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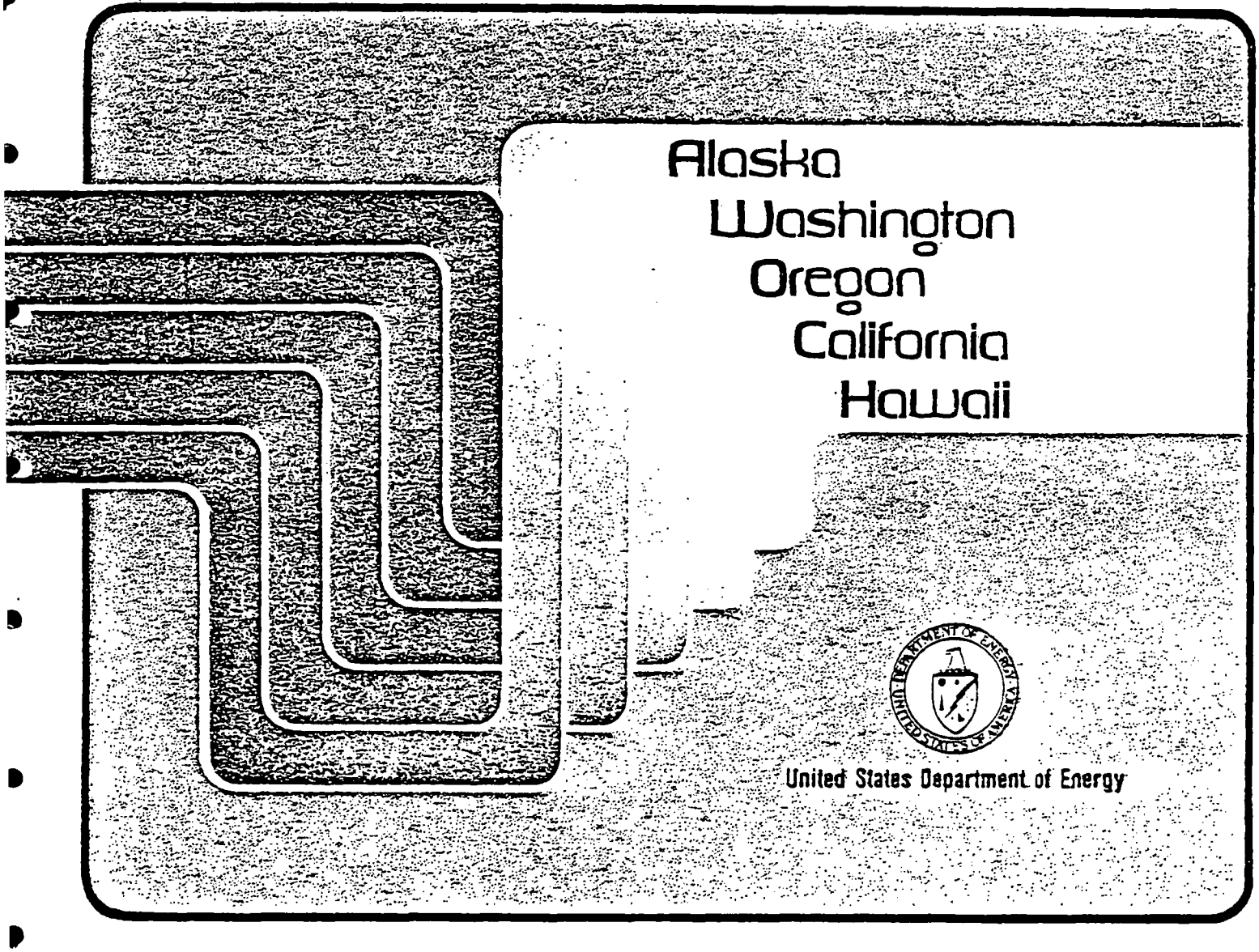
PACIFIC REGION FEDERAL GEOTHERMAL COMMERCIALIZATION PLAN



United States Department of Energy

DEPARTMENT OF ENERGY
DIVISION
OF
GEOTHERMAL ENERGY

PACIFIC REGION FEDERAL GEOTHERMAL COMMERCIALIZATION PLAN

(WORKING DRAFT)
16 October 1978

Prepared by

San Francisco Operations Office
for
Pacific Region Program Manager

EXECUTIVE SUMMARY

INTRODUCTION

The growing realization of the finite nature of fossil fuels has led to increased interest in the viability of alternate energy sources. Geothermal energy is one such resource that shows great promise as a substitute for oil and natural gas in electric and direct heat applications. The Geothermal Energy Research, Development and Demonstration Act of 1974 (P.L. 93-410) provides for a comprehensive program to effectively develop geothermal energy resources. Extensive studies have shown that substantial differences exist in the factors involved in geothermal development in various regions of the Nation. Therefore, the Division of Geothermal Energy (DGE) of the Department of Energy has elected to proceed on a regional basis.

This document outlines the Pacific Region Team (PRT) programs to accelerate the commercialization of geothermal energy development in the Pacific Region, which consists of the States of Alaska, California, Hawaii, Oregon and Washington. The plan is intended to be a dynamic one, responsive to the needs of the geothermal community in the Region. It will be refined and updated in collaboration with industry, state and local government, and other entities in the Region.

Both an extensive resource base and a market for economical utilization of geothermal energy have been identified within the Region. With respect to electrical development, the major area has been The Geysers, which has a generating capacity of over 500 MW. In addition, over the past several years, there has been extensive exploration and development activity in the Imperial Valley, as well as the Puna

rift area of Hawaii, where an exploratory well resulted in the discovery of a maximum down hole temperature of 676°F, probably the hottest well in the world. Resources suitable for direct use are widespread throughout the Region, with notable utilization at Klamath Falls, Oregon, and Susanville, California.

APPROACH

The Pacific Region programs are intended to accelerate the utilization of geothermal energy in the Region by stimulating the industry to achieve the following goals:

Year / Application	1985	1990	2000	2020
Electric Power On-Line (MW)	2700	5000	10,000	20,000
Direct Heat Uses (Quads/Yr.)	0.01	0.02	0.1	0.3

Achievement of these goals requires coordinated commitments by the key participants in the development process. The basic PRT program strategy is to help provide the basis for these commitments, using a prospect-specific approach to development.

Because the geothermal resources of the Pacific Region are at different stages of development and commitment, the near-term emphasis must be on working with involved interests to not only advance certain prospects to the stage where commercialization can be considered, but also to stimulate activity in those areas where the resource has already been proven. In these areas, power-on-line programs are being implemented, commencing with scenario development to identify those sites with production potential.

For direct heat applications, the scope of funded activity will focus on broadening the applications considered and limiting studies to site-specific, industry-specific feasibility analyses. A field commercialization team is being considered to serve as the focus for planning and execution of commercialization projects and a center for information dissemination and technology transfer activities.

