,002	8,089	8,357	8,999
Other than permanent employment	1,036	1,019	1,222	1,298	1,564	1,436
Topographic Division	2,132	2,079	2,045	2,020	1,956	1,877
Permanent employment	1,936	1,893	1,828	1,758	1,762	1,719
Other than permanent employment	196	186	217	262	194	158
Geologic Division	2,058	2,048	2,060	2,147	2,406	2,572
Permanent employment	1,783	1,765	1,706	1,766	1,888	2,135
Other than permanent employment	275	283	354	381	518	437
Water Resources Division	3,364	3,427	3,409	3,419	3,611	3,610
Permanent employment	2,886	2,965	2,876	2,900	2,910	2,957
Other than permanent employment	478	462	533	519	701	653
Conservation Division	479	492	549	568	647	990
Permanent employment	461	475	529	547	612	926
Other than permanent employment	18	17	20	21	35	64
Land Information and Analysis Office	--	--	51	72	85	114
Permanent employment	--	--	39	52	68	89
Other than permanent employment	--	--	12	20	17	25
Director's Office [1]	77	94	64	57	64	66
Permanent employment	67	79	51	55	62	57
Other than permanent employment	10	15	13	2	2	9
Administrative Division	351	362	360	382	408	441
Permanent employment	328	336	326	341	366	398
Other than permanent employment	23	26	34	41	42	43
Facilities [2]	--	--	--	--	15	30
Permanent employment	--	--	--	--	15	30
Other than permanent employment	--	--	--	--	--	--
Computer Center Division	157	153	170	174	182	198
Permanent employment	134	142	150	153	159	178
Other than permanent employment	23	11	20	21	23	20
Publications Division	516	537	516	548	547	537
Permanent employment	503	518	497	517	515	510
Other than permanent employment	13	19	19	31	32	27

[1] Includes Land Information and Analysis Office personnel for fiscal years 1970–71.
[2] Administrative Division personnel assigned to the operation of the Survey's Headquarter facilities.

TABLE 45.—*Number of Geological Survey reports approved for publication, by organizational unit, fiscal years 1970–75*

Organizational Unit	1970	1971	1972	1973	1974	1975
Total	2,292	2,320	2,351	2,548	2,755	2,888
Book reports [1]	217	183	163	147	155	144
Journal of Research articles [2]	133	126	106	107	90	85
Open file reports	386	399	447	380	440	570
Basic data reports	110	131	196	255	230	256
Outside publications	1,446	1,481	1,439	1,659	1,840	1,833
Topographic Division	45	53	42	53	53	33
Book reports	--	--	--	--	--	--
Journal of Research articles	2	--	--	2	1	--
Open file reports	3	--	--	--	--	--
Outside publications	40	53	42	51	52	33
Geologic Division	1,328	1,311	1,329	1,419	1,546	1,811
Book reports	109	93	102	91	96	90
Journal of Research articles	94	90	78	79	69	70
Open file reports	205	189	258	216	245	379
Outside publications	920	939	891	1,033	1,136	1,272
Water Resources Division	850	865	875	953	1,002	926
Book reports	100	88	59	54	56	50
Journal of Research articles	37	36	28	26	20	15
Open file reports	158	200	180	149	181	152
Basic data reports	110	131	196	255	230	256
Outside publications	445	410	412	369	515	453
Conservation Division	12	11	15	17	18	44
Book reports	7	--	1	--	2	1
Open file reports	3	5	8	13	11	32
Outside publications	2	6	6	4	5	11
Director's Office [3]	57	80	90	106	136	74
Book reports	1	2	1	2	1	3
Open file reports	17	5	1	2	3	7
Outside publications	39	73	88	102	132	64

[1] Book reports include U.S. Geological Survey Professional Papers, Bulletins, Water-Supply Papers, Circulars, and other report series.
[2] Before January 1973 articles were published as part of the annual "Geological Survey Research" Professional Paper.
[3] Includes reports of the Land Information and Analysis Office, Administrative Division, Computer Center Division, and Publications Division.

TABLE 46.—*Number of maps produced by the Geological Survey, by organizational unit, fiscal years 1970–75*

Organizational Unit	1970	1971	1972	1973	1974	1975
Total [1]	4,243	4,553	6,094	10,304	7,361	8,713
Topographic Division	3,174	3,541	4,817	5,313	4,938	7,279
Quadrangle maps	2,984	3,346	4,641	5,117	4,780	7,087
New standard quadrangles	1,620	1,692	2,544	2,347	2,052	2,016
Orthophotoquads	--	--	--	49	15	2,869
Revisions	719	953	1,223	1,118	966	923
Reprints	645	701	874	1,603	1,747	1,279
Small scale and special maps	132	135	112	148	121	162
1:250,000 series	9	19	26	57	50	52
Antarctica	4	10	--	5	--	4
State bases	3	6	8	2	--	2
Other	12	13	20	25	8	24
Reprints	104	87	58	59	63	80
Topographic map indexes	58	60	64	48	37	30
Geologic Division [2]	226	119	315	320	215	229
Water Resources Division	841	876	952	4,650	2,192	1,198
Hydrologic maps	39	49	47	84	52	58
Flood prone area maps	802	827	905	4,566	2,140	1,140
Conservation Division [3]	2	17	10	8	9	5
Director's Office [3]	--	--	--	13	7	2

[1] Additional maps are produced for inclusion in book reports.
[2] Geologic and geophysical maps.
[3] Miscellaneous maps and charts.

TABLE 47.—*Oil and gas operations on Outer Contental Shelf lands, calendar years 1970–75*

Activity	1970	1971	1972	1973	1974	1975 (estimated)
Number of exploration permits issued	253	254	254	350	400	519
Lease sales:						
Number of sales	2	1	2	6	5	4
Tracts offered:						
Number	161	18	210	276	1,006	1,374
Area (acres in thousands)	667	56	971	1,515	5,006	7,248
Tracts sold:						
Number	138	11	178	187	356	321
Area (acres in thousands)	599	37	826	1,033	1,762	1,680
Percentage of tracts sold	85.7	61.1	84.8	67.8	35.4	23.4
Bonus (dollars in thousands)	$945,065	$96,304	$2,251,348	$3,082,463	$5,022,861	$1,088,133
Status of leases:						
Total number of leases supervised	1,017	1,083	1,023	1,266	1,590	1,784
Total area (acres in thousands)	4,281	4,603	4,339	5,614	7,247	8,217
Number of producing leases	608	649	698	726	748	790
Area (acres in thousands)	2,530	2,710	2,915	3,039	3,147	3,253
Percentage	59.8	59.9	68.2	57.3	47.0	42.7
Number of non-producing leases	409	434	325	540	842	994
Area (acres in thousands)	1,751	1,893	1,424	2,575	4,100	4,964
Percentage	40.2	40.1	31.8	42.7	53.0	57.3
Lease operations:						
Number of platforms	1,800	1,856	1,963	2,016	2,059	2,084
Number of new well starts	900	841	847	820	816	873
Number of new wells completed	605	407	338	420	310	397
Number of new zones completed	960	640	496	600	398	513
Oil zones	681	393	306	304	226	223
Gas zones	266	240	180	288	155	277
Service zones	13	7	10	8	17	13
Total number of completed wells	5,359	5,718	6,032	6,421	6,519	6,404
Total number of completed zones	8,830	9,348	9,716	10,187	10,353	10,490
Oil zones	6,447	6,657	6,740	6,868	6,863	6,755
Gas zones	2,219	2,474	2,680	2,987	3,108	3,410
Service zones	164	217	296	332	382	325
Miles of pipeline under supervision (estimated)	4,000	5,000	6,000	6,450	6,700	7,150
Production:						
Oil and condensate (barrels in millions)	361	419	412	395	361	330
Percentage of domestic production	10.3	12.1	11.9	11.8	11.2	11.1
Gas (cubic feet in billions)	2,419	2,777	3,038	3,212	3,515	3,459
Percentage of domestic production	11.0	12.6	13.5	14.0	16.0	16.9
Gasoline and LPG (gallons in millions)	1,075	1,551	1,737	1,635	2,032	1,989
Percentage of domestic production	4.3	5.9	6.5	6.1	7.9	8.5

TABLE 48.—*Revenues from leases on Outer Continental Shelf lands, calendar years 1970–75*

[Dollars in thousands]

Source of revenue	1970	1971	1972	1973	1974	1975 (estimated)
Total revenue	$1,238,961	$456,012	$2,624,958	$3,494,981	$5,598,758	$1,723,724
Bonuses	945,065	96,304	2,251,347	3,082,463	5,022,861	1,088,133
Minimum royalties	1,746	1,891	2,020	2,391	2,048	2,000
Rentals	8,608	7,742	7,985	8,949	13,533	18,000
Number of accounts	(676)	(735)	(529)	(647)	(1,036)	(1,270)
Shut-in gas payments	48	32	50	53	32	30
Royalties	283,494	350,042	363,556	401,126	560,284	615,561
Production value	(1,707,593)	(2,135,677)	(2,229,179)	(2,486,865)	(3,570,054)	(3,925,023)
Number of acounts	(694)	(754)	(912)	(1,158)	(2,260)	(2,600)
Oil and condensate:						
Royalties	207,076	253,229	247,689	271,491	384,367	399,531
Production value	(1,193,592)	(1,481,681)	(1,453,966)	(1,620,732)	(2,398,794)	(2,428,874)
Gas:						
Royalties	69,445	87,406	105,892	118,245	142,257	195,908
Production value	(438,136)	(549,648)	(663,648)	(736,878)	(881,634)	(1,210,314)
Gasoline and LPG:						
Royalties	3,729	5,944	6,525	7,768	19,797	16,376
Production value	(51,180)	(80,563)	(89,214)	(105,437)	(254,744)	(216,043)

TABLE 48.—*Revenues from leases on Outer Continental Shelf lands, calendar years 1970–75*—Continued

