# THE SEVENTH ANNUAL INTERAGENCY GEOTHERMAL COORDINATING COUNCIL REPORT FISCAL YEAR 1982

MARCH 30, 1983

# 1.0 INTRODUCTION

Geothermal energy is the natural heat of the earth, and can be tapped as a clean, safe, and economical alternative source of energy. Three types of geothermal resources (hydrothermal, geopressured and hot dry rock) are expected to be commercially exploited by the year 2000. Of these, only hydrothermal resources, which are underground accumulations of hot water or steam, are technically and economically feasible for exploitation at this time. Figure 1 is a map of the United States indicating known and potential hydrothermal resources. Some of these resources are being tapped now, but much more of this energy resource is recoverable with current or near current technology. Therefore, those resources could make a significant contribution both to increasing domestic energy supplies, and to reducing the United States' dependence on imported oil. Moreover, it can be used for various purposes: electric power production, residential and commercial space heating and cooling, industrial process heat, and agricultural process applications.

Although not intended as a statement of goals or targets, energy projections were prepared in July 1982 in conjunction with the National Energy Policy Plan. With a midrange total U.S. energy consumption in 1990 and 2000 of 87 and 99 quads, respectively, geothermal electric production of 0.2 and 0.4 quads and direct-heat use, of 0.07 and 0.2 quads are projected. Although these contributions would be less than one percent of national energy consumption, regional contributions are expected to exceed several percent in a number of areas throughout the western U.S., with a much larger percentage in certain areas of California, Nevada, Hawaii, Utah, and parts of the Cascade Range. Thus, geothermal energy represents one of several alternate energy sources which will play an increasingly important role in the U.S. energy future.

The Federal government has been actively involved in the development of geothermal energy since 1970, when the Geothermal Steam Act was passed. Since then it has been engaged in the leasing of Federal lands as well as numerous research, development, and demonstration programs to investigate the use of geothermal energy. This report summarizes the accomplishments of the Federal government during fiscal year 1982, and describes Federal geothermal energy programs. Table 1 presents a chronological history of significant geothermal energy developments.

In 1982, an overall objective of the Federal geothermal program was to respond to the needs of private industry by undertaking long-term, high-risk, potentially high-payoff R&D, thus enabling private industry to undertake commercial development of geothermal resources; the Federal Government provided an appropriate level of assistance while removing technical barriers to exploration and development. Private industry's leading role in the direct planning and construction of geothermal energy systems other than DOE sponsored test or pilot plants, reflects the Administration's policy of relying on the marketplace for energy industrialization activities, including geothermal.