PROGRAM STRUCTURE

The Pacific Region Program is composed of six elements. In the first element, Regional Planning, primary emphasis is on defining potential geothermal uses and the actions required to achieve them. This is accomplished through the development of aggressive scenarios, market analysis and penetration studies and the establishment of feedback channels to the program. The goal of the Commercialization Support element is to transform the geothermal option from a technologically demonstrated alternative to commercial implementation. The activities involved include cooperative programs and tests, technical and financial support and education and technology transfer. The third element, Institutional Support, focuses on one of the chief impediments to development – the need for coordinated policies and timely agency review of proposed industry geothermal development activities. A reliable inventory of proven geothermal resources capable of supporting commercial electric or direct heat use on a site-specific basis is the goal of the fourth element of the program, Resource Definition and Development Support. Environmental Support is the next element. This element provides support to various activities in the Region which ensure that proper consideration is given to the identification and resolution of potential issues, so that development can proceed in an environmentally responsible manner. The last element is Technology Applications. Through interaction with industry

and feedback on problems encountered, specific technology application needs have been identified in the following areas: resource and well technology, geochemistry, extraction technology, conversion technology, and direct use hardware. Coordination with the DGE technology development program will ensure complementary efforts.

MANAGEMENT STRUCTURE

Development of the PRT goals and objectives, program planning and execution, interface with other government agencies and industry, budget formulation and defense, and detailed project planning and project management are the responsibility of the Pacific Region Program Manager as the Pacific Region Team Leader. Members of the team are located in the Division of Geothermal Energy, Washington, D.C., and the Geothermal Energy Division of the San Francisco Operations Office, Oakland, California. Specific functional responsibilities for each member and for support from the DOE Regional Offices are being developed in Management Agreements for approval by the Director of the Division of Geothermal Energy and the Manager of the San Francisco Operations Office.

A Regional Industrial Review Panel is being considered within the structure of the Advisory Committee on Geothermal Energy to focus on industrial participation in implementing geothermal energy utilization. In order to coordinate geothermal policy formulation and program development among the federal agencies involved in geothermal activities, a group may be formed among the regional offices of the various agencies to provide a formal mechanism for input to the planning process. Formal mechanisms will also be set up to provide for state and local input. The PRT will orchestrate these activities in addition to fostering communication of ideas and resolution of concerns.

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FOREWORD

The Geothermal Energy Research, Development and Demonstration Act of 1974 (P.L. 93-410) provides for a comprehensive program to effectively develop geothermal energy resources. The role of the Federal Government is to accelerate the commercial development and utilization of geothermal energy as an economic, reliable, and environmentally acceptable energy source.

Different areas of the nation have different energy needs, as well as different economic, environmental and institutional issues and concerns. Geothermal resources also vary from region to region. These factors have led the Division of Geothermal Energy (DGE) of the Department of Energy to adopt a regional approach to the definition and implementation of its geothermal energy program.

This document outlines the plan of the Pacific Region Team (PRT) of DGE for the commercialization of the geothermal resources in the Pacific Region, considering both direct use and electric applications. In order to achieve the stated objectives, the program must reflect not only the goals and responsibilities of state, local and Federal agencies, but also the needs of industry in the area of geothermal exploration and development. This interaction will determine the future of geothermal energy in the Region.

This document represents the initial Federal and state cooperative effort to develop a dynamic and comprehensive commercialization plan. Subsequent documents will incorporate the inputs of other Federal agencies and the principal thrust of each state's geothermal commercialization plan, specific input from other sectors of the geothermal community, and site development scenarios. The individual commercialization plans for each state and the Federal commercialization plan will be key appendices to an overall Pacific Region Master Development Plan to be prepared in the near future.

I. INTRODUCTION

A. The Region

For the purpose of the DGE's Geothermal Energy Program, the Pacific Region is defined as the states of Alaska, California, Hawaii, Oregon, and Washington. The Region's geothermal energy resources can be utilized to meet a substantial amount of the five states' energy needs. However, the present status of development is such that only a small fraction of the geothermal potential is being utilized.

B. The Resource

An assessment of the geothermal resource base by the USGS in 1975 (Circular 726) identified 131 hydrothermal sources distributed throughout the Region. The temperatures of 32 of these systems were estimated to be above 150°C, with the remaining 99 systems exhibiting estimated temperatures between 90 and 150°C. The identified electrical potential of the high temperature systems was estimated to be in excess of 20,000 MWe (for 30 years). This assessment is presently being updated, with particular emphasis on low- and moderate-temperature resources.

C. Potential

The market for the utilization of geothermal energy is such that resources must be located where they are capable of supplying needs more economically than other existing resources, or where they meet a regional shortfall in supply. Many studies have concentrated on the potential of geothermal development and the projected utilization rates, under various assumptions.

An informal survey was made by EPRI* of the electric utility industry estimate of the growth of geothermal energy development. Figure 1 shows estimates of development within the Pacific Region, primarily in California. The lower bars in Figure 1 represent the utilities' announced plans - either publicly or through PUC biennial reports - for geothermal electric power development. The higher bars depict DGE's power-on-line projections assuming execution of this plan. In California alone, the demand increase projected by utilities through 1990 is in excess of 20,000 MW of generating capacity. Acceleration of geothermal energy development over the announced projections could contribute significantly to meeting the demand increases of the utilities.

Figure 2 shows projections of the potential development of direct use applications, and the impact of this plan on direct use development.

In both figures the lower bars represent the development pace which would be likely if there were no DGE program. Since it is in the national, as well as the regional, interest to ensure the most effective utilization of all energy resources, the DGE program exists to stimulate and accelerate geothermal development on a time scale approaching that represented by the upper bars.

*Ref: Kruger, Paul and Roberts, Vasel, Utility Estimates of Geothermal Electricity Generating Capacity, EPRI, Proceedings of the 1978 Geothermal Resources Annual Meeting, July 1978.

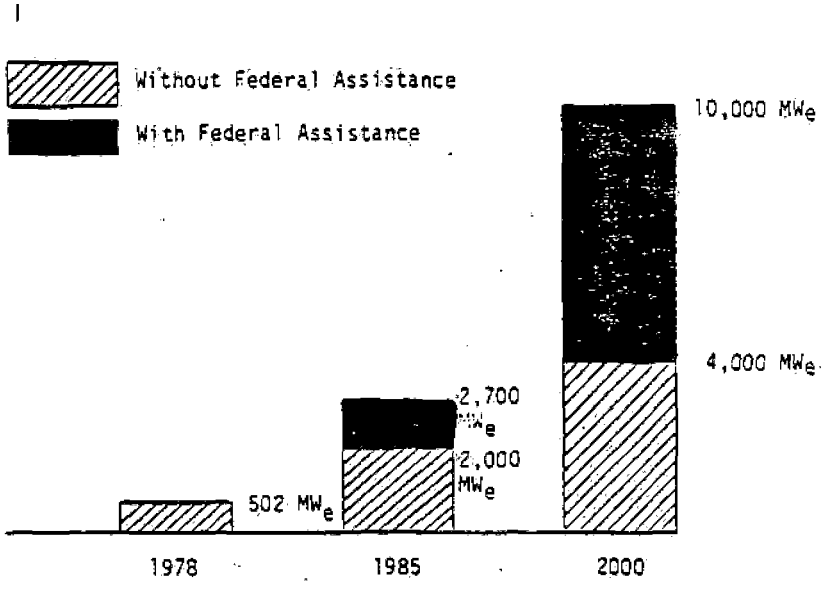


Figure 1. Projection of Geothermal Electrical Power Generation in the Pacific Region