Commodity	1970	1971	1972	1973	1974	1975 (estimated)
Salt:						
Royalties	8	11	11	11	10	8
Production value	(49)	(67)	(65)	(69)	(62)	(54)
Sulfur:						
Royalties	3,236	3,452	3,439	3,611	3,853	3,738
Production value	(24,637)	(23,718)	(22,287)	(23,749)	(34,820)	(69,738)

TABLE 49.—*Oil, gas, and geothermal operations on Federal and Indian lands, calendar years 1970–75*

Actiivty	1970	1971	1972	1973	1974	1975
Competitive oil and gas lease sales Federal lands:						
Tracts offered:						
Number of tracts	255	418	464	339	421	390
Area (acres)	41,796	121,962	130,546	86,681	98,064	99,839
Tracts sold:						
Number of tracts	185	206	279	311	295	334
Area (acres)	38,724	52,102	88,326	89,315	65,247	90,367
Percentage of tracts sold	72.6	49.3	60.1	91.7	70.1	85.6
Bonus (dollars in thousands)	$479	$1,163	$1,118	$2,203	$2,296	$6,334
Status of oil and gas leases:						
Total number of leases supervised	115,993	112,784	113,158	115,761	123,652	126,718
Total area (acres in thousands)	70,767	70,628	75,213	79,116	89,829	93,604
Number of producing leases	11,135	11,285	11,640	11,953	12,386	13,036
Area (acres in thousands)	5,563	5,629	5,741	5,902	6,349	6,680
Percentage	9.6	10.0	10.3	10.3	10.0	10.3
Number of non-producing leases	104,858	101,499	101,518	103,808	111,266	113,682
Area (acres in thousands)	65,204	64,999	69,472	73,214	83,480	86,924
Percentage	90.4	90.0	89.7	89.7	90.0	89.7
Oil and gas lease operations:						
Number of new well starts	1,765	1,651	1,956	1,848	2,312	2,321
Number of new wells completed	1,083	883	1,045	1,132	1,280	1,617
Number of new zones completed	1,104	907	1,081	1,172	1,341	1,660
Oil zones	829	589	660	507	701	927
Gas zones	234	271	374	601	579	614
Service zones	41	47	47	64	61	119
Total number of completed wells	36,587	36,936	37,441	38,199	38,372	38,218
Total number of completed zones	38,368	38,686	39,159	39,991	40,251	40,300
Oil zones	23,511	23,366	23,282	23,139	22,791	21,866
Gas zones	9,913	10,159	10,421	11,083	11,487	12,282
Service zones	4,944	5,161	5,456	5,769	5,973	6,152
Oil and gas production:						
Oil and condensate (barrels in millions)	243	228	217	208	208	198
Percentage of domestic production	6.9	6.6	6.3	6.2	6.4	6.4
Gas (cubic feet in billions)	1,135	1,173	1,124	1,153	1,234	1,057
Percentage of domestic production	5.2	5.2	5.0	5.1	5.6	5.3
Gasoline and LPG (gallons in millions)	626	713	641	669	567	521
Percentage of domestic production	2.5	2.7	2.4	2.5	2.2	2.1
Status of geothermal leases:						
Total number of leases in effect	--	--	--	--	--	552
Total area (acres in thousands)	--	--	--	--	--	1,270

TABLE 50.—*Royalties from oil and gas leases on Federal and Indian lands, calendar years 1970–75*

[Dollars in thousands]

Commodity	1970	1971	1972	1973	1974	1975 (estimated)
Total royalties	$114,439	$115,997	$115,204	$134,568	$219,630	$245,345
Total production value	(916,406)	(938,276)	(918,360)	(1,074,758)	(1,728,536)	(1,915,768)
Oil and condensate:						
Royalties	90,374	90,753	87,594	100,963	176,566	193,608
Production value	(706,756)	(714,767)	(678,085)	(783,149)	(1,349,656)	(1,459,088)

TABLE 50.—*Royalties from oil and gas leases on Federal and Indian lands, calendar years 1970–75*—Continued

Commodity	1970	1971	1972	1973	1974	1975 (estimated)
Gas:						
Royalties	22,479	23,449	25,905	31,263	39,798	47,508
Production value	(177,512)	(187,032)	(206,625)	(248,768)	(315,490)	(374,785)
Gasoline and LPG:						
Royalties	1,564	1,771	1,686	2,323	3,238	3,789
Production value	(31,617)	(35,921)	(33,226)	(42,398)	(62,758)	(76,632)
All others:						
Royalties	22	24	19	19	28	440
Production value	(521)	(556)	(424)	(424)	(632)	5,263

TABLE 51.—*Mining operations on Federal and Indian lands by commodity, fiscal years 1970–75*

Activity and commodity	1970	1971	1972	1973	1974	1975
Total number leases supervised	2,491	2,566	2,647	2,579	2,488	2,479
Total area (acres in thousands)	4,372	5,873	5,924	7,566	7,830	7,977
Total number of producible mines	414	405	343	338	377	435
Total commodity production (tons in thousands)	39,051	46,363	48,135	51,782	65,810	88,270
Coal:						
Number of leases supervised	548	558	560	561	563	565
Area (acres in thousands)	782	903	934	1,038	977	1,023
Production (tons in thousands)	12,044	17,263	18,966	24,247	32,139	43,590
Percentage of domestic production	2.0	3.1	3.2	4.1	5.4	7.2
Phosphate:						
Number of leases supervised	227	243	226	219	194	194
Area (acres in thousands)	170	145	136	131	100	100
Production (tons in thousands)	3,702	3,256	3,124	3,156	6.258	5,772
Percentage of domestic production	9.6	8.4	7.7	7.4	14.0	11.8
Potash:						
Number of leases supervised	164	159	164	163	158	161
Area (acres in thousands)	265	250	249	246	238	237
Production (tons in thousands)	13,842	14,175	12,476	13,196	14,383	15,459
Percentage of domestic production	77.0	81.6	72.0	75.5	79.2	87.8
Sodium:						
Number of leases supervised	91	91	87	84	84	84
Area (acres in thousands)	138	138	133	132	132	132
Production (tons in thousands)	2,390	2,230	2,606	2,336	2,092	2,826
Percentage of domestic production	72.9	62.5	66.5	50.5	45.4	58.9
Oil shale:						
Number of leases supervised	--	--	--	--	4	4
Area (acres in thousands)	--	--	--	--	20.4	20.4
Production (tons in thousands)	--	--	--	--	--	--
Other:						
Number of leases supervised	1,461	1,515	1,610	1,552	1,485	1,471
Area (acres in thousands)	3,017	4,437	4,472	6,019	6,363	6,465
Production (tons in thousands)	7,073	9,439	10,963	8,847	10,938	20,623

TABLE 52.—*Revenues from mining leases on Federal and Indian lands by commodity, fiscal years 1970–75*

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

Commodity	1970	1971	1972	1973	1974	1975
Total revenue	$12,153	$21,851	$14,841	$16,484	$470,464	$31,596
Bonuses	370	7,627	--	34	449,192 [1]	36
Total royalties	11,783	14,224	14,841	16,450	21,272	31,560
Total production value	(244,184)	(293,983)	(301,665)	(335,282)	(463,811)	(681,281)
Coal:						
Royalties	1,760	2,654	3,119	4,044	5,535	8,335
Production value	(48,064)	(70,552)	(78,256)	(93,307)	(140,307)	(224,947)

See footnote at end of table.

TABLE 52.—*Revenues from mining leases on Federal and Indian lands by commodity, fiscal years 1970–75*—Continued

Commodity	1970	1971	1972	1973	1974	1975
Phosphate:						
Royalties	952	838	811	842	1,618	1,538
Production value	(10,755)	(9,669)	(9,674)	(11,314)	(31,158)	(28,383)
Potash:						
Royalties	2,880	3,695	3,104	3,270	3,962	5,565
Production value	(65,480)	(83,521)	(72,227)	(75,872)	(96,897)	(132,518)
Sodium:						
Royalties	2,189	1,960	2,531	2,547	2,439	5,046
Production value	(53,181)	(47,680)	(59,728)	(58,179)	(56,240)	(109,590)
Copper:						
Royalties	180	198	153	158	563	1,331
Production value	(3,749)	(4,137)	(2,995)	(2,691)	(6,087)	(7,140)
Fluospar:						
Royalties	14	40	70	86	31	--
Production value	(155)	(485)	(698)	(865)	(322)	--
Lead and zinc:						
Royalties	1,431	1,765	1,695	2,192	3,241	5,109
Production value	(35,885)	(44,017)	(42,195)	(54,640)	(75,319)	(115,340)
Limestone:						
Royalties	2	4	3	4	6	10
Production value	(48)	(75)	(20)	(54)	(86)	(83)
Sand and gravel:						
Royalties	342	614	886	623	633	842
Production value	(4,621)	(6,879)	(9,713)	(6,846)	(7,340)	(18,774)
Silica—pumice:						
Royalties	--	--	--	1	--	--
Production value	--	--	--	(14)	--	--
Uranium:						
Royalties	1,838	2,176	2,205	2,303	2,224	2,664
Production value	(15,743)	(18,370)	(18,394)	(18,822)	(22,014)	(16,938)
Zinc:						
Royalties	130	206	214	336	936	1,066
Production value	(3,232)	(5,119)	(5,219)	(8,207)	(22,806)	(24,413)
Other:						
Royalties	65	75	50	42	84	56
Production value	(3,272)	(3,478)	(2,546)	(4,490)	(5,146)	(3,155)

[1] Includes bonuses of $448,797,000 from four competitive oil shale lease sales.