GURE 1

# Known and Potential Hydrothermal Resources

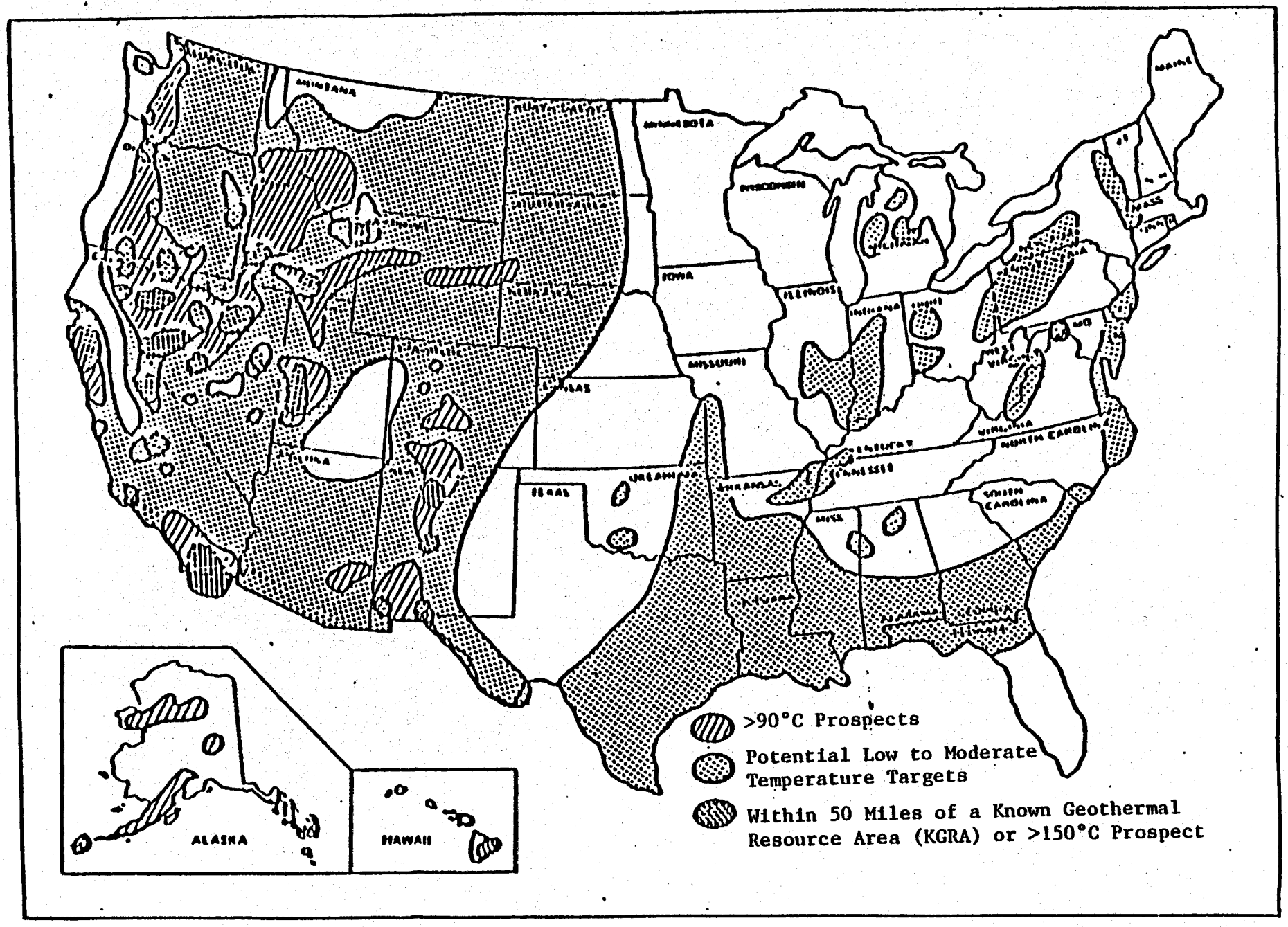

TABLE 1

SIGNIFICANT EVENTS IN THE DEVELOPMENT
OF GEOTHERMAL ENERGY IN THE UNITED STATES

| | |
|---|---|
| 1894 | District heating implemented in Boise, Idaho |
| 1900 | Hot water provided to homes in Klamath Falls, Oregon |
| 1916 | Power generation at The Geysers resort |
| 1927 | First exploratory geothermal wells were drilled in Imperial Valley, California by Pioneer Development Company |
| 1959 | Small pilot plant operated near Niland, California on Sinclair No. 1 well |
| 1960 | Commercial electricity generated from dry steam at The Geysers, California |
| 1970 | Geothermal Steam Act Passed (PL 91-581) |
| 1972 | NSF became lead agency for Federal Geothermal Programs |
| 1973 | USGS, AEC, NSF prepared the first Federal Geothermal Program Plan |
| 1974 | Geothermal RD&D Act passed (PL 93-410) which included the establishment of the Geothermal Loan Guaranty Program (GLGP) |
| 1975 | ERDA formed; Division of Geothermal Energy formed primarily from NSF, AEC staff |
| | USGS released first national geothermal resource estimates and inventory |
| 1977 | DOE formed; DGE continued to manage the program |
| | Bureau of Reclamation successfully completed desalting tests to produce fresh water from geothermal brines |
| 1978 | Energy Tax Act passed (PL 95-618) |
| | EPA issued pollution control guidelines for geothermal energy development |
| | Successful Hot Dry Rock experiment conducted in New Mexico |
| | First geothermal crop-drying plant built in Nevada |

TABLE 1

SIGNIFICANT EVENTS IN THE DEVELOPMENT
OF GEOTHERMAL ENERGY IN THE UNITED STATES (Continued)

| | |
|---|---|
| 1979 | USGS released updated national geothermal resource estimates and inventory |
| | Streamlining task force recommended measures to speed Federal leasing to IGCC |
| | U.S. Navy awarded a contract to develop 75 MWe at the Coso KGRA on the Naval Weapons Center, China Lake, California |
| | First geothermal electricity produced from Federal lands, at The Geysers, California |
| | World's first experimental binary cycle plant (~10 MWe) built by industry at East Mesa, California |
| | Issued the first Geothermal Loan Guarantee to Geothermal Food Processors, Inc., for an onion drying plant at Brady Hot Springs, Nevada |
| 1980 | World's largest single geothermal power unit (129 MWe) generated electricity at The Geysers, California |
| | 10 MWe flash-steam plant built by industry at Brawley, California |
| | First electric power from a Hot Dry Rock resource produced at Fenton Hill, New Mexico |
| | First geothermal ethanol plant began production at La Grande, Oregon, under private funding |
| | First 5 DOE-sponsored field demonstrations of direct heat applications became operational |
| | First deep geothermal reservoir confirmation well drilled in Atlantic Coastal Plain, near Crisfield, Maryland |
| | Crude Oil Windfall Profits Tax Act passed, providing tax credit increase for geothermal equipment (PL 96-223) |
| | Energy Security Act, containing Title VI, "The Geothermal Energy Act of 1979", passed (PL 96-294) |
| 1981 | First U.S. geothermal electric generation plant outside the 48 contiguous states brought on-line in the Puna resource areas in Hawaii |
| | The Insurance Company of North America began offering insurance against the financial risk of reservoir failure |

TABLE 1

SIGNIFICANT EVENTS IN THE DEVELOPMENT
OF GEOTHERMAL ENERGY IN THE UNITED STATES (Continued)

The practical demonstration of generating electricity from moderate-temperature geothermal fluids was accomplished at Raft River, Idaho

A mobile well-head generator with a net output of 1.6 MWe was installed at Roosevelt Hot Springs, Utah

USGS research drilling at Newberry Volcano, Oregon, indicated for the first time that temperatures (256°C at 3,057 ft) sufficient for electrical production existed in the Cascade Range

A 76 MW geothermal electric powerplant was certified by the Federal Energy Regulatory Commission as a Qualifying Small Power Production plant using a renewable energy source. The plant is to be constructed in the Imperial Valley, California by Republic Geothermal, Inc. Qualifying power production facilities are entitled to the benefits specified under Section 210 of PURPA

1982 A 10 MWe flash plant utilizing hypersaline brine began operation at the Salton Sea, KGRA, California

On January 19, 1982, the Secretary of Interior established the Minerals Management Service (MMS) by Order No. 3071. MMS performs the functions previously carried out by the Conservation Division of the USGS. On December 3, 1982, by Order No. 3087, the Secretary transferred the functions performed by the Onshore Minerals Management Service from MMS to the Bureau of Land Management