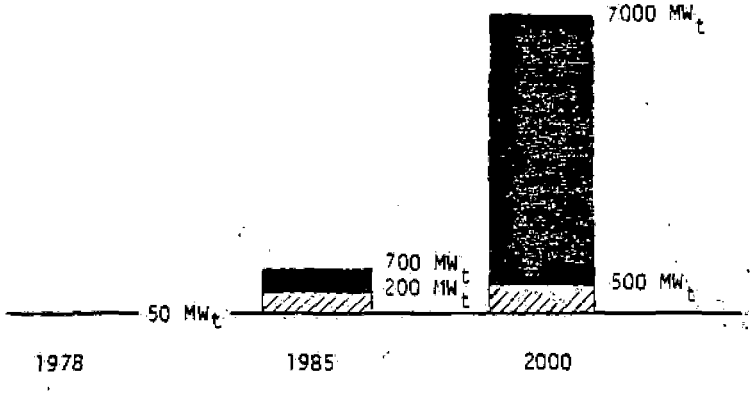


Figure 2. Projection of Geothermal Direct Use in the Pacific Region

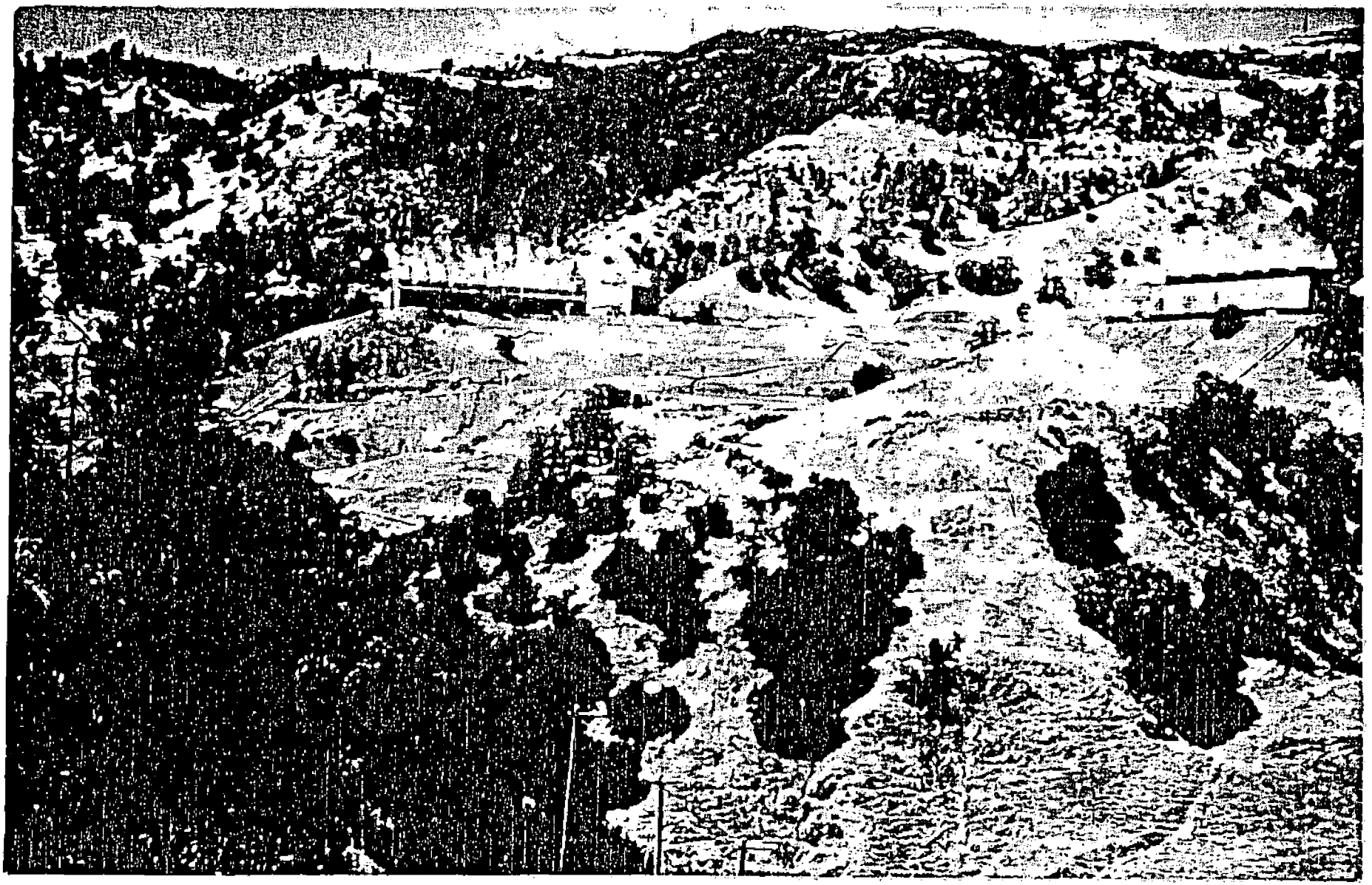
D. Current Development Status

Electrical Applications

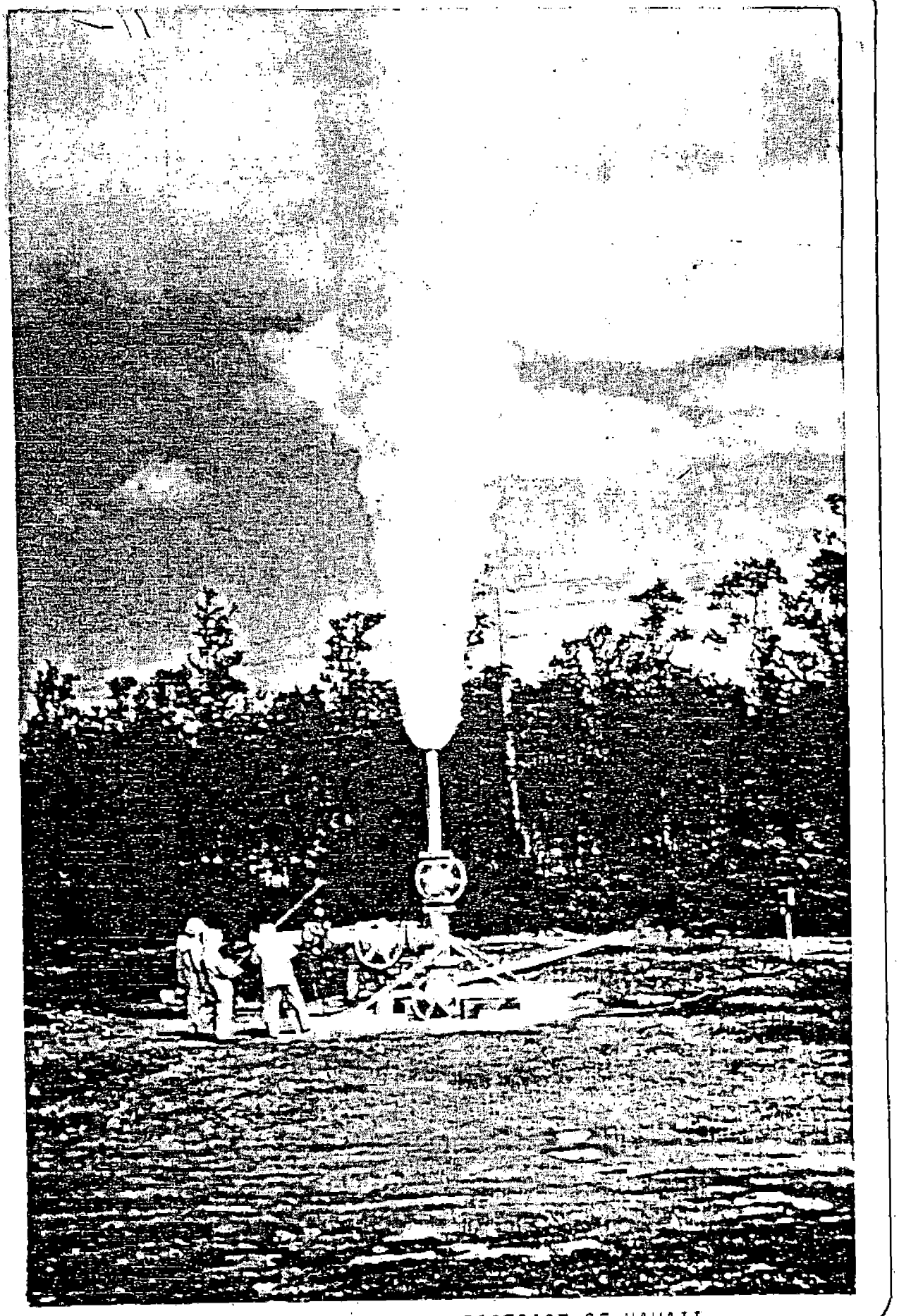
The geothermal resources of the Pacific Region are in various stages of development. At present, California is leading the Region in development of the resource for production of electricity. The major geothermal development in the Geysers area began in 1957 and currently has a generating capacity in excess of 500 MW with an additional 400 MW under construction. By 1979, over 900 MW will be on-line. Utility forecasts show the field reaching development of 2000 MW in the 1985 time period.

Over the past several years, there have also been extensive resource exploration and development activities in the Imperial Valley of California, which show strong promise for major development. In 1976, San Diego Gas & Electric Co. (SDG&E), jointly with DGE, established the Geothermal Loop Experimental Facility (GLEF) using fluid supplied by Magma Energy Company's wells near the Salton Sea. This cooperative industry-DOE project has made tremendous strides in controlling silica scale and reducing injection well plugging.

Magma is also constructing an 11 MWe binary cycle power plant at East Mesa, to be completed late this year. Union Oil Company has entered into a contract with Southern California Edison Company (SCE) to sell SCE geothermal energy produced at Brawley, with first power production coming from a 10 MW pilot plant to be built by SCE. Republic Geothermal has announced plans for a 48 MW plant, with the first 10 MW increment scheduled for 1980. SDG&E will operate the plant and distribute the power generated. At Heber, SCE has announced plans jointly with Chevron for a 50 MW_e double flash plant to be completed in 1982. Recently, the Union Oil Company joined with the Southern Pacific Land Company and SCE in a project that could lead to an initial 10 MW power plant using the highly saline fluids of the North