TABLE 53.—*Information products ordered from the EROS Data Center, fiscal years 1973–75*

Product	1973		1974		1975	
	Items	Dollars	Items	Dollars	Items	Dollars
Totals	165,023	$374,318	284,097	$836,747	414,084	$1,609,842
Landsat images	81,071	228,042	157,178	528,514	195,125	760,263
Landsat computer-compatible data tapes	10	1,600	228	36,480	879	169,300
Gemini, Apollo, and Skylab images and photographs	--	--	17,201	34,421	28,049	113,473
Aerial photographs	83,942	144,676	109,490	237,332	190,031	566,806

TABLE 54.—*Number of jobs processed by Geological Survey computer faciliites, by organizational unit, fiscal years 1973–75*

Organizational unit	1973	1974	1975
Total jobs processed	140,361	186,450	259,891
Topographic Division	13,880	17,373	24,713
Geologic Division	21,148	20,412	22,354
Water Resources Division	64,756	90,346	143,137
Conservation Division	9,166	16,319	26,846
Other Geological Survey Units	5,006	11,223	12,474
Non-Geological Survey Organizations	26,405	30.777	30,367
Average cost per job (dollars)	$26.80	$22.63	$17.57

TABLE 55.—*Geological Survey expenditures for automatic data processing services, fiscal years 1971–75*

[Dollars in thousands]

	1971	1972	1973	1974	1975
Total	$5,582	$4,862	$6,168	$6,987	$8,425
In-house expenditures	5,249	4,572	5,243	5,244	5,443
Contractual services (Government)	228	199	463	577	884
Contractual services (Commercial)	105	91	462	1,166	2,098

TABLE 56.—*Geological Survey Library operating statistics, fiscal years 1970–75*[1]

[N.A., not applicable]

Activity	1970	1971	1972	1973	1974	1975	Estimated total holdings
Library acquisitions:							
Total number of items	70,955	80,401	94,445	84,208	91,047	136,106	1,864,000
Bound and unbound issues of periodicals and serials	40,327	47,194	50,322	45,499	48,095	49,775	585,000
Books and monographs	7,274	10,189	7,693	7,183	11,600	12,891	315,000
Pamphlets and reprints	5,816	5,221	2,660	2,425	2,901	2,798	350,000
Single-sheet maps	12,723	14,091	19,817	20,653	19,439	21,777	350,000
Photographs and negatives	1,820	2,568	12,558	7,121	7,818	3,485	200,000
Aerial photographs	2,768	777	1,100	1,019	812	45,000	52,000
Field record notebooks and related materials	227	361	295	308	382	380	12,000
New serial titles (number of titles)	304	542	959	650	434	657	N.A.
Library users:							
Total number of visits	43,900	42,497	47,744	45,526	43,948	52,092	N.A.
Geological Survey users	38,577	35,897	39,141	37,211	37,327	46,210	N.A.
Other users	5,323	6,600	8,603	8,315	6,621	5,882	N.A.
Library circulation:							
Total number of items	73,941	78,075	69,302	66,327	61,656	80,991	N.A.
Books and periodicals	71,122	75,850	66,627	63,980	59,402	76,658	N.A.
Maps	2,819	2,225	2,675	2,347	2,254	4,333	N.A.
Interlibrary loans:							
Total number of items	19,634	18,548	19,156	16,308	15,252	20,356	N.A.
Items loaned	16,102	15,272	16,138	13,818	13,073	16,965	N.A.
Items borrowed	3,532	3,276	3,018	2,490	2,179	3,391	N.A.
Reference queries	12,091	13,302	13,093	11,358	14,047	14,774	N.A.

[1] Statistics include the operations of the Survey's main library in Reston, Va. and branch libraries in Denver, Colo., Menlo Park, Calif., and Flagstaff, Ariz.

TABLE 57.—*Publications Division operating statistics, fiscal years 1970–75*

Activity	1970	1971	1972	1973	1974	1975
Number of public inquiries (thousands)	127	143	154	155	179	244
Book reports:						
Number of books published[1]	256	204	278	173	145	169
Number of copies distributed (thousands)[2]	527	473	464	452	399	385
Number of booklets distributed (millions)[3]	2.4	2.2	1.7	1.8	1.2	1.5
Maps:						
Number of maps printed	4,660	5,494	6,269	6,049	9,109	7,531
Number of copies printed (millions)	16.9	19.1	18.2	21.0	20.0	18.3
Number of copies distributed (millions)[4]	7.4	8.1	9.5	10.3	9.9	10.6
Number of copies sold (millions)	5.0	5.6	6.2	7.2	7.3	7.8
Receipts from map sales (dollars in millions)[5]	$1.87	$2.00	$2.25	$3.00	$3.19	$3.46
Number of individual orders processed (thousands)	497	480	533	628	625	782

[1] Books printed by the Government Printing Office.
[2] Book distributed for official use and without charge. Number does not include copies distributed by the Government Printing Office.
[3] Booklets distributed without charge.
[4] Includes topographic index maps distributed for official use and without charge and maps sold over the counter and by mail.
[5] Deposited to Miscellaneous Receipts in the U.S. Treasury.

CHRONOLOGY OF LEADERSHIP OF THE U.S. GEOLOGICAL SURVEY

YEAR	PRESIDENT OF THE UNITED STATES	SECRETARY, DEPARTMENT OF THE INTERIOR	DIRECTOR, GEOLOGICAL SURVEY
1877	Rutherford B. Hayes	Carl Schurz	
1879			Clarence King
1881	James A. Garfield Chester A. Arthur	Samuel J. Kirkwood	John Wesley Powell
1882		Henry M. Teller	
1885	Grover Cleveland	Lucius Q. C. Lamar	
1888		William F. Villas	
1889	Benjamin Harrison	John W. Noble	
1893	Grover Cleveland	Hoke Smith	
1894			Charles D. Walcott
1896		David R. Francis	
1897	William McKinley	Cornelius N. Bliss	
1899		Ethan Allen Hitchcock	
1901	Theodore Roosevelt		
1907		James R. Garfield	George Otis Smith
1909	William Howard Taft	Richard A. Ballinger	
1911		Walter L. Fisher	
1913	Woodrow Wilson	Franklin K. Lane	
1920		John B. Payne	
1921	Warren G. Harding	Albert B. Fall	
1923	Calvin Coolidge	Hubert Work	
1928		Roy O. West	
1930	Herbert Hoover	Ray L. Wilbur	
1931			Walter C. Mendenhall
1933	Franklin D. Roosevelt	Harold L. Ickes	
1943			William E. Wrather
1945	Harry S. Truman		
1946		Julius A. Krug	
1949		Oscar L. Chapman	
1953	Dwight D. Eisenhower	Douglas McKay	
1956		Fred A. Seaton	Thomas B. Nolan
1961	John F. Kennedy	Stewart L. Udall	
1963	Lyndon B. Johnson		
1965			William T. Pecora
1969	Richard M. Nixon	Walter J. Hickel	
1971		Rogers C.B. Morton	Vincent E. McKelvey
1974	Gerald R. Ford		
1975		Stanley K. Hathaway Thomas S. Kleppe	


SURVEY
PUBLICATIO
ON FLOODS
OIL SHALE
a potential
source of energy
THE
ANTARCTIC
AND ITS
SELECTED
BIBLIOGRAPHY
ON MAPS
AND MAPP
types of maps
SATELLITE IMAGES
POPULAR
PUBLICATIONS
of the
UNITED STATES
GEOLOGICAL
SURVEY
THE
NATIONAL ATLAS
STORY
aerial
photographic
LANDSLIDES
UNITED STATES
DEPARTMENT OF THE
INTERIOR
GEOLOGICAL SURVEY
DENVER'S
GEOLOGIC
SETTING
GEOLOGIC
TIME
TOPOGRAPHIC MAPS
SILENT GUIDES
for
OUTDOORSMEN
MOTION
PICTURE
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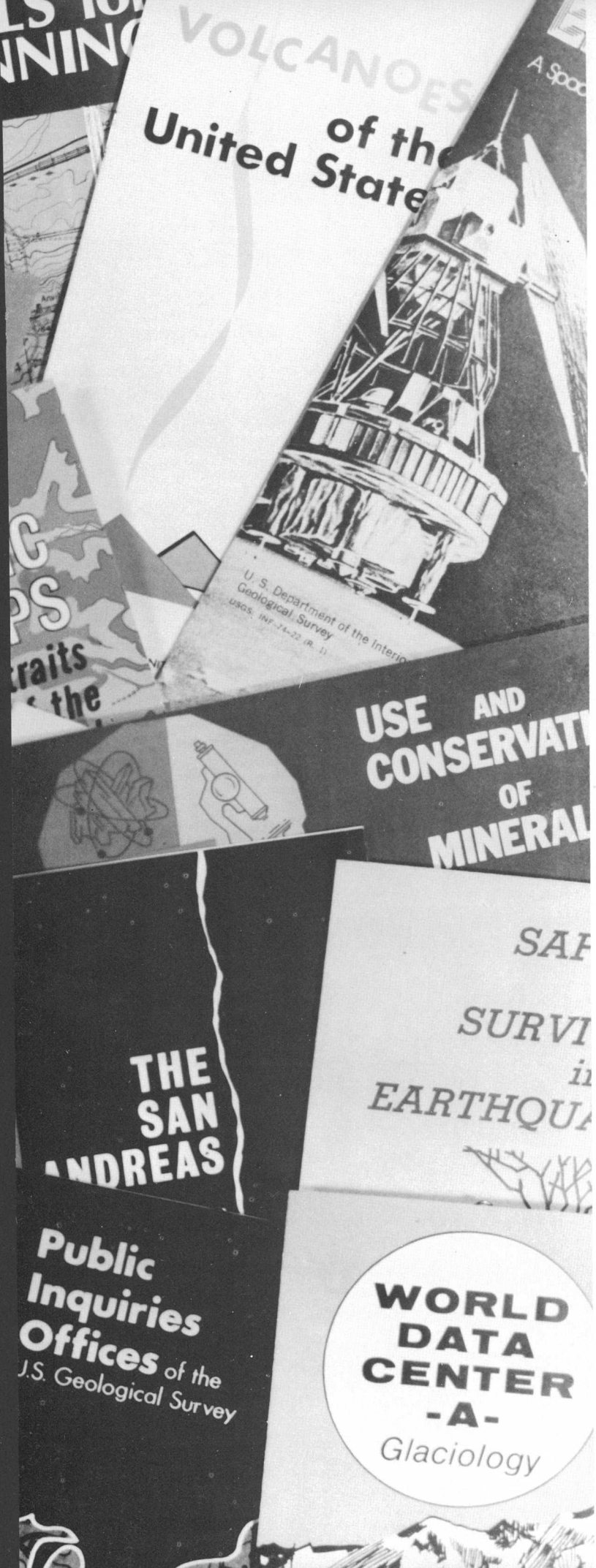

Guide to Publications and Information Services

Throughout this report reference has been made to information services and publications of the Geological Survey. This section lists the major publications series and information services provided by the Survey and describes how the public may acquire further information about them. Italicized items in the text refer to major headings in the list of information products, services, and sources.