An 80 MW geothermal electric powerplant to be constructed by Occidential Geothermal, Inc. in Lake County, California and a 49 MW geothermal electric powerplant to be constructed by Republic Geothermal, Inc. and the Parsons Corporation in the Imperial Valley, California were certified by the FERC as qualifying facilities. Magma Power Company and Magma Development Corporation issued a public notice of self-qualification for an existing 11 MW geothermal powerplant located in East Mesa, California

In an effort by DOI to accelerate the geothermal leasing program, a record 16 competitive lease sales were held in which 578,656 acres were offered

TABLE 1

SIGNIFICANT EVENTS IN THE DEVELOPMENT
OF GEOTHERMAL ENERGY IN THE UNITED STATES (Concluded)

| | |
|---|---|
| | USGS completed the first quantitative national assessment of low-temperature (< 90°C) geothermal resources of the United States |
| | An additional 140 MWe of power generating capacity from geothermal energy was brought on line in 1982, bringing current on-line capacity to 1167 MWe |

The efficient and timely development of geothermal resources depends on the coordinated efforts of Federal, state, and local governments; industry, consumer and environmental groups; and private citizens. Federal responsibilities and programs are divided among a number of agencies whose activities are coordinated through the Interagency Geothermal Coordinating Council (IGCC), which was established in 1974 by PL 93-410. The IGCC brings together all of the Federal agencies with responsibilities related to geothermal energy development, and serves as a forum for interagency program coordination and information exchange.

The IGCC consists of the Federal agencies which participate in the geothermal program and is responsible for supervising and coordinating the activities of the Federal government community. This responsibility is spelled out in the Geothermal Research, Development, and Demonstration Act of 1974 (PL 93-410); specifically it is "...to coordinate those Federal plans, activities, and policies which are related to or impact on geothermal energy, including auxiliary activities of agencies not represented in the council membership". The Council, through the Chairman, may make recommendations to the appropriate agencies and the President with regard to alternative policies or action considered necessary or desirable to expedite the development and utilization of geothermal energy resources. Member agencies include the Departments of Energy, Commerce, Defense, Interior, Housing and Urban Development, Treasury and Agriculture, and the Environmental Protection Agency. The Federal Geothermal Program budget of the member agencies is presented in Table 2.

## 2.0 LEASING

The goal of Federal geothermal leasing activities is to make lands available to industry for exploration and development. Leasing is accomplished by the Bureau of Land Management, with the consent of the Forest Service where National Forest System Lands are involved.

During FY 1982, the Federal government issued leases for 1,044,390 acres, more than twice the expectation of the Leasing Policy Development Office (500,000 acres per year). Federal leases are issued either through the competitive or non-competitive leasing program.

### Competitive Leasing

The Bureau of Land Management (BLM) conducts competitive geothermal lease sales several times each year. At the lease sales, parcels of land located in Known Geothermal Resource Areas (KGRAs) are offered to the public. Typically, a lease sale involves several tracts of land; each tract is bid on separately. The highest qualified bidder receives rights to explore and develop the geothermal resources, conditioned on compliance with applicable laws, regulations, and lease terms of the sale, and geothermal operational orders.

# TABLE 2

## FEDERAL FUNDING FOR GEOTHERMAL ENERGY ($000)*

| ORGANIZATION UNIT | Actual 1979 | Actual 1980 | Actual 1981 | Actual 1982 | Estimated 1983 | Requested 1984 |
|---|---|---|---|---|---|---|
| **Department of Agriculture** | | | | | | |
| U.S. Forest Service | 780 | 750 | 700 | 600 | 525 | 525 |
| **Department of Defense** | | | | | | |
| Navy | 300 | 230 | 930 | 848 | 1,155 | 1,450 |
| Air Force | 0 | 200 | 1,010 | 182 | 1,486 | 0 |
| DOD Total | 300 | 430 | 1,940 | 1,030 | 2,641 | 1,450 |
| **Department of Energy** | | | | | | |
| Conservation & Renewable Energy | 152,990 | 149,870 | 142,521 | 43,713 | 87,700 | 15,553 |
| Office of Energy Research | 2,100 | 3,102 | 3,305 | 2,650 | 2,120 | 2,100 |
| Environment | 2,820 | 1,950 | 723 | 0 | 0 | 0 |
| GLGP (Administrative Expenses) | 0 | 181 | 193 | 200 | 400 | 100 |
| DOE Total | 157,910 | 155,103 | 146,742 | 46,563 | 90,220 | 17,753 |
| **Department of Interior** | | | | | | |
| National Park Service | ** | ** | ** | 100 | 50 | 150 |
| Fish & Wildlife Service | 200 | 200 | 70 | 100 | 50 | 50 |
| Bureau of Land Management | 2,590 | 2,550 | 2,650 | 2,233 | 2,261 | *** |
| Bureau of Mines | 1,050 | 800 | 400 | 384 | 300 | 0 |
| Bureau of Reclamation | 550 | 910 | 60 | 60 | 30 | 0 |
| USGS, Geothermal Research Program | 12,043 | 10,047 | 7,889 | 7,953 | 6,953 | 5,046 |
| MMS, Geothermal Evaluation & Lease Regulation | 750 | 860 | 898 | 1,822 | 1,600 | *** |
| DOI Total | 17,183 | 15,367 | 11,069 | 12,652 | 11,244 | 5,246 |
| Environmental Protection Agency | 920 | 850 | 1,550 | 0 | 0**** | 0 |
| TOTAL FEDERAL GEOTHERMAL PROGRAM BUDGET | 177,093 | 172,500 | 162,001 | 60,845 | 104,630 | 24,974 |

* Budget authority rounded to nearest thousand.
** Not known.
*** Not known due to MMS/BLM Consolidation.
**** While the FY 83 EPA budget does not target resources specifically for geothermal, other R&D at EPA (e.g., disposal of liquid effluents) or programmatic activities (e.g., permitting assistance to states) may be applicable to geothermal energy.