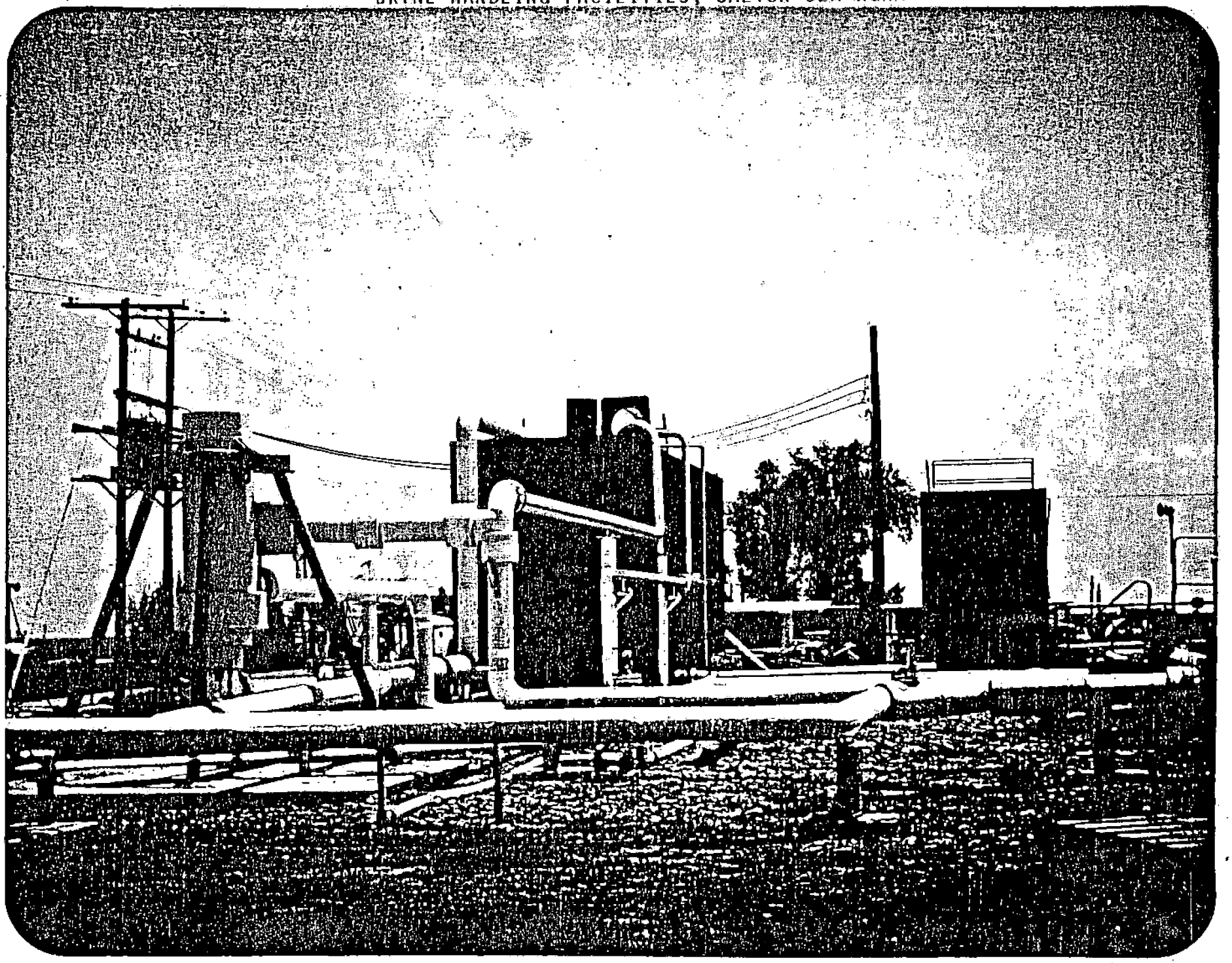


TYPICAL POWER PLANT, THE GEYSERS KGRA



HGP-A WELL, PUNA DISTRICT OF HAWAII

BRINE HANDLING FACILITIES, SALTON SEA KGRA



Salton Sea area. At the Puna rift on the Island of Hawaii, an exploratory well has resulted in the discovery of what could prove to be a major geothermal resource with a maximum down hole temperature of 676°F. With DGE's support, a 3.5 MW_e wellhead generator will be installed with power expected on-line in 1980.

The developmental status of electric power generation projects throughout the Pacific Region is summarized in Table 1.

Direct Use

Geothermal resources suitable for direct use applications in the Region are abundant, with substantial known resources in each state. To date, utilization has been limited to a few sites, most notably at Klamath Falls, Oregon, and Mammoth Lakes and Susanville, California. The Federal program has recently made inroads in stimulating increased usage in the Region via cost-sharing of field experiments. Projects are currently underway in Oregon and California. It is anticipated that additional projects will commence in FY 79.

Table 2 summarizes the status of direct use projects and studies in the Pacific Region.

E. Barriers to Geothermal Energy Development

Even with the increased activities and interest associated with geothermal development, there are still significant technical, economic and institutional barriers which will make accelerated development difficult to achieve. These barriers are discussed in detail in subsequent sections. The Pacific Region Program will address each of these impediments and the programs which will be implemented to alleviate their impact.

Table 1. Pacific Region - Status of Selected Electrical Prospects

STATE	PROSPECT	STATUS
CALIFORNIA	HEBER	SURFACE RIGHTS: PRIVATE POTENTIAL: 1000 MW DEVELOPERS: CHEVRON, UNION, NARCO
	EAST MESA	SURFACE RIGHTS: BLM-LEASED POTENTIAL: 500 MW - TENTATIVE DEVELOPERS: MAGMA: 11 MW BINARY PLANT, START-UP 11/78 REPUBLIC: 10 MW FLASH PLANT, START-UP '79 48 MW FLASH PLANT, START-UP '80
	BRAWLEY	SURFACE RIGHTS: PRIVATE POTENTIAL: 1000 MW - TENTATIVE DEVELOPERS: UNION/SCE: 10 MW FLASH PLANT, START-UP '80 CHEVRON: McCULLOCH CURRENTLY DRILLING, S. BRAWLEY
	SALTON SEA, INC. WESTMORLAND, N.SS.	SURFACE RIGHTS: PRIVATE; STATE POTENTIAL: 2000 MW - TENTATIVE DEVELOPERS: MAGMA/NARCO: 49 MW BINARY PLANT, START-UP '82 UNION/SCE/SPL: 10 MW BINARY PLANT, START-UP '82 REPUBLIC/SDGE: 50 MW FLASH PLANT, START-UP '83 McCULLOCH DRILLING. N.SS.
	MONO-LONG VALLEY	SURFACE RIGHTS: BLM + USFS - LAND MGMT PLAN BEING COMPLETED POTENTIAL: 2000 MW - TENTATIVE DEVELOPERS: MAGMA, UNION - ON PRIVATE LANDS
	COSO	SURFACE RIGHTS: BLM & USN POTENTIAL: 2000 MW - TENTATIVE DEVELOPERS:
HAWAII	PUNA	SURFACE RIGHTS: PRIVATE POTENTIAL: 500 MW - TENTATIVE DEVELOPERS: DOE-FUNDED 3 MW WELLHEAD GENERATOR PROJECT