INSTRUCTIONS FOR ORDERING BOOK REPORTS AND MAPS

Mail orders for Geological Survey publications must be accompanied by payment in the form of check or money order payable to "U.S. Geological Survey." Postage stamps are not accepted. Do not send cash. Remittances must be in United States currency. The list prices shown in *Publications of the Geological Survey, New Publications of the Geological Survey, Topographic Map Indexes,* and in other catalogs of Survey reports are subject to change. Prices include the cost of domestic surface transportation. For transmittal outside the U.S.A. (except to Canada and Mexico) a surcharge of 25 percent of the net bill should be included to cover surface transportation.

Ordering books and monographs

To order books, give the series designation and number, such as "Geological Survey Bulletin 738," and the full title. Professional Papers, Bulletins, Water-Supply Papers, Techniques of Water-Resources Investigations, bulk quantities of most nontechnical publications, and some miscellaneous reports, including some from all the foregoing series that have gone out of print at the Government Printing Office, may still be obtained from:

Branch of Distribution
U.S. Geological Survey
1200 South Eads Street
Arlington, VA 22202

(703) 557–2751
Hours: 8:00–4:00

or from Geological Survey *Public Inquiries Offices* (authorized agents of the Superintendent of Documents). Periodicals (*Journal of Research of the U.S. Geological Survey, Earthquake Information Bulletin*) can be obtained ONLY from:

Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402.

On orders of 100 copies or more of the same report sent to the same address, a 25-percent discount is allowed. Limited quantities of circulars and nontechnical publications may be obtained (usually free of charge) by writing to *Public Inquiries Offices* or the *Branch of Distribution Offices. Open-File Reports, Topographic Instructions, Water-Resources Investigations reports,* and reports available only through the *National Technical Information Service* may be ordered according to instructions under appropriate headings in this guide.

Ordering maps

To order maps give name or series designation and number such as "Fairfax, Va., 7.5-minute" or "GQ–851." Address mail orders to:

Branch of Distribution
U.S. Geological Survey
1200 South Eads Street
Arlington, VA 22202
(703) 557–2751
Hours: 8:00–4:00

for maps of areas east of the Mississippi River, including Minnesota, Puerto Rico, and the Virgin Islands, and to:

Branch of Distribution
U.S. Geological Survey
Box 25286, STOP 306
Denver Federal Center (Bldg. 41)
Denver, CO 80225
(303) 234–3832
Hours: 8:00–4:00

for maps of areas west of the Mississippi River, including Alaska, Hawaii, Louisiana, Guam, and American Samoa.

Residents of Alaska may order Alaskan maps from:

Distribution Section
U.S. Geological Survey
310 First Avenue
Fairbanks, AK 99701.
(907) 452–1951
Hours: 8:00–5:00

On an order amounting to $300 or more at the list price, a 30-percent discount is allowed; no other discount is applicable. The discount applies to all published maps and charts distributed by the Geological Survey.

Over-the-counter services

U.S. Geological Survey books may be obtained over the counter from all *Public Inquiries Offices* (except Reston, Va.) and from the *Branch of Distribution Office* in Arlington, Va. Maps may be obtained over the counter from all *Public Inquiries Offices, Branch of Distribution Offices,* and the Mid-Continent and Western *Mapping Centers*.

Geological Survey maps are also sold by about 1,550 commercial dealers throughout the United States at prices somewhat higher than those shown in Survey catalogs.

INFORMATION PRODUCTS, SERVICES, AND SOURCES

Advance material from topographic mapping

Advance material from current topographic mapping is indicated on individual State Advance Material Indexes. This material, which includes such items as aerial photographs, geodetic control data, and advance copies of maps in various stages of preparation and editing, may be purchased.

Availability: Information concerning the ordering of these items is contained in the text of the State indexes. Requests for the indexes or inquiries concerning the availability of advance material should be directed to the *Mapping Centers* or to the *National Cartographic Information Center.*

Aerial photographs

The Geological Survey acquires vertical aerial photographs for use in topographic and geologic mapping. Contact prints, enlargements, and photoindexes

Indexes to aerial photographs aid in answering requests for information.

are available for purchase. These services are described in a *Popular Publication,* "Aerial Photographic Reproductions."

Availability: The *EROS Data Center* serves as the primary repository for Geological Survey aerial photographs as well as aerial photographs and space images acquired by the National Aeronautics and Space Administration. Information about the availability and ordering of aerial photographs may be obtained from the *EROS Data Center, National Cartographic Information Center,* Topographic Division *Mapping Centers,* and *EROS Applications Assistance Facilities.* All of these facilities have microfilm browse files of the data and access to the EROS Data Center's computerized index of aerial photographs. Special-purpose photographs may be purchased from the *Photographic Library* and the *Glaciology-World Data Center-A.*

Alaska Technical Data Unit

The Alaska Technical Data Unit maintains a reference library of maps, reports, field notebooks, and photographs related to the Geological Survey's fieldwork in Alaska.

Availability: Information on the use of this reference collection may be obtained from:

Technical Data Unit
Branch of Alaskan Geology
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025.

(415) 323–8111
ext. 2342
Hours: 7:45–4:15

Antarctic data

The Scientific Committee on Antarctic Research (SCAR) maintains distribution centers for the exchange of Antarctic cartographic materials published by 12 member nations. The SCAR depository for the United States is operated by the *National Cartographic Information Center.* The SCAR files include two copies of all cartographic publications received from SCAR member nations and what is believed to be the world's largest collection of photographs of Antarctica (about 250,000 prints).

Availability: Information on Antarctic data and contact prints of Antarctic aerial photographs (acquired by the United States) may be obtained through the *National Cartographic Information Center.* Visits to the SCAR Mapping Center should be arranged through:

Branch of International Activities
U.S. Geological Survey
National Center, STOP 515
Reston, VA 22092.

(703) 860–6241
Hours: 7:45–4:15

Books and reports

The Geological Survey publishes several series of monographs, Professional Papers, Bulletins, and Water-Supply Papers which present the results of geologic and hydrologic field investigations and research. Topographic Instructions and Techniques of Water Resources Investigations describe field and laboratory methods and procedures. Open-file reports and Water-Resources Investigations reports describe the results of field investigations and research which require immediate release for interim use pending publication or which have limited interest. These reports are listed in *Publications of the Geological Survey.* New reports are announced in *New Publications of the Geological Survey.*

Availability: Professional Papers, Bulletins, Water-Supply Papers, and Techniques of Water Resources Investigations are sold by *Public Inquiries Offices,* the *Branch of Distribution Office,* Arlington, Va., and the Superintendent of Documents (see "Instructions for ordering book reports and maps"). Instructions for obtaining *Open-File Reports, Topographic Instructions, Water-Resources Investigations reports,* and reports available only through the *National Technical Information Service* are given under the headings italicized above. Books and reports of the Geological Survey may be consulted in Geological Survey Libraries (see *Library services*) and in various *Depository libraries.*

Branch of Distribution Offices

The Geological Survey maintains three offices to distribute Survey publications and maps:

Alaska:
Distribution Section
U.S. Geological Survey
310 First Avenue
Fairbanks, AK 99701
(907) 452–1951
Hours: 8:00–5:00

Colorado:
Branch of Distribution
U.S. Geological Survey
Box 25286, STOP 306
Denver Federal Center (Bldg. 41)
Denver, CO 80225
(303) 234–3832
Hours: 8:00–4:00

Virginia:
Branch of Distribution
U.S. Geological Survey
1200 South Eads Street
Arlington, VA 22202.
(703) 557–2751
Hours: 8:00–4:00

All mail orders for maps and publications should be sent to the Arlington, Va., office. All offices provide over-the-counter services for maps. Books may also be purchased over the counter from the Arlington, Va., office.

Cartographic data

See the *National Cartographic Information Center.*

Catalog of Information on Water Data

See *Water data.*

Circulars

Circulars are informal Survey publications designed to present summary statements and reports of popular interest to a wide range of audiences. Circulars are listed in *Publications of the Geological Survey*. New circulars are announced in *New Publications of the Geological Survey*.

Availability: Circulars are free on application to the *Public Inquiries Offices* or to the *Branch of Distribution Office* in Arlington, Va.

Depository libraries

Many libraries throughout the United States are depository libraries of the Superintendent of Documents and maintain collections of Geological Survey publications and maps for reference by the general public. These libraries are listed on *State list of publications on hydrology and geology* and on the State *Topographic Map Indexes*.

Earthquake data

See *National Earthquake Information Service*.

Earthquake Information Bulletin

The *Earthquake Information Bulletin* is published bimonthly by the Geological Survey to provide current information on earthquakes and seismological activities of interest to both general and specialized readers. Correspondence and inquiries concerning the bulletin (other than subscription orders) should be directed to:

Earthquake Information Bulletin (703) 860–6575
U.S. Geological Survey Hours: 7:45–4:15
National Center, STOP 904
Reston, VA 22092.