During FY 1982, the Federal government received $23,550,522 of acceptable bonus bids for 203,413 acres leased through the competitive process. Table 3 is a breakdown of acreage leased competitvely in FY 1982 on a state-by-state basis and includes acceptable bonus bids generated from these sales. Table 4 presents acceptable bonus bids from competitve lease sales in FY 1982 and the total for all years (1974-1982). Table 5 delineates the average high bid price per acre in FY 1982 at KGRA sites. With the exception of 1974 and 1978 when Federal land at The Geysers was offered, 1982 saw the highest average price per leased acre. Since 1980, the average price per acre has increased from $32.52 in 1980 to $84.41 in 1981 to $108.86 in 1982. A major factor in these increases has been a better understanding of the nature, occurrence, and utilization of geothermal resources as a result of R&D studies. Table 6 is a summary of the competitive leasing process and indicates acreage leased by state, by year.

## Non-competitive Leasing

Non-competitive leases are issued by the Federal government on land not located within a KGRA. During FY 1982, 804,977 acres were leased through this process. Table 7 summarizes the non-competitive leasing activity.

## Post-lease Operations

The Office of the Deputy Minerals Manager for Geothermal (DMM, Geothermal) is responsible for the regulation of all phases of post-lease geothermal development on Federal leases. The level of geothermal activity on Federal leases during fiscal year 1982 remained fairly constant when compared with the previous two fiscal years. The number of shallow temperature gradient wells drilled decreased from 106 and 124 for FY 1980 and FY 1981 respectively, to 89 for FY 1982. However, the number of deep wells drilled in FY 1982 increased to 35 from FY 1980 and FY 1981 totals of 27 and 30.

Of the twelve power plants in various stages of certification or construction at the end of FY 1982, four are located on Federal land and two on Federal leases on Stock-Raising Homestead Land. Construction of the Northern California Power Agency #2 110 MW power plant in The Geysers was approximately 90% complete, and construction of the Sacramento Municipal Utility District 72 MW plant was 50% complete. The remaining three plants in The Geysers are in the certification process or the early stages of construction. At Roosevelt Hot Springs, Utah, the Utah Power and Light Company and Phillips Petroleum Company began construction of a 20 MW power plant at the end of FY 1982. Phillips drilled two new production wells during FY 1982 at Roosevelt Hot Springs, and testing showed these to be the best producing wells in the unit.

TABLE 3

TOTAL ACREAGE LEASED COMPETITIVELY IN FY 1982

| State | Acres | Acceptable Bonus Bids |
|---|---|---|
| Utah | 9,230 | $74,968 |
| New Mexico | 4,391 | 14,270 |
| Oregon | 16,411 | 67,636 |
| California | 168,411 | 23,386,248 |
| Idaho | 1,883 | 6,311 |
| Washington | 2,307 | 231 |
| Arizona | 780 | 858 |
| | 203,413 | $23,550,522 |

TABLE 4

ACCEPTABLE BONUS BIDS - COMPETITIVE LEASE SALES

| State | FY 1982 | Total for all years |
|---|---|---|
| California | $23,386,248 | $57,829,646 |
| Utah | 74,968 | 4,457,192 |
| Nevada | 0 | 3,950,048 |
| New Mexico | 14,270 | 1,933,588 |
| Oregon | 67,636 | 2,210,223 |
| Idaho | 6,311 | 6,311 |
| Colorado | 0 | 13,577 |
| Washington | 231 | 231 |
| Arizona | 858 | 858 |
| | $23,550,522 | $70,401,674 |

TABLE 5

AVERAGE HIGH BID PRICE PER ACRE
FY 1982

| State | KGRA Site | Average Price Per Acre |
|---|---|---|
| California | East Brawley | $150.66 |
| | The Geysers-Calistoga | 878.77 |
| | Randsburg | 114.16 |
| | Glass Mountain | 258.85 |
| | Lake City - Surprise Valley | 3.00 |
| | Coso Hot Springs | 12.00 |
| | Wendel - Amedee | 20.25 |
| | Knoxville | 31.05 |
| | Bodie | 2.00 |
| | Mono-Long Valley | 20.66 |
| | Salton Sea | 9.56 |
| New Mexico | Socorro Peak | 3.25 |
| Arizona | Clifton | 1.10 |
| Oregon | Alvord | 9.37 |
| | Crump Geyser | 2.54 |
| | Klamath Falls | 2.08 |
| | Vale Hot Springs | 1.53 |
| Idaho | Raft River | 3.35 |
| Utah | Cove Fort - Sulphurdale | 8.63 |
| | Roosevelt Hot Springs | 1.31 |
| Washington | Indian Heaven | 0.10 |
| | GRAND TOTAL AVERAGE: | $108.86* |

* The acreage leased at each site is accounted for in this weighted average.