OREGON	ALVORD KGRA	SURFACE RIGHTS: BLM + PRIVATE POTENTIAL: UNKNOWN DEVELOPERS: ANADARKO: 71 TEMPERATURE HOLES PERMITTED REPUBLIC, GETTY, PHILLIPS
	VALE HOT SPRINGS	SURFACE RIGHTS: PRIVATE + BLM POTENTIAL: UNKNOWN DEVELOPER: UNION, REPUBLIC, AMAX, GEOTHERMAL RESOURCES INTERN'L, TECHNOLOGY INTERN'L
	CRUMP GEYSER	SURFACE RIGHTS: BLM POTENTIAL: UNKNOWN DEVELOPER: CHEVRON IS DRILLING

Table 2. STATUS OF DIRECT USE PROJECTS

PACIFIC REGION

Project Description	Sponsor	Location	Status
ALASKA			
Greenhouses: Cantaloupes Space Heating		Manley Hot Springs	Operating
Salmon Aquaculture	DOE/Alaska State Energy Office	Alaska	Study Completed
Space Heating	DOE/Pacific Sierra Research Corp.	Alaska	Study Completed
CALIFORNIA			
Water desalination - initial operations of the BuRec pilot program showed promise for feasible development of geothermal resources to provide an economical high-quality water supply.	DOE	East Mesa KGRA	Project Abandoned as Uneconomic
Geothermal Component Test Facility	DOE	East Mesa, KGRA	Operating
Investigating applications of geothermal energy: greenhouse culturing of European cucumber and aquaculture operations using the Malaysian fresh water prawn.	DOE/JPL	Desert Hot Springs	
Plans to construct 150 greenhouses. Raising tomatoes, lettuce, cucumbers, and other experimentally grown produce, which will be sold locally and to major markets and chain outlets.	-	Lassen County	
CDWR drying of lumber mill waste and possible retrofit of mills for geothermal use to display additional wood waste for wood fired power plant.	State of California	Northeastern California	Proposed

STATUS OF DIRECT USE PROJECTS (CONT)

Project Description	Sponsor	Location	Status
Fish farming, processed and smoked catfish, live fingerlings, fish for stocking other farms.	--	Paso Robles	Operating
Greenhouse. Hobo Wells - tomatoes, bell peppers, potted plants. Expect to harvest 160 tons of tomatoes per acre of greenhouse per year. Utilize hydroponic technique. Plan to expand outside Susanville to north around Surprise Valley.	--	Susanville	Operating
Refrigeration for food processing	DOE/Aerojet Energy Conversion Co.	Multiregional	Study Completed
Evaporation and crystallization of industrial liquids and wastes	DOE/Bechtel Corp.	Multiregional	Study Completed
District space/water heating Mammoth lakes	DOE/The Ben Holt Co. State of Calif.	Mammoth Lakes Village	Study Completed Pilot Plant Operating
Food production and processing	DOE/Geonomics, Inc.	Lake County	Study Completed
Greenhouse: fish farming	DOE/International Engineering Co.	California	Study Completed
Holly Beet Sugar Refinery	DOE/TRW, Inc.	Imperial Valley	Study Completed
Production of fertilizer-valley nitrogen	DOE/WESTEC Services, Inc.	Heber KGRA	Study Completed
District heating system for industrial and agribusiness applications	DOE/Aerojet Energy Conversion Co.	Susanville	Study Completed
District heating system for space industry and agribusiness in El Centro	DOE/WESTEC Services, Inc.	Heber KGRA	Study Completed