Availability: Subscriptions to the Bulletin may be purchased from:

Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402.

Energy- and mineral-resources data files

The Geological Survey has developed several energy- and mineral-resource data files, four of which are operational; the remaining files are in various stages of development. Computerized Resource Information Bank (CRIB) at present contains over 30,000 mineral-resource records for the United States (15 percent) and the rest of the world (85 percent). Each record contains data on location, products and by-products, exploration and development history, geology and mineralogy, and bibliographic references.

The Rock Analysis Storage System (RASS) is a geochemical data bank containing limited geologic descriptions and comprehensive geochemical analyses of rocks. This file contains over 200,000 records and is increasing in size at a rate of 30,000 records per year.

The National Coal Resources Data System (NCRDS) is nearing completion of a 30,000-record inventory of coal resources and chemical analyses which are available by location, resource delimiters, or tonnage.

The Petroleum Data System contains approximately 68,000 records on oil and gas pools in the United States and Canada.

Availability: The CRIB and Petroleum Data System files are directly accessible by the public through commercial time-sharing computer systems. Some geochemical and geophysical data are also available from the *National Technical Information Service* on magnetic tape. Such data releases are announced in *New Publications of the Geological Survey*. For further information contact:

Office of Resource Analysis (703) 860–6446
U.S. Geological Survey Hours: 7:45–4:15
National Center, STOP 920
Reston, VA 22092.

EROS Applications Assistance Facilities

The *EROS Data Center* operates several Applications Assistance Facilities which maintain microfilm copies of aerial photographs and space images stored at the Center. Scientific personnel are available to assist users in selecting the appropriate data to apply to a variety of resource and environmental problems and to assist users in ordering data through a computer inquiry system.

Availability: It is recommended that Applications Assistance Facilities be contacted by phone or mail in advance, so that suitable arrangements can be made for a visit if desired. EROS Applications Assistance Facilities are located in the following states:

Alaska:

EROS Applications Assistance Facility (907) 479–7558
University of Alaska Hours: 8:00–5:00
Geophysical Institute
College, AK 99701 (Fairbanks)

Arizona:

EROS Applications Assistance Facility (602) 261–3188
U.S. Geological Survey Hours: 8:00–5:00
Suite 1880 Valley Center Bldg.
Phoenix, AZ 85073

California:

EROS Applications Assistance Facility (415) 323–8111
U.S. Geological Survey ext. 2157
122 Building 3 Hours: 8:00–4:15
345 Middlefield Road
Menlo Park, CA 94025

Canal Zone:

EROS Applications Assistance Facility (202) 697–1201
HQ Inter American Geodetic Survey ext. 83–3897
Headquarters Bldg. Hours: 7:00–3:45
Drawer 934
Fort Clayton, Canal Zone

Colorado:
EROS Applications Assistance Facility (303) 234–4879
U.S. Geological Survey Hours: 8:00–4:30
Box 25046, STOP 504
Denver Federal Center (Bldg. 25)
Denver, CO 80225

Mississippi:
EROS Applications Assistance Facility (601) 688–3541
U.S. Geological Survey Hours: 8:00–4:30
B-210 Building 1100
National Space Technology Laboratories
Bay St. Louis, MI 39520

South Dakota:
EROS Applications Assistance Facility (605) 594–6111
EROS Data Center Hours: 8:00–4:30
U.S. Geological Survey
Sioux Falls, SD 57198

Virginia:
EROS Applications Assistance Facility (703) 860–7868
U.S. Geological Survey Hours: 8:00–4:15
National Center, STOP 730
1925 Newton Square East
Reston, VA 22090.

EROS Data Center

The Earth Resources Observation Systems (EROS) Data Center, located near Sioux Falls, South Dakota, provides remotely sensed data as well as user assistance to scientists, resource planners, managers, and the public. These data include aerial photographs acquired by the Department of the Interior and aerial photographs and images acquired by the National Aeronautics and Space Administration with research aircraft and with Landsat, Skylab, Apollo, and Gemini spacecraft. The primary functions of the Center are data storage and reproduction and user assistance and training. A *Popular Publication,* "The EROS Data Center," describes the operations, data products, services, and procedures for ordering remotely sensed data. Guidance in the use of remotely sensed data is available at the EROS Data Center in the form of scheduled training courses and workshops. The Center periodically offers courses on the application of remote sensing to such fields as agriculture, forestry, geography, geology, and hydrology. Visitors to the Center also receive assistance in the operation of specialized equipment such as densitometers, additive color viewers, zoom transfer scopes, and stereo viewers, and in the use of computerized multispectral systems to classify specific phenomena.

Availability: Orders for photographs and images may be placed directly with:

User Services Unit (605) 594–6111
EROS Data Center Hours: 7:45–7:00
U.S. Geological Survey
Sioux Falls, SD 57198.

Microfilm copies of the data may be viewed at locations having *EROS Data Reference Files.* The microfilmed data may be viewed and orders for data may be placed at *EROS Applications Assistance Facilities,* the Topographic Division *Mapping Centers* in Menlo Park, Calif., Denver, Colo., and Rolla, Mo., and at the *National Cartographic Information Center.*

EROS Data Reference Files

The *EROS Data Center* has established EROS Data Reference Files at several locations in the United States to enable users to view microfilm copies of aerial photographs and space images available from the Center before placing an order by mail. Applications assistance is not provided.

EROS Data Center, Sioux Falls, South Dakota.

Availability: EROS Data Reference Files may be consulted at the following locations:

Alaska:
EROS Data Reference File
Public Inquiries Office
U.S. Geological Survey
108 Skyline Bldg.
508 Second Avenue
Anchorage, AK 99501
(907) 277–0577
Hours: 9:00–5:30

California:
EROS Data Reference File
Public Inquiries Office
U.S. Geological Survey
7638 Federal Bldg.
300 North Los Angeles Street
Los Angeles, CA 90012
(213) 688–2850
Hours: 9:00–4:30

District of Columbia:
EROS Data Reference File
Public Inquiries Office
1028 GSA Bldg.
19th and F Streets, NW
Washington, DC 20244
(202) 343–8073
Hours: 8:15–3:45

Florida:
EROS Data Reference File
State Topographic Office
Lafayette Bldg., Koger Office Center
Tallahassee, FL 32304
(904) 488–2168
Hours: 8:15–5:15

Hawaii:
EROS Data Reference File
University of Hawaii
Department of Geography
313C Physical Science Bldg.
Honolulu, HI 96825
(808) 944–8463
Hours: 8:00–4:00

Massachusetts:
EROS Data Reference File
U.S. Geological Survey
80 Broad Street, 5th Floor
Boston, MA 02110
(617) 223–7202
Hours: 9:00–5:00

Missouri:
EROS Data Reference File
U.S. Geological Survey
1400 Independence Road
Rolla, MO 65401
(314) 364–3680
ext. 111
Hours: 8:00–5:00

New York:
EROS Data Reference File
U.S. Geological Survey
343 Post Office and Courthouse Bldg.
Albany, NY 12201
(518) 474–3107
Hours: 8:00–4:30

Ohio:
EROS Data Reference File
U.S. Geological Survey
975 West Third Avenue
Columbus, OH 43212
(614) 469–5553
Hours: 8:00–4:30

Oregon:
EROS Data Reference File
Bureau of Land Management
720 NE. Oregon Street
Portland, OR 97208
(503) 234–3361
ext. 4000
Hours: 8:00–4:00

Tennessee:
EROS Data Reference File
Maps and Surveys Branch
Tennessee Valley Authority
20 Honey Bldg.
311 Broad Street
Chattanooga, TN 37401
(615) 755–2133
Hours: 8:00–4:00

Washington:
EROS Data Reference File
Public Inquiries Office
U.S. Geological Survey
678 U.S. Courthouse Bldg.
West 920 Riverside Avenue
Spokane, WA 99201.
(509) 456–2524
Hours: 9:00–4:30

Flood information

The Geological Survey collects basic information on the flow of streams, including the maximum flow during floods; studies areas that have been flooded frequently or with unusual severity; and conducts research on the magnitude, frequency, and other characteristics of floods in drainage basins throughout the United States. The basic information collected, the completed studies of areas, and the results of research are published as Water-Supply Papers, Hydrologic Investigations Atlases, or Circulars. Descriptions of monthly streamflow conditions and recent flood events in the U.S. appear in *Water Resources Review*. A *Popular Publication*, "U.S. Geological Survey Publications on Floods," describes each type of flood report and lists the publications since 1950.

The Survey, in cooperation with the U.S. Department of Housing and Urban Development, is currently conducting a mapping program to delineate the approximate flood boundaries of streams throughout the Nation. The information on flood-prone areas is presented on topographic quadrangle maps which serve as valuable guides for public agencies and private citizens concerned with future land development.

Availability: Flood-prone-area maps and leaflets are free and may be obtained by contacting the District Chief of the Water Resources Division at the U.S. Geological Survey's District Office in your state (p. 145).

Geologic, hydrologic, and miscellaneous maps

The Geological Survey publishes several series of technical maps that present geologic and hydrologic data. The Hydrologic Investigations Atlases contain information on hydrology and geohydrology in map and graph form. Geologic Quadrangle Maps and most Miscellaneous Geologic Investigations Maps are multicolored geologic maps. Other map series include Geophysical Investigations Maps, Oil and Gas Investigations Maps and Charts, Mineral Investigations Field Studies Maps, Mineral Investigations Resource Maps, Geologic Atlas of the Moon, Atlas of Mars, and special geologic maps, such as the Geologic Map of the United States. These maps are listed in *Publications of the Geological Survey*. New maps are announced in *New Publications of the Geological Survey*.

Availability: These maps may be consulted in Geological Survey Libraries (see *Library services*) or *Depository libraries*. Maps may be purchased from *Public Inquiries Offices* or from the *Branch of Distribution Office* in Arlington, Va. (see "Instructions for ordering books and maps").