TABLE 6

COMPETITIVE LEASING BY STATE, TOTAL ACREAGE LEASED, BY YEAR

| STATE | 1974 - 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982* | Total for all Years |
|---|---|---|---|---|---|---|---|---|
| Nevada | 120,996 | 36,663 | 9,322 | 24,298 | 20,419 | 15,304 | 0 | 227,002 |
| Utah | 76,539 | 12,788 | 1,658 | 0 | 0 | 0 | 9,230 | 100,215 |
| New Mexico | 32,564 | 48,065 | 8,767 | 7,063 | 0 | 13,835 | 4,391 | 114,685 |
| Oregon | 68,872 | 0 | 5,818 | 0 | 32,630 | 0 | 16,411 | 123,732 |
| California | 36,937 | 2,856 | 4,395 | 6,959 | 10 | 84,914 | 168,411 | 306,782 |
| Idaho | 24,903 | 6,985 | 0 | 0 | 0 | 0 | 1,833 | 33,711 |
| Colorado | 5,036 | 0 | 0 | 0 | 0 | 0 | 0 | 5,036 |
| Washington | 0 | 0 | 0 | 0 | 0 | 0 | 2,307 | 2,307 |
| Arizona | 0 | 0 | 0 | 0 | 0 | 0 | 780 | 780 |
| Total Acres Leased | 365,847 | 107,357 | 29,960 | 38,320 | 53,059 | 114,053 | 203,413 | 914,310 |

* Totals include pending leases which may take up to 1 year after sale to be awarded.

TABLE 7

CUMULATIVE NONCOMPETITIVE LEASE TOTALS, 1976 - 1982

| Year | Leases Issued | Acreage Leased* |
|---|---|---|
| 1976 | 656 | 1,141,980 |
| 1977 | 904 | 1,500,005 |
| 1978 | 1,117 | 1,930,163 |
| 1979 | 1,332 | 2,314,670 |
| 1980 | 1,675 | 2,933,901 |
| 1981 | 1,958 | 3,446,436 |
| 1982 | 2,411 | 4,256,211 |

* Includes acreage subsequently relinquished.

Of the six power plants under certification or construction on private lands, three will utilize wells located either on Federal land or within a Federal unit. In addition, plans for Environmental Baseline Data Collection, a preliminary step for approval of a power plant, were submitted for three Federal areas in Nevada. Royalties collected in FY 1982 from geothermal production on Federal land totalled approximately $2,000,000 in California and $5,000 in New Mexico.

## 3.0 HYDROTHERMAL RESOURCE IDENTIFICATION, ASSESSMENT, AND EXPLORATION

The United States Department of Energy and the United States Geological Survey have several programs designed to evaluate the geothermal energy potential in the U.S. These programs are complementary in nature but focus on different aspects of this goal. USGS activities emphasize geothermal resource inventory and assessment work; DOE activities focus on more detailed study of specific resource areas. The main objectives of the programs are to: (1) charactize the geological, hydrological, geochemical, and geophysical nature of the various types of geothermal resources; (2) estimate the location, distribution, and energy content of both the presently identified and the undiscovered geothermal resources of the U.S.; (3) develop resource assessment technology; (4) conduct regional resource assessments and national resource inventories, and (5) contribute to the confirmation of selected specific geothermal reservoirs. The programs also address geoenvironmental effects and issues dealing with longevity of geothermal systems.

Major accomplishments in FY 1982 included:

- Completed the first quantitative national assessment of low-temperature (less than 90°C) geothermal resources of the United States. This provides an expanded basis for estimating the potential for non-electrical uses of geothermal energy throughout the United States.

- Completed the remaining maps of a six-map series that shows the distribution, rock type, and age of young volcanic centers in the United States. These maps provide information needed to assess geothermal potential related to the large number of magmatic heat sources in the western U.S.

- Initiated field studies and office compilation of a new geologic map of the Cascade Range. This map will provide key information for the regional assessment of the large geothermal potential that is inferred but presently undiscovered in the Cascade Range from Washington into northern California.

- Completed a seismic refraction survey in the Mt. Shasta-Medicine Lake Highlands region of the Cascade Range in northern California; aeromagnetic and gravity surveys of the Oregon and California parts of the Cascade Range; and a new geologic map of Newberry Volcano in central Oregon. Subsequent interpretation of these data will provide a framework for assessing the geothermal potential of the Cascade Range and for characterizing the nature of this apparently large but relatively unknown resource.

- Published the results of a geologic study of the East Rift Zone of Kilauea Volcano in Hawaii. Potential magmatic heat sources were identified in this important developing geothermal area.

- Completed aeromagnetic data collection for the San Francisco Volcanic Field in Arizona. This completes all planned geophysical surveys for the geothermal assessment of this region.

## 4.0 HYDROTHERMAL TECHNOLOGY DEVELOPMENT

The process of locating, producing, and utilizing large volumes of fluids from high temperature, fractured, hard rock formations imposes a number of technological and economic constraints on geothermal development which forestall full-scale resource exploitation by the private sector. Conventional oil and gas technology, presently employed for exploration, drilling, reservoir assessment, and production of geothermal fields has proven expensive, unreliable and frequently non-functional in the hot, chemically hostile, downhole geothermal environment. Surface equipment, including power plant components, lack the efficiency and reliability for electric power generation for all except the high temperature, high flow rate, most benign hydrothermal reservoirs. As a result, only a small percent of the available hydrothermal reservoirs can be economically exploited with current technology.

The current R&D activities are in areas of high-risk and are directed toward substantially reducing hard rock drilling costs, increasing moderate temperature energy conversion efficiency through binary cycle technology, increasing reservoir production rates through well stimulation techniques and improved downhole brine pumps, developing reliable exploration techniques, greatly improving reservoir engineering methods for assessing site-specific capacity and longevity, and developing environmental control technology required to meet state and Federal standards for geothermal air emissions, and solid and liquid waste disposal.