STATUS OF DIRECT USE PROJECTS (CONT)

Project Description	Sponsor	Location	Status
Space Heating	Department of Defense (Navy)	China Lake NWTC	Suggested by Navy
HAWAII			
Puna Canesugar Refinery	DOE/Puna Sugar Company, Ltd.	Puna, Island of Hawaii	Study Not Completed
OREGON			
Milk pasturization in Medo-Bel Creamery. Melting snow from pavement. Prevent floor from freezing and frost heaving in cold storage plant. Accelerate curing of concrete. Direct use in a laundry. Space heating for 500 buildings including residences, schools, OIT campus, hospital, and businesses-construction of Klamath County, Nursery home underway, to be heated geothermal.		Klamath Falls	
Investigating prospects for using hot water from the Mt. Hood area for space heating and industrial needs.		Portland	Exploratory Well Drilling Continuing
Space heating of ski lodge	DOE/	Mt. Hood	Drilling Ongoing
Greenhouse heating. Steel-framed fiberglass. 70°F year-round, automatic environmental control -ystem, heat exchanger, tomatoes. 2415 m^2 greenhouse. In Cove, Lehman Hot Springs, Lakeview, Vale, and Klamath Falls. Studies being conducted at the Oregon Institute of Technology on greenhouse and aquaculture applications, as well as food processing for sugar beets.		Oregon	Operating

STATUS OF DIRECT USE PROJECTS (CONT)

Project Description	Sponsor	Location	Stutus
Ore-Ida is undertaking a development program with DOE to locate and use geothermal heat in their potato processing plant. About one-half of their energy needs may be met with geothermal energy at about 300°F.		Ontario	Study Completed
Food Processing, District heating system.	DOE/OIT Klamath Falls. DOE, Klamath Falls and county-joint funding	Klamath and snake river basin.	Study Completed To begin in 1978, heating for 14 city, county, state and federal buildings.

WASHINGTON

NO ACTIVE PROJECTS

Geothermal Heating Demonstration at Mammoth Lakes Village

II. REGIONAL PROGRAM APPROACH

A. Objective and Goals

The objective of the Pacific Region Program is to accelerate the utilization of geothermal energy in the states of Alaska, California, Hawaii, Oregon, and Washington, by stimulating the growth of the geothermal industry in order to achieve the following goals:

	1985	1990	2000	2020
Power-on-line (MW_e)	2700	5000	10,000	20,000
Direct heat uses (Quads/yr./(MW_t)	0.01/700	0.02/1400	0.1/6,700	0.3/20,000

B. Regional Approach - Electric Power

1. Strategy

In pursuing the power-on-line goals, the PRT recognizes that:

- geothermal development will be the result of a coordinated commitment process by resource development companies, potential users, and associated government agencies;
- the program must be supportive of that decision/commitment process; and
- the program must address prospect-specific requirements due to the variety of responsible agencies, key industrial entities, geothermal resource properties, technology requirements and environmental issues within the Region.

Figure 3 shows the major participants in the geothermal development process. These participants include:

1. Resource Developers: the high-risk organizations that drill and produce the resource.

2. Users: the low-risk regulated public and private utilities and industrial users that produce their own power.

3. Industry Infrastructure: A & E's, planners, exploration companies, component suppliers, etc.

4. Government Agencies: the Federal, state and local agencies whose responsibilities cover geothermal resource development and user applications.

5. Financial Community: the investors who fund speculative high-risk efforts, and those banks and other lenders which support the orderly development of geothermal energy.

Development is the result of the coordinated commitment of those participants on a prospect-to-prospect basis. The underlying strategy in the program approach is to lay the groundwork for favorable commitments by key participants.

Economic analysis by the private sector is an ongoing process and forms the basis for each of the private sector commitments. Early in the developmental process, risks are higher. These risks must decrease in order to justify increased financial commitments.