Glaciology- World Data Center-A

The Geological Survey and the National Academy of Sciences operate one of three international data centers serving the field of glaciology. Located in Tacoma, Wash., World Data Center-A facilitates the international exchange of glaciological data and serves as a national information center for texts and pictures related to snow and ice research. A *Popular Publication,* "World Data Center-A: Glaciology," describes the facility which includes a research library, a photograph library, a map collection, and a historical collection of data on glacial variations and climatic changes. The Center provides copies of research papers and data upon request, on an exchange basis or at the cost of reproduction. Space and facilities are available for those who wish to examine the collection personally. For information contact:

World Data Center-A: Glaciology
U.S. Geological Survey
1305 Tacoma Avenue South
Tacoma, WA 98402.

(206) 593–6506
Hours: 8:00–4:30

Hydrologic maps

See *Geologic, hydrologic, and miscellaneous maps.*

Reading room at World Data Center-A, Tacoma, Washington.

Journal of Research of the U.S. Geological Survey

The "Journal of Research of the U.S. Geological Survey" is a bimonthly periodical designed to provide relatively rapid publication of short scientific papers by Survey personnel.

Availability: Subscriptions and single issues can be purchased from:

Superintendent of Documents
U.S. Government Printing Office
Washington, D C 20402.

Land use data

See *National Cartographic Information Center.*

Library services

The Geological Survey Library is one of the largest earth-science libraries in the world. The main library is in Reston, Va.; three branch libraries are located in Denver, Colo.; Menlo Park, Calif.; and Flagstaff, Ariz. All libraries are open to the public. Librarians wishing to borrow books, periodicals, and maps for the use of their patrons are requested to use the approved American Library Association interlibrary loan form. A *Popular Publication,* "U.S. Geological Survey Library," describes the Library's collections.

Geological Survey libraries are located as follows:

Library
U.S. Geological Survey
National Center, STOP 950
Reston, VA 22092

(703) 860–6671
Hours: 7:45–4:15

Library
U.S. Geological Survey
Box 25046, STOP 914
Denver Federal Center (Bldg. 25)
Denver, CO 80225

(303) 234–4133
Hours: 8:00–4:30

Library
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025

(415) 323–8111
ext. 2208
Hours: 8:00–4:30

Library
U.S. Geological Survey
601 East Cedar Avenue
Flagstaff, AZ 86001.

(602) 774–1330
Hours: 8:00–4:30

Libraries are closed on Saturdays, Sundays, and Federal holidays.

Map reference libraries

See *Depository libraries.*

Map separates

Special maps for special needs can be made from the scribed sheets which are used to produce the Geological Survey's Topographic Quadrangle Maps. Quadrangle maps are published in five colors—black,

Entrance to National Center Library, Reston, Virginia.

brown, blue, red, and green. Each color is printed from a separate pressplate, and each pressplate is prepared from one or more scribed negatives called color separates. Film positive or negative copies of each individual color separate can be combined to make a single film positive or negative. The purchaser of film copy of color separates can then add or delete map detail by standard cartographic procedures. Limited base maps, street atlases, regional planning maps, and road maps are but a few of the special-purpose maps which can be prepared from the color separates.

Availability: Copies of color separates are available in either positive or negative form from the Topographic Division *Mapping Center* where the original materials are filed. Inquiries and orders may be made directly to the *Mapping Center* responsible for your geographic area of interest (fig. 61) or to the *National Cartographic Information Center.*

Mapping Centers

The Geological Survey's topographic mapping activities are conducted from four regional Mapping Centers and a Special Mapping Center (fig. 61):

Eastern Mapping Center
U.S. Geological Survey
National Center, STOP 567
12201 Sunrise Valley Drive
Reston, VA 22092
(703) 860–6352
Hours: 7:45–4:15

Mid-Continent Mapping Center
U.S. Geological Survey
1400 Independence Road
Rolla, MO 65401
(314) 364–3680
ext. 111
Hours: 8:00–5:00

Rocky Mountain Mapping Center
U.S. Geological Survey
Box 25046, STOP 510
Denver Federal Center (Bldg. 25)
Denver, CO 80225
(303) 234–2351
Hours: 8:00–4:30

Western Mapping Center
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025
(415) 323–8111
ext. 2411
Hours: 7:45–4:15

Special Mapping Center
U.S. Geological Survey
National Center, STOP 560
1925 Newton Square East
Reston, VA 22090.
(703) 471–1711
Hours: 7:45–4:15

Alaska is assigned to the Rocky Mountain Mapping Center; Hawaii, including the Pacific Trust Territories, to the Western Mapping Center; and Puerto Rico, including the Virgin Islands (U.S.), to the Eastern Mapping Center.

Each Mapping Center, except the Special Mapping Center, functions as an extension of the *National Cartographic Information Center* by providing information to the public about *Aerial photographs, Space images, Advance materials from topographic mapping, Map separates,* and other cartographic data. Microfilm copies of the aerial photographs and space images stored at the *EROS Data Center* and computer-inquiry ordering services are provided by the Mid-Continent, Rocky Mountain, and Western Mapping Centers.

The mapping centers publish Advance Material Indexes and accept inquiries and orders for Geological Survey *Aerial photographs, Advance material from topographic mapping,* and *Map separates.* All mapping centers except the Eastern Mapping Center sell topographic maps over the counter. Inquiries about the availability of these products may be sent also to the *National Cartographic Information Center.*

Mineral lease information

The Geological Survey is responsible for regulating oil and gas and mineral lease operations on Federal and Indian lands. Information describing these programs, statistics on production and collected royalties, reserve estimates, and other related information is available from:

Office of the Chief,
Conservation Division
U.S. Geological Survey
National Center, STOP 600
Reston, VA 22092
(703) 860–7524
Hours: 7:45–4:15

Conservation Manager, Gulf of
Mexico—OCS Operations
U.S. Geological Survey
P.O. Box 7944
Metairie, LA 70011
(504) 837–4720
ext. 381
Hours: 8:00–4:30

Conservation Manager,
Eastern Region
1725 K Street, N W., Suite 213
Washington, DC 20244
(202) 254–3137
Hours: 7:45–4:15

Conservation Manager,
Central Region
U.S. Geological Survey
Box 25046, STOP 609
Denver Federal Center
Denver, CO 80225
(303) 234–2855
Hours: 8:00–4:30

Conservation Manager,
Western Region
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025.
(415) 323–8111
ext. 2563
Hours: 7:45–4:15

Motion picture films

Geological Survey motion picture films, produced for educational and training purposes, are available for loan or purchase. Subjects range from popular accounts of volcanic eruptions to technical descriptions of procedures used in topographic, geologic, and hydrologic investigations. A *Popular Publication,* "Motion Picture Film Services of the U.S. Geological Survey," describes the contents of currently available films and loan procedures.

Availability: These films are available on a free-loan, short-term (2–3 days) basis to educational institutions, professional and scientific societies, civic and industrial groups, and other established organizations. For further information contact:

U.S. Geological Survey
Branch of Visual Services
National Center, STOP 303
Reston, VA 22092.
(703) 860–6171
Hours: 7:45–4:15

National Atlas

The "National Atlas of the United States of America" was published in 1970. The Atlas was compiled as a reference tool for use by public officials, business and industrial organizations, libraries, educational institutions, and scholars throughout the world who seek information about the United States. The 431-page volume contains 336 pages of multicolored maps and an index with more than 41,000 entries. Twenty-eight individual map sheets are available as separate sales items.

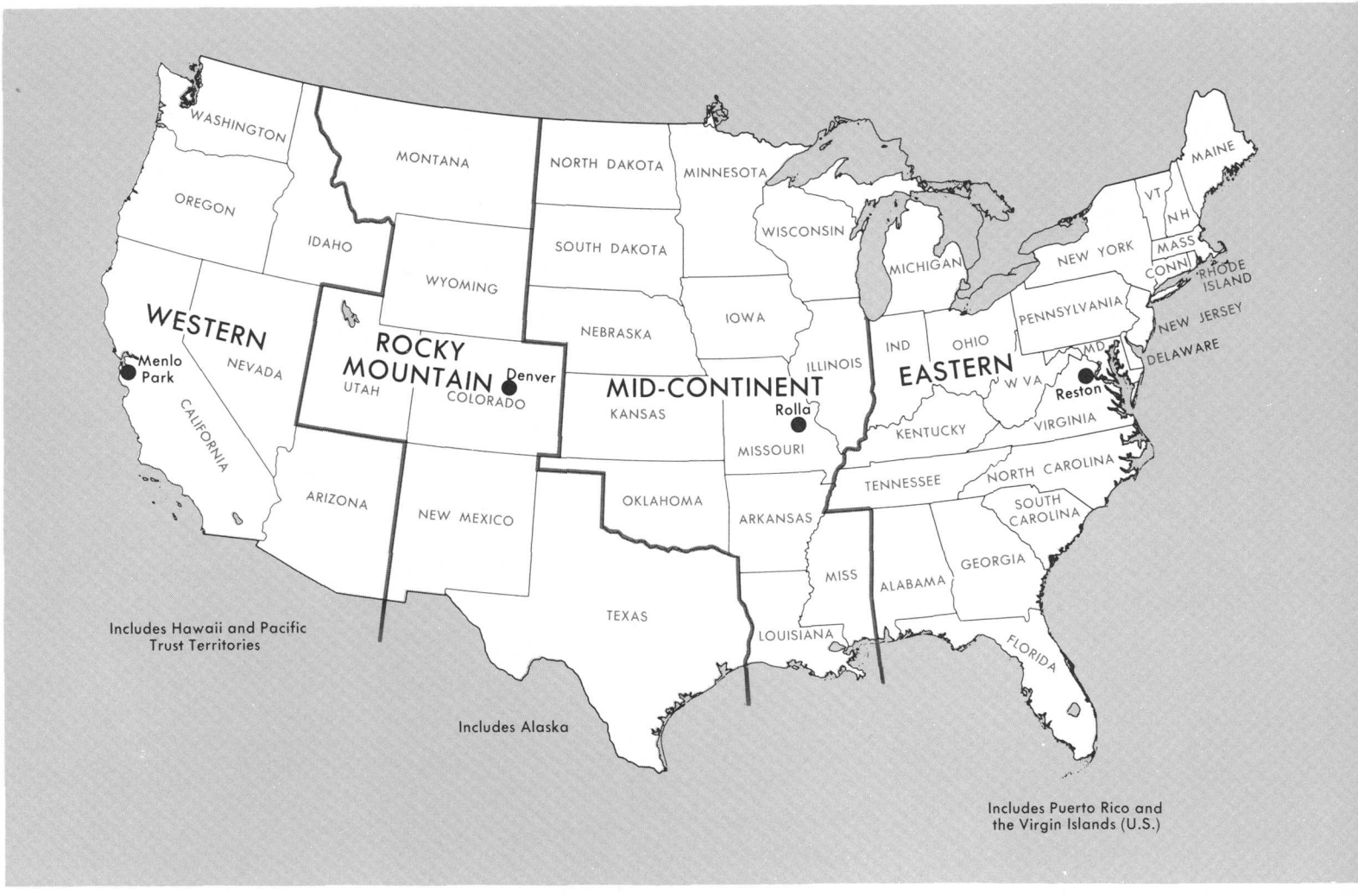

FIGURE 61.—Location of Geological Survey regional Mapping Centers.