Major accomplishments in FY 1982 included:

## Drilling and Well Completion Technology

- Designed and developed a new concept for drilling using a cavitating jet nozzle to enhance the drilling rate of existing bits.
- Successfully tested an inertial navigation system, adopted for use as a high-accuracy well surveying tool.
- Successfully tested the use of a non-corrosive inert gas (nitrogen) drilling technique; completed the design of an inert gas generator (diesel exhaust purifier).
- Completed assembly of a facility for test of materials and techniques to control lost circulation.

## Energy Conversion Technology

- Field tested a 500 kWe direct contact heat exchanger in a binary cycle pilot plant at East Mesa, CA.
- Completed field test of 1 MWe helical screw expander (total flow power system) in Italy under IEA agreement.
- Completed testing of isobutane/hexane working fluid mixtures in the 60 kWe prototype power system at Raft River site.
- Achieved continuous operation of a geothermally hardened 80 HP electric downhole brine pump for a record-setting 11 months.

## Reservoir Stimulation Technology

- Completed two acid-wash well treatments at the Baca, N.M. site, resulting in increased well production but with flow rates short of single-well requirements for a commercial-size power plant.

## Geochemical Engineering and Materials Research

- Successfully completed testing of a carbonate scale inhibitor
- Installed isobutane corrosion probes and initiated testing under operating conditions at the 10 MWe power plant at East Mesa, CA.
- Completed evaluation of designs of $CO_2$ and pH probes for monitoring hydrothermal power plant operations.
- Completed high temperature brine tests of perfluorocarbon elastomer seals.

Geoscience Technology

- Completed field testing of the EM-60 (electromagnetic exploration system).
- Completed field testing of the Automated Seismic Processor which is a real-time, field-portable microearthquake location and analysis system which is currently being marketed by private industry.
- Completed the collection and evaluation of reservoir performance data from the Cerro Prieto geothermal field.

Hydrothermal Power Plant-Projects

- Completed 95% of the final design and initiated long-lead-time equipment procurements for Heber 50 MWe geothermal binary cycle power plant.
- Completed operational tests of the 5 MWe Raft River binary cycle, pilot plant.
- Completed phase-out activities and most of the site restoration work on the 50 MWe flash-steam power plant project at Baca, N.M.

## 5.0 HOT DRY ROCK RESOURCES

The goal of the Hot Dry Rock (HDR) Program is to establish the technical feasibility of extracting energy from the earth's hot, water-deficient rocks. Intermediate objectives to attain the realization of this goal include: (1) developing a technology base for HDR energy extraction; (2) confirming that the resource potential is large and accessible; and (3) verifying that resource development can be undertaken with acceptable environmental effects. Successful demonstration of the technical feasibility of extracting HDR energy has been proven with a 5 megawatt (MW) thermal loop at Fenton Hill, New Mexico.

Major accomplishments in FY 1982 included:

- Experimental data from the 5 MW thermal loop at Fenton Hill have been analyzed and published results indicate that recoverable heat from the reservoir is 6 times larger than originally estimated due in part to the thermal contraction effects as well as pressurization and hydraulic fracturing.
- A preliminary assessment of HDR resource potential was completed and 24 prospective sites were identified.
- A revised thermal gradient map for the continental U.S. was completed.

- Results of evaluations of HDR exploration techniques were completed and published.

- Five separate hydraulic fracturing experiments were conducted in the injection well of the new HDR system at Fenton Hill.

- The 5 million gallon water storage pond at Fenton Hill was completed, lined, and covered. The pond will supply make-up water to the new HDR thermal loop presently under construction.

## 6.0 GEOPRESSURED RESOURCES

During the past several years, the Geothermal Geopressured Program has established that there is a very large quantity of hot brine contained at high pressure in sandstone aquifers beneath the Texas-Louisiana Gulf Coast. Essentially all of this brine is saturated with dissolved natural gas (methane), for a total of about 5,700 quadrillion (quads) BTU's of gas in place (U.S. gas consumption is about 18 quads/year). The thermal energy content of the brines is about equal to the chemical (methane) energy content, although the recoverable thermal energy is less than that of the gas. It is technically feasible to produce the brine at high rates through wells, separate the gas, and inject the spent brine into suitable underground formations. The principal program activity is the production testing of four specially-designed wells. Brine flow rates of up to 40,000 barrels per day will provide data on geopressured reservoir performance. Analysis of these data should allow industry to predict how much methane and thermal energy can be recovered from a geopressured reservoir.

Major accomplishments in FY 1982 included:

- Completed a well at the Parcperdue site in Louisiana and acquired 6 months of production test data.

- Repaired a well in Brazoria County, Texas, and resumed flow tests.

- Determined the cause of tubing failures in the McCall well in Louisiana, and initiated a repair effort.

## 7.0 GEOSCIENCES RESEARCH

Numerous entities, including the Office of Energy Research of the Department of Energy and the United States Geological Survey, Bureau of Mines, and the Bureau of Reclamation within the Department of Interior, have undertaken R&D activities in the geosciences area. A significant portion of these activities is centered on the conduct of basic R&D. Research and development activities have been struc-

tured to resolve uncertainties in determining the location, size, chemical and temperature characteristics, and longevity of geothermal reservoirs. In addition to research and development activities that have been conducted in the area of resource recognition and evaluation, other geothermal-related activities, such as mineral recovery from geobrines and the production of fresh water supplies through the desalting of geothermal brines, have been undertaken.