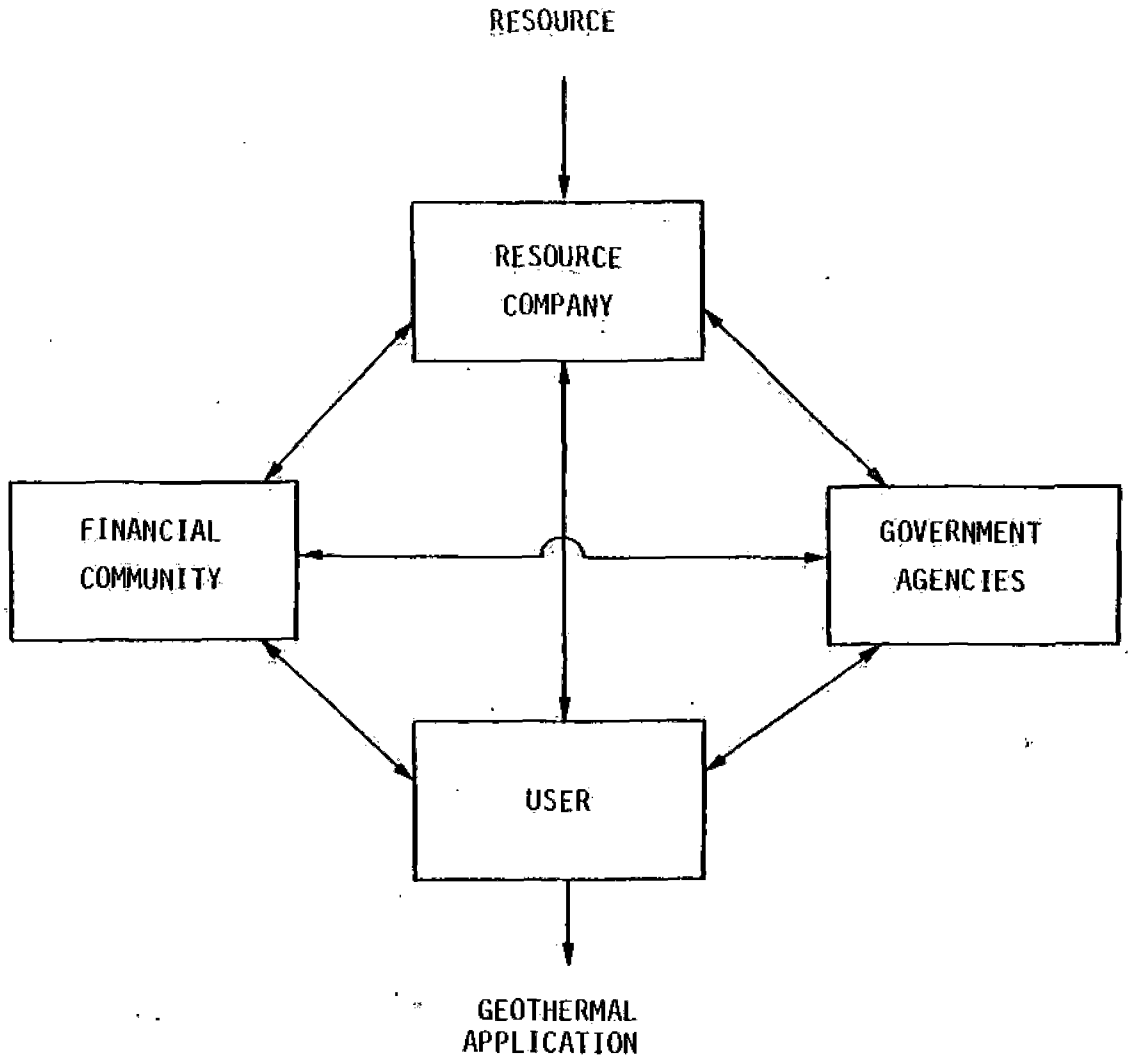


Figure 3. The Participants in Geothermal Development

The general phases of the plant development cycle may be summarized as follows:

- Resource Exploration and Land Acquisition
  Rights are acquired to the prospect area by purchase or lease from public or private landowners. The geological and geophysical exploration of likely prospects is made.

- Exploration Drilling
  Permits are obtained with appropriate environmental review for exploratory drilling. Subsequently, deep drilling proceeds to verify the existence of a resource.

- Environmental Assessment
  In parallel with final exploration activities, permit requirements are defined, and preliminary data for the environmental assessments are obtained.

- Resource Characterization
  Following a "successful" discovery, permits are obtained for the additional deep drilling and testing to characterize and determine the magnitude of the resources. This phase is critical to proving the resource viability to the potential user. Typically, the potential user works with the resource developer on preliminary plant design during this phase.

- Plant Design and Construction
  Once the resource is well characterized and the necessary agreements are consummated between the resource company and the user, the plant design is finalized and construction and field development proceeds. The actual construction phase and subsequent operations are preceeded by a substantial environmental regulatory review. An important aspect of geothermal development is to anticipate the required environmental review process and to appropriately address the requirements at each stage. If the review is only addressed in a reactive fashion after decisions and commitments have been made, substantial risks of delays will arise.

The key regulatory steps are:

a. The environmental review and associated land use approval proceeding exploratory drilling;

A closely-coupled interface with the DGE, Rocky Mountain Region will be effected in an effort to maximize the overall benefits of the individual regional programs. Periodic meetings will be instituted to encourage the timely exchange of information regarding all projects and commercialization activities so as to encourage an exchange of information.

D. Program Structure

The Pacific Region Program is structured to meet the needs of each of the participants in the development process as well as to provide a coordinated and integrated effort. The program is comprised of the following elements:

- Regional Planning
- Commercialization Support
- Institutional Support
- Resource Definition and Development Support
- Environmental Support
- Technology Application

These elements will be addressed in detail in the following sections.

b. the environmental review of the permits necessary for deep drilling and testing for exploration and resource characterization; and

c. environmental review (and, in the case of utilities, certification) for siting and potential impact of the proposed plant.

As one proceeds through the development cycle, there is a substantial increase in the investment of industry capital, time, and public resources, such as land, water, site preparation, etc. These commitments will only be made if it can be shown that the associated risk is acceptable. The PRT programs are directed to this end.

2. Near-Term Regional Program Emphasis

The geothermal resources of the Pacific Region are at different stages of development and commitment. At The Geysers, a rapid expansion of power plants is planned, providing environmental concerns are resolved. In the Imperial Valley and at the Puna rift, the geothermal resources are being proven and increased user interest and activity exists. Considerable resource assessment and exploration will be required to advance the other prospects in the Region until they can be commercially developed. Because of these different stages of development, it would be expected that power-on-line will be realized first from The Geysers, then Imperial Valley and Puna, and subsequently from other anomalies which are yet to be proven.

In order to achieve significantly accelerated geothermal energy utilization, the PRT will work with the geothermal community in the Region to (1) demonstrate the required H_2S abatement technology and resolve other environmental concerns, (2) develop and demonstrate the technology required to reliably utilize the hot water resources of the Imperial Valley, (3) encourage and facilitate resource assessment, exploration and demonstrations to expand the "proven" resource base, (4) streamline the Federal/state/local regulatory procedures, (5) assist in

the demonstration of the technology required to reduce costs and increase system reliability, (6) encourage substantive changes in tax and regulatory policy to put geothermal resources on a parity with other energy resources, and (7) develop integrated program plans reflecting the needs of each state in the Pacific Region.

3. "Power-on-line" Programs

The development of these programs is an evolutionary process, which is initiated with scenario development to identify those sites with the greatest power production potential. The site-specific scenarios have been aggregated to develop an optimistic regional assessment, which then serves as a basis for identifying needs and developing supportive programs to meet those needs. In parallel, power plant conceptual designs and estimates of power costs are generated for those sites identified, via the scenarios, as most likely to provide power-on-line at an early date. Based on these initial designs and analyses, methods for reducing capital and operating costs are identified and programs implemented to reduce the subsequent cost of power until it is competitive with other available energy forms.

C. Regional Approach - Direct Use Applications

The Pacific Region Team will pursue a direct use program to meet the specific needs of the Region and to emphasize commercialization activities leading to the increased utilization of the geothermal resources for direct use purposes.

At present, the program includes DGE sponsorship of engineering and economic feasibility studies and field experiments for direct heat applications. The studies and the field experiments result from competitive solicitations, such as Program Research and Development Announcements (PRDA's) and Program Opportunity Notices (PON's) issued periodically over the past two years.

In the future, the scope of planned activity will be modified to broaden the potential applications considered, eliminate certain applications, and limit engineering and economic (E&E) studies to site-specific, industry-specific application and feasibility analyses. New applications to be emphasized include forest products, mineral extaction/ processing, food processing, chemical processes, cosmetic processing, etc. In addition to technical viability, all such studies will emphasize real-world economics, financing mechanisms, marketing strategies, and institutional incentives and/or barriers. Where necessary, co-sponsorship of projects qualifying for other Federal agency subsidies may be actively pursued to permit the development of substantial direct heat systems.

Further, the National PON approach for effecting field experiments may be discontinued and be replaced by the issuance of solicitations for selected applications on a regional basis. The scope of planned activities may be expanded to include hybrid systems, heat augmentation, and initial phase funding of scale-up projects. The latter projects may be in conjunction with a loan guaranty for later project phases. In concert with an expanded PRT resource confirmation program in the Region, most project related resource work may be completed prior to proposal submittal.