Availability: The National Atlas may be purchased at *Public Inquiries Offices* in Reston, Va., and Washington, D.C., or from the *Branch of Distribution Office* in Arlington, Va.

National Cartographic Information Center

The National Cartographic Information Center (NCIC) provides a central source of information about U.S. maps and charts, aerial photographs and space images, geodetic control, land use data, and related cartographic data that are available from over 30 Federal agencies, all States, and many private organizations.

NCIC collects and indexes information on these data holdings and assists users with finding and obtaining the data. NCIC provides a direct inquiry and ordering service for *Aerial photographs* and *Space images* from the *EROS Data Center;* provides information and accepts orders for *Advance material from topographic mapping* and *Map separates* held by the Topographic Division; and refers orders for Geological Survey maps to the *Branch of Distribution Offices.* NCIC sells reproductions of out-of-print Survey topographic maps and copies of digital terrain tapes originally prepared by the Defense Mapping Agency. The Center also maintains and staffs the U.S. Scientific Committee on Antarctic Research depository of *Antarctic data.*

Availability: Inquiries should be directed to:

National Cartographic Information Center — (703) 860–6045
Hours: 7:45–4:15
U.S. Geological Survey
National Center, STOP 507
Reston, VA 22092.

National Earthquake Information Service

The Geological Survey's National Earthquake Information Service (NEIS) is responsible for rapidly locating significant earthquakes and for issuing notification to the proper authorities, scientists, and the public within 2 hours of the occurrence. For a few days after a disastrous earthquake, the alerting service also acts as a clearinghouse for information from and to the stricken area.

About 5,000 earthquakes are located annually from observations collected from seismic stations throughout the world. Lists of preliminary determinations of epicenters are published within a few weeks of each earthquake occurrence and are followed by monthly summaries. For information write:

National Earthquake Information Service — (303) 234–3994
Hours: 8:00–4:30
U.S. Geological Survey
Box 25046, STOP 967
Denver Federal Center
Denver, CO 80225.

National Technical Information Service

Some Geological Survey reports, including computer programs, data and information supplemental to map or book publications, and data files, are released through the National Technical Information Service (NTIS). Reports available through NTIS include *Water-Resources Investigations* (generally of local interest) and Computer Contributions. Geological Survey reports that are released through NTIS, together with their NTIS order numbers and prices, are announced in *New Publications of the Geological Survey.*

Availability: These reports, available either in paper copies, in microfiche, or sometimes as magnetic tapes, can be purchased ONLY from:

National Technical Information Service
U.S. Department of Commerce
Springfield, VA 22161.

National Water Data Exchange

The National Water Data Exchange (NAWDEX) serves as a clearinghouse for hydrologic data acquired by Federal and non-Federal organizations which are members of NAWDEX. These organizations collect water information, such as data on surface water, water quality, and ground water; the exchange refers public requests to the holder of the data.

Availability: Requests for information or assistance in acquiring water data collected by other agencies may be directed to the NAWDEX Program Office in Reston, Va., or to Local Assistance Centers currently located at many of the Water Resources Division district offices (p. 145).

National Water Data Exchange — (703) 860–6031
U.S. Geological Survey — Hours: 7:45–4:15
National Center, STOP 421
Reston, VA 22092

Water data collected by the Geological Survey and placed in the National Water Data Storage and Retrieval System (WATSTORE) may be obtained from:

Office of the Chief Hydrologist — (703) 860–6921
U.S. Geological Survey — Hours: 7:45–4:15
National Center, STOP 409
Reston, VA 22092.

New Publications of the Geological Survey

New publications, including topographic quadrangle maps, are announced monthly in "New Publications of the Geological Survey."

Availability: A free subscription to this list may be obtained on application to:

U.S. Geological Survey — (703) 860–6713
National Center, STOP 329 — Hours: 7:45–4:15
Reston, VA 22092.

News media services

Press and feature news releases and related visual materials pertaining to Geological Survey activities

and programs are prepared by the Survey's Information Office for use by the news media.

Availability: These materials may be obtained from:

Information Office
U.S. Geological Survey
National Center, STOP 119
Reston, VA 22092.

(703) 860–7444
Hours: 7:45–4:15

Oil and gas lease information

See *Mineral lease information.*

Open-File Reports

Manuscript reports, maps, data, and other preliminary material are available for public use and consultation. Since May 1974, all reports and maps released only in the open files have been listed monthly in *New Publications of the Geological Survey.* Annual listings of reports issued prior to this date are published as *Circulars* ("Reports and maps of the Geological Survey released only in the open files").

Availability: Open-File Reports are available only for public inspection at one or more of the Geological Survey Libraries (see *Library services*), *Public Inquiries Offices,* and other depositories listed in "New Publications of the Geological Survey," Arrangements can generally be made to reproduce these reports at private expense by writing to the appropriate depository, where the reproducible materials are held.

Outer Continental Shelf oil and gas lease information

See *Mineral lease information.*

Photographic Library

The Geological Survey maintains a special collection of approximately 140,000 photographs of subjects taken during geological studies of the United States and its territories from 1869 to the present. Of these photographs, about 132,000 are black and white, and most of the remainder are color transparencies. A *Popular Publication,* "Geological Survey Photographic Library," describes how to acquire copies of photographs.

Availability: The Photographic Library is located in Denver, Colo., and may be used by the general public. Persons may select material from the collection for reproduction by visiting the library. Photographs may also be selected through a search of the illustrations in Geological Survey publications. A charge is made for prints, copy negatives, and duplicates of 35-mm color transparencies. For further information contact:

Photographic Library
U.S. Geological Survey
Box 25046, STOP 914
Denver Federal Center (Bldg. 25)
Denver, CO 80225.

(303) 234–4004
Hours: 8:00–4:30

Popular Publications

In addition to its technical publications, the Geological Survey also publishes a series of popular publications to inform the general public and to answer inquiries about geology, hydrology, topographic mapping, and related earth sciences. Currently available booklets are listed in a catalog "Popular Publications of the Geological Survey."

Availability: Single copies of the catalog and any popular publication are available free on request from *Public Inquiries Offices* or *Branch of Distribution Offices.* Additional copies or bulk quantities may be purchased from the *Branch of Distribution Office* in Arlington, Va.

Program information

Technical programs of the Geological Survey are carried out by the Topographic, Geologic, Water Resources, and Conservation Divisions and the Land Information and Analysis Office. Information about current program activities may be obtained from several sources. Questions of a general nature should be directed to the *Public Inquiries Offices.* Questions about current Geological Survey activities in a particular State should be referred to the Survey's Water Resources Division District Office in that State (p. 145). Current Water Resources projects are described in *State Water-Resources Investigations Folders.* Technical questions about the Survey's programs and policies should be addressed to the appropriate Division Chief; Chief, Land and Information Analysis Office; or the Director, Geological Survey (p. 143).

Public Inquiries Offices

The Geological Survey operates nine Public Inquiries Offices to provide convenient points of contact for obtaining information about Survey products. Each office (except those in Reston, Va., and Washington, D.C.) maintains a reference library of Survey publications and serves as a depository for selected *Open-File Reports.* The Anchorage, Alaska; Los Angeles, Calif.; Spokane, Wash.; and Washington, D.C., offices have a microfilm reference file of Landsat (formerly ERTS) remote-sensing images of the United States and can assist users with ordering space photographs from the *EROS Data Center.* Each office (except that in Reston, Va.), acting as a sales agent for the Superintendent of Documents, sells topographic, geologic, and hydrologic maps relating to its geographic area, and book reports and maps of general interest. Mail orders for maps should be sent to the appropriate *Branch of Distribution Office.* Public Inquiries Offices are located in the following states:

Alaska:
Public Inquiries Office (907) 277–0577
U.S. Geological Survey Hours: 9:00–4:30
108 Skyline Bldg.
508 Second Avenue
Anchorage, AK 99501

California:
Public Inquiries Office (213) 688–2850
U.S. Geological Survey Hours: 9:00–4:30
7638 Federal Bldg.
300 North Los Angeles Street
Los Angeles, CA 90012

Public Inquiries Office (415) 556–5627
U.S. Geological Survey Hours: 8:30–4:00
504 Custom House
555 Battery Street
San Francisco, CA 94111

Colorado:
Public Inquiries Office (303) 837–4169
U.S. Geological Survey Hours: 8:30–4:00
1012 Federal Bldg.
1961 Stout Street
Denver, CO 80202

District of Columbia:
Public Inquiries Office (202) 343–8073
U.S. Geological Survey Hours: 8:15–3:45
1028 GSA Bldg.
19th and F Streets NW.
Washington, DC 20244

Texas:
Public Inquiries Office (214) 749–3230
U.S. Geological Survey Hours: 9:00–4:30
1C45 Federal Bldg.
1100 Commerce Street
Dallas, TX 75202

Utah:
Public Inquiries Office (801) 524–5652
U.S. Geological Survey Hours: 9:00–4:30
8102 Federal Bldg.
125 South State Street
Salt Lake City, UT 84138

Virginia:
Public Inquiries Office (703) 860–6167
U.S. Geological Survey Hours: 8:15–3:45
1C402 National Center, STOP 302
12201 Sunrise Valley Drive
Reston, VA 22092

Washington:
Public Inquiries Office (509) 456–2524
U.S. Geological Survey Hours: 9:00–4:30
678 U.S. Courthouse
West 920 Riverside Avenue
Spokane, WA 99201.