Major accomplishments in FY 1982 included:

- Continued research to devise and demonstrate technology for the recovery of mineral and metal values from geobrines. Two papers were presented during FY 1982: "Corrosion of Carbon and Alloy Steels in Salton Sea Geothermal Environment," and "Corrosion of Nickel Alloys in Salton Sea Geothermal Environment." The geobrine work is scheduled for completion in FY 1983.

- Researchers at MIT have developed methods to determine the extent, orientation, multiplicity, and spacing of fractures in regions of geothermal potential from data obtained in downhole active seismic experiments.

- Experiments at Sandia National Laboratory have demonstrated that high levels of energy extraction from magma are possible.

- Experiments recently reported by Sandia National Laboratory have provided the first results that show superconvection near the critical point in a fluid saturated permeable medium. Heat transfer rates increased by a factor of 70 or more as the critical point was approached. Enhanced heat transfer of this type has potential application to geothermal energy extraction.

- Completed preliminary resource investigations in California, Arizona, New Mexico, and Nevada. The investigations have been undertaken with the objective of producing fresh water supplies through the desalting of geothermal brines.

- Completed computer modeling of a hydrothermal convection system to predict hydrologic behavior under various assumed conditions of fluid flow and withdrawal.

## 8.0 HYDROTHERMAL TECHNOLOGY TRANSFER

The goal of the Hydrothermal Technology Transfer effort is to provide an appropriate level of Federal support to industry so that development of geothermal resources can proceed. The effort focuses on low-to moderatetemperature resources for direct applications and high-temperature geothermal resources for electric power generation. Hydrothermal resource development is impeded by the private sector's

perception of economic and technical risk, reservoir performance uncertainties, and a variety of legal and institutional barriers.

DOE's Hydrothermal Technology Transfer effort in FY 1982 consisted of information dissemination; legal and regulatory reform and streamlining; site-specific direct heat feasibility studies and field demonstrations; and administration of the Geothermal Resources Development Fund. The Geothermal Energy Research Development and Demonstration Act of 1974 provided for the establishment of the Geothermal Loan Guaranty Program (GLGP) and of the Geothermal Resource Development Fund (Table 8 presents the FY 1982 status of the Fund) to support the program. The objectives of the GLGP are to encourage the private and public sectors to accelerate the utilization of geothermal resources by minimizing lenders' financial risk; develop a financial service infrastructure to ultimately provide financing of geothermal projects without Federal assistance; promote competition and encourage new entrance of firms into the geothermal marketplace.

Financial and economic incentives for private sector development are also provided by other Federal agencies. The Departments of Commerce and Housing and Urban Development offer financing opportunities for geothermal development in their grant programs. Communities may choose to utilize their HUD Community Development Block Grant (CDBG) funds for this purpose, and may request Urban Development Action Grants (UDAG's) provided that private sector leveraging and other requirements are met. During FY 1982, HUD funded 4 preliminary feasibility studies of geothermal district heating systems: Bellows Falls, Vermont; Berlin, Maryland; Thermopolis, Wyoming; and Union County, Oregon. Total funding for the four projects was approximately $200,000.

## 9.0 ENVIRONMENT

The Federal Geothermal Environment Program focuses on characterization of the environmental impacts from the development of geothermal energy sources and the development and evaluation of control methods to mitigate or eliminate environmental concerns, including health. The coordination between the private sector, the research community, and Federal and state government agencies on environmental matters is provided by the IGCC's Environmental Controls Panel. The Environmental Controls Panel successfully completed its effort in FY 1981 to refocus and integrate Federal environmental research programs, with EPA, DOE and DOI being the principal participants in the environmental program. The environmental program has included acquisition of baseline data, monitoring, and research related to air quality, surface and ground water quality, hydrological alterations, ecology, solid residuals, subsidence and seismicity, health effects, and socioeconomic problems; regional and site specific assessments of the environmental, health, and socioeconomic impacts of geothermal resource development; and development and evaluation of environmental control technologies.

TABLE 8

GEOTHERMAL RESOURCES DEVELOPMENT FUND(1)
AND GUARANTY AUTHORITY

| | FY 82 | |
|---|---|---|
| | FUND | AUTHORITY |
| Interest Differential | $ 2,000,000 | |
| Unexpended Appropriations, Carried Forward from FY 81 | 20,212,807 | |
| Guaranty Authorization | | $500,000,000 |
| Value of Loans Guaranteed (5 projects) | | 136,000,000 |
| Value of Conditionally Approved Applications FY 82 (2 projects) | | 8,800,000 |
| Uncommitted Guaranty Authorization(2) Carried to FY 83 | | 355,200,000 |
| Administrative Expenses Incurred(3) (FY 82) | 200,000 | |
| Guaranty Fees Collected in FY 82 | 509,604 | |
| Unobligated Appropriation Carried to FY 82 | 6,858,793 | |
| Guaranty Fees Collected in FY 82 and Deposited in GRDF | 509,604 | |
| Appropriation Reduction by Congress(4) | 14,000,000 | |

(1) This financial information is included in the Seventh Annual Report to satisfy the requirements of PL 93-410, Section 204.

(2) The value of applications currently under review is $300,600,000. In addition, of the 5 projects that currently have loan guarantees, certain of these may require follow-on loans for powerplant construction.

(3) Contractor and consultant costs necessary to assist in evaluating technological, geophysical, financial, marketing, management and legal data submitted with guarantee applications and to assist in monitoring guaranteed projects.