Publications of the Geological Survey

Results of research and investigations by the Geological Survey are made available to the public through Professional Papers, Bulletins, Water-Supply Papers, Circulars, miscellaneous reports, and several map and atlas series. All books, maps other than topographic quadrangle maps, and related Survey publications are listed in the catalogs, "Publications of the Geological Survey, 1879–1961" and "Publications of the Geological Survey, 1962–1970." Yearly supplements keep these catalogs up to date (see also *New Publications of the Geological Survey*).

Selecting maps from stock at a Public Inquiries Office.

Availability: The catalogs and annual supplements are available free on request from Geological Survey *Public Information Offices* and *Branch of Distribution Offices*.

Reports

See *Books and reports*.

Satellite image maps

Satellite images are converted into a map by fitting a common reference grid to the image or mosaic. The Geological Survey publishes satellite-image maps at scales of 1:250,000 and 1:500,000 and in various experimental formats and renditions of the images.

Availability: Contact the *National Cartographic Information Center* for information on map coverage. Satellite image maps may be purchased from *Public Inquiries Offices* and from the *Branch of Distribution Office* at Arlington, Va.

Space images

See the *EROS Data Center*.

State list of publications on hydrology and geology

"Geologic and Water-Supply Reports and Maps, (State)," list Geological Survey publications by State and give the location of *Depository libraries* where Survey reports and maps may be consulted.

Availability: They are available free on request from *Public Inquiries Offices* and from the *Branch of Distribution Office* at Arlington, Va.

State Water-Resources Investigations Folders

A series of folders entitled "Water-Resources Investigations in (State)" inform the public about the current water-resources program of the Geological Survey in the 50 States and Puerto Rico, the Virgin Islands, Guam, and American Samoa.

Availability: The folders are available free on request from Survey Water Resources Division District Offices (p. 145) or from:

Reports Section
U.S. Geological Survey
National Center, STOP 439
Reston, VA 22092.

(703) 860–6881
Hours: 7:45–4:15

Technical exhibits

More than 200 exhibit panels are available on loan from the Geological Survey for display at professional meetings, technical conventions, and other public gatherings. These panels illustrate recent work of the Geological Survey in conservation, geology, hydrology, and topography. Structural supports and lighting for free-standing displays are provided.

Availability: Geological Survey exhibit panels are available on loan. For information contact any one of the following offices:

Branch of Exhibits
U.S. Geological Survey
National Center, STOP 301
Reston, Va. 22092

(703) 860–6010
Hours: 7:45–4:15

Branch of Exhibits
U.S. Geological Survey
Box 25046, STOP 960
Denver Federal Center
Denver, CO 80225

(303) 234–3566
Hours: 8:00–5:00

Branch of Exhibits
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025.

(415) 323–8111
ext. 2389
Hours: 7:45–4:15

Techniques of Water-Resources Investigations

Techniques of Water-Resources Investigations describe the methodology and techniques used by the Geological Survey to collect, analyze, and process hydrologic data. These reports are listed in *Publications of the Geological Survey*. New reports are announced in *New Publications of the Geological Survey*.

Availability: Techniques of Water-Resources Investigations are sold by *Public Inquiries Offices, Branch of Distribution Office*, Arlington, Va., and the Superintendent of Documents (see "Instructions for ordering book reports and maps").

Topographic Instructions

Topographic Instructions describe the techniques and criteria used by the Geological Survey to obtain aerial photographs, make field surveys, and compile topographic maps. These reports are listed in *Publications of the Geological Survey*. New reports are announced in *New Publications of the Geological Survey*.

Availability: Topographic Instructions can be obtained ONLY from:

Technical Information Office
U.S. Geological Survey
National Center, STOP 520
Reston, VA 22092.

(703) 860–6275
Hours: 7:45–4:15

Topographic maps

The Geological Survey publishes the national topographic map series, which consists of several quadrangle and other map series. They include quadrangle maps at scales of 1:24,000, 1:20,000 (Puerto Rico), 1:62,500, 1:63,360 (Alaska), 1:100,000, 1:250,000, and 1:1,000,000. In addition there are metropolitan-area maps, county maps, National Park maps, State and U.S. base maps, maps of Antarctica, and special maps of principal rivers and their flood plains. Orthophotoquads, *Satellite image maps,* and other special-purpose maps are also published by the Survey. *Topographic Map Indexes* showing the coverage of published maps for each State are available free upon request. See also *Advanced material available from topographic mapping* and *Map separates.*

Availability: Topographic maps may be consulted in Geological Survey Libraries (see *Library services)* or *Depository libraries.* Maps may be purchased over the counter from *Public Inquiries Offices* or from *Branch of Distribution Offices* (see "Instructions for ordering books and maps"). Information about the availability of maps published by the Geological Survey or maps available from other agencies may be obtained from the *National Cartographic Information Center.*

Topographic Map Indexes

State index maps, "Index to Topographic Mapping in (State)," show the location of available 7.5-minute quadrangles (1:24,000) and 15-minute quadrangles (1:62,500). In addition, the indexes list other special maps and sheets pertinent to a particular State and of general interest. Depository libraries, where published maps of the Geological Survey may be consulted, and commercial dealers, who carry in stock some or all of the maps described in the index, are also listed.

Availability: State index maps are available free on request from *Public Inquiries Offices,* the *National Cartographic Information Center,* regional *Mapping Centers,* and the *Branch of Distribution Office* at Arlington, Va.

Water data

The Geological Survey collects a wide range of water-related information (see also *Flood information).* Much of this information is stored in computer

files soon after it is collected and can be retrieved by computer terminals located in most Water Resources Division District Offices. Much of the data is also published annually for each State.

Beginning with the 1960 water year (October 1, 1959), daily streamflow records, discharge measurements, reservoir contents, and station descriptions have been published annually on a State-boundary basis in "Water Resources Data for (State): Part 1, Surface Water Records." The data are also published in Water-Supply Papers at 5-year intervals. The first group of "Surface Water Supply" papers covers the water years 1961–65.

Indexes, which list all streamflow and reservoir stations for which records have been published in Geological Survey reports through September 30, 1970, are titled "Index of Surface Water Records to September 30, 1970—Part (number and basin)."

Annual publication of water-quality records began in 1964 with "Water Resources Data for (State): Part 2, Water Quality Records." The annual publication in the Geological Survey Water-Supply Papers of "Quality of Surface Water of the United States" by drainage basins has been continued. Distribution of the State water-resources data (parts 1 and 2) is limited.

Availability: Inquiries about the availability of water data collected by the Geological Survey should be directed to the Survey's Water Resources Division District Office in the appropriate State. Similarly, requests for free copies of "Water Resources Data for (State)" should also be addressed to the appropriate District Office (p. 145). Indexes of surface-water records are published as *Circulars*.

Information about Federal, State, and local agency collection of various water data is available in three national indexes to the "Catalog of Information on Water Data" supplemented by index maps showing the location of water-data-collection sites. Current editions of the indexes are as follows: (1) Station listings for streamflow and stage, quality of surface water, and quality of ground water, 1974 (21 volumes by water-resources regions); (2) index to areal investigations and miscellaneous water-data activities, 1970 (one volume); and (3) index to ground-water stations, 1968 (one volume). These indexes are available free on request. Address inquiries to:

Office of Water Data Coordination (703) 860–6931
U.S. Geological Survey Hours: 7:45–4:15
National Center, STOP 417
Reston, VA 22092.

Assistance in determining the availability of water data may be obtained from the *National Water Data Exchange*. Inquiries about accessing or purchasing magnetic tape copies of Survey water-data files should be addressed to:

Office of the Chief Hydrologist (703) 860–6921
U.S. Geological Survey Hours: 7:45–4:15
National Center, STOP 409
Reston, VA 22092.

Water-Resources Investigations reports

Water-Resources Investigations reports describe the results of investigations which are principally of local interest, such as the water resources of intrastate river basins, counties, or specific sites. Reports are listed in *Publications of the Geological Survey*. New reports are announced in *New Publications of the Geological Survey*.

Availability: Most Water-Resources Investigations reports are microfilmed and are available from the *National Technical Information Service*. Selected reports are not sold but may be examined at local Geological Survey offices listed in *New Publications of the Geological Survey* and at:

Water Information Group (703) 860–6867
U.S. Geological Survey Hours: 7:45–4:15
National Center, STOP 420
Reston, VA 22092.

Water Resources Review

The Water Resources Review, prepared in cooperation with the Canadian Department of the Environment, is a monthly summary of streamflow and ground-water conditions, reservoir contents, and other water data of current interest to the United States and southern Canada. Special-purpose issues describing floods or other hydrologic events and summary issues are published as needed.

Availability: Subscriptions are free on request to:

Water Resources Review (703) 860–6884
U.S. Geological Survey Hours: 7:45–4:15
National Center, STOP 419
Reston, VA 22092.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest 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 interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

Cover photograph of the USGS National Center
courtesy of Edward B. Templeman, USGS