(4) Appropriation transfer to another program.

Major accomplishments in FY 1982 included:

- Completed a study for the IGCC of the difficulties of protecting hydrothermal features in national parks from adjacent geothermal development and recommendend general, technically-based concepts to guide Federal development and protection programs.

- Completed analyses of hazardous components of geothermal solid wastes at several U.S. sites. The degree to which solid wastes are hazardous appears to be directly related to the chemical nature of geothermal fluids: thus, only high-salinity fluids among those studied produced solid wastes which met some EPA criteria for hazardous wastes.

- Completed a survey of environmental regulations and updated Federal, state, and local regulations applicable to geothermal energy development. This revised guidebook can be used by industry and state/local regulators as a planning tool.

- Completed a study of electrochemical removal of dissolved sulfate from geothermal brines. This bench-scale study found that hydrogen-sulfide ($H_2S$) can be removed successfully from geothermal brines upstream of the energy conversion system with only a small (< 1%) energy penalty.

- Completed a "desktop" assessment of non-$H_2S$ emissions. Available data from sources world-wide were evaluated to understand the extent of non-$H_2S$ air pollution emission problems. The study found that treatment for non-$H_2S$ emissions is not likely to be needed at most geothermal sites.

- Completed an environmental assessment of sub-surface injection of spent geothermal fluids. Based on an examination of available hydrological and geological data from several geothermal resources in the western U.S., few environmental problems are foreseen with injection requirements that appear likely to be applied. Significant contamination of drinking water-quality aquifers does not appear likely if available practices for careful, cost-effective injection are followed.

- Completed an environmental assessment of direct uses of geothermal energy. Available data revealed no occurences of environmental degradation at over 100 sites world-wide where direct use of geothermal energy exists and where basic precautions were followed to protect environmental quality. No sites where damage occurred were identified.

- Completed chemical analyses of geothermal fluids from Lassen Volcanic National Park in northern California and adjacent areas. Preliminary interpretation of the analyses indicates that a single, high-temperature, vapor-dominated geothermal system is centered beneath the Park and that a deeper hot-water part of this system feeds hot springs in the Lassen KGRA outside the Park.

## 10.0 FEDERAL USE OF GEOTHERMAL ENERGY

Where economically appropriate, the Federal government has been involved in the utilization of geothermal resources. In particular, the Department of Defense has been active in the development and use of geothermal energy at several military installations throughout the U.S. and the world.

Major accomplishments in FY 1982 included:

- An invitation for bids (IFB) for developing up to 75 MWe from the geothermal resource at the Naval Air Weapons Training Complex, Fallon, Nevada was issued in August 1982. Two bids were received at bid opening in October 1982. The Navy expects to award the contract in the immediate future.

- The Navy awarded a contract to develop up to 75 MWe at the Coso KGRA on the Naval Weapons Center, China Lake, California in December 1979. By 1982, the contractor had completed the formal environmental hearing process and drill hole siting. The contractor drilled six geothermal wells in 1982, which are all considered to be economically viable producers with their power output totaling approximately 40 MWe.

- Conversion of buildings to a geothermal heating system at the U.S. Naval Station at Keflavik, Iceland was about two thirds complete in FY 1982. The project will provide a geothermal fluid distribution system and convert over 300 buildings to use the geothermal energy. The buildings already converted displaced approximately 18,140 barrels of oil in 1982. When the project is complete approximately 167,000 barrels of oil will be displaced per year.

- The Air Force did a feasibility study in FY 1982 for using a hot water geothermal resource at Lackland AFB, Texas. The study showed the best application is to heat 6 dormitory type buildings, which would have about a 7-year payback. The Air Force is working with DOE/Idaho Falls to do a more advanced geologic study and to drill a test well in FY 1983.

- The Air Force did a preliminary feasibility study, which was completed in September 1982, to use a geothermal resource at the air base on Ascension Island, in the South Atlantic Ocean. The study showed potential to generate electricity from the resource. The Air Force intends to conduct more advanced geologic testing and to drill a test well in 1983.

- The Navy completed a geothermal evaluation for the Marine Corps Air Station on the Island of Oahu, Hawaii. The report was published in June 1982. The study concluded that the probability of the existence of a useable geothermal resource is very small.

- The Navy is continuing to evaluate the geothermal potential of other sites such as Marine Corps Base, Twentynine Palms, California and at the weapons test areas in the Imperial Valley through geologic/geophysical investigations and the drilling of thermal gradient holes.

- DOE continued its efforts to assist other Federal agencies in identifying buildings and facilities that could use geothermal energy for heating and cooling.

## 11.0 PRIVATE SECTOR USE OF GEOTHERMAL ENERGY

Geothermal energy has been used for space heating in the United States since the early 1900's and for district heating systems since the 1930's. Current uses include agricultural and aquacultural applications, space/ district heating, and industrial applications. Currently, direct utilization of geothermal energy is approximately .012 quads/yr. Most of the direct-utilization of geothermal energy is concentrated in California, Idaho, Nevada, New Mexico, Oregon, and South Dakota. Direct-utilization is expected to grow dramatically over the next few years with significant expansion projected in industrial applications and district heating systems.

The production of electricity from geothermal energy first occurred in the United States in 1960 at The Geysers in California. Since that time numerous facilities have been constructed and currently account for 1,167 MWe power-on-line. Over the next two years, several additional geothermal electric power facilities are scheduled to begin operation in California (Geysers-595 MWe, Imperial Valley-97 MWe), and Utah (Roosevelt Hot Springs - 20 MWe).