As viable resources are identified or developed as a result of state-coupled and Federal resource assessment programs, the field experiment program will, in effect, perform a brokerage function. Solicitations for potential projects could be made based upon resource confirmation and user profile data. These solicitations would be targeted at applications that represent intensive energy savings, potential for improved energy system economics, and more optimum utilization of the resource. Industry associations will be enlisted to help maximize the probability of reaching organizations likely to participate.

Programmatic activities that fall within the categories of proven applications and projects requiring extensive Federal assistance ($\geq$ \$10M) are likely candidates for the Geothermal Loan Guaranty Program.

Concurrently, a commercialization field team is being considered and could include representatives from the San Francisco Operations Office, the Regional Representatives office, Lawrence Berkeley Laboratory, Jet Propulsion Laboratory, regional planning contractors, and the states. This team could serve as the focus for the planning and execution of the initial commercialization projects in the Region, and for information dissemination and technology transfer activities.

Continued support of the environmental assessment work for the field experiments will be performed by the Oak Ridge National Laboratory or suitable contractor. In addition, the field team could identify specific areas in the Region which warrant regional environmental baseline studies. This determination will be largely dependent on the prospects for near-term development.

As previously mentioned, the program will continue to emphasize PRT sponsorship of the perceived high-risk resource assessment and confirmation actions in the Region. This front-end activity is designed to increase private sector investment in energy-intensive geothermal applications, such as industrial process heat or industrial-agribusiness ventures. The state-coupled assessment will continue to be coordinated with USGS programming. Additionally, the current resource engineering and reservoir management support will provide the necessary link to move fledgling projects into full geothermal development and expansion. The PRT is planning to establish a working relationship with the University of Utah's Resource Assessment group, in order to utilize their considerable expertise in assessment of lower-temperature hydrothermal anomalies.

III. PROGRAM ELEMENTS

In the sections that follow, the elements of the Pacific Region Program are summarized.

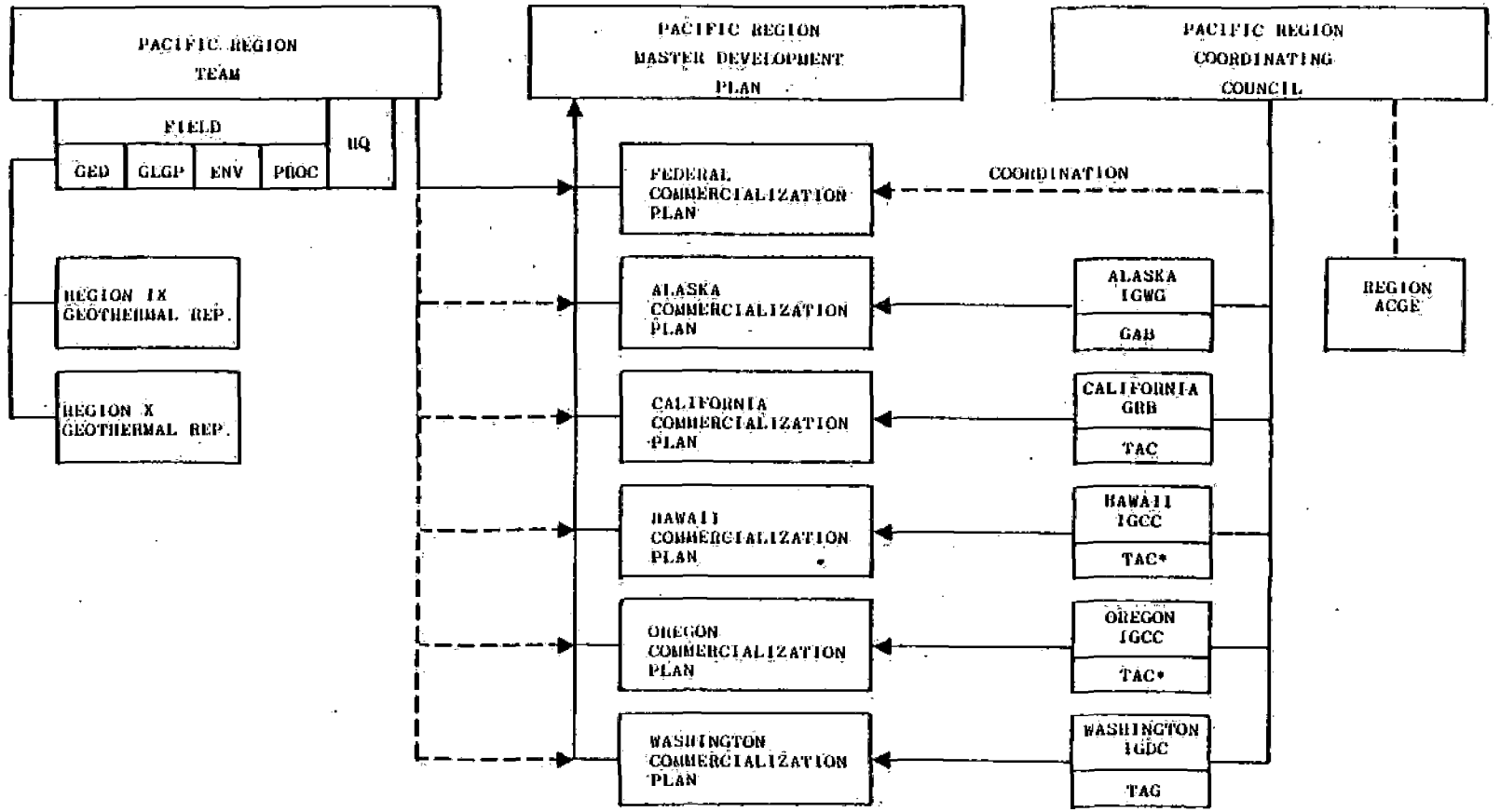
A. Regional Planning

The primary emphasis in regional planning is on defining the type and magnitude of potential geothermal energy uses, and the specific actions required to achieve early commercialization of geothermal energy. Planning for geothermal development extends far beyond actions to be taken by PRT. Almost all of the decisions which determine the course of future development will be made by organizations other than PRT, both public and private. In pursuit of the goals of accelerating geothermal energy development, optimistic, aggressive developmental scenarios have been prepared to depict possible future conditions. These scenarios are being refined as additional information is being gathered. Market analyses and penetration studies are used to provide realistic information on how to achieve results approaching the scenarios in the energy marketplace. Feedback channels to the planning program, and to the users and the other decision-makers, have been established to ensure timely transfer of information and further refinement of user needs. These activities will also provide a means of maintaining and updating the Pacific Region Plans, whose hierarchy is shown in Figure 4.

Recognizing the substantial differences involved in planning for direct use, as opposed to electrical applications, the planning activities will be segregated by application. This segregation will be most apparent in the utilization of parallel planning support contractors addressing the scenario development and market analyses for direct use and electric applications.

1. Scenario Development

Specific goals have been developed for bringing geothermal energy on-line at various



*OFFICIAL DESIGNATION TO BE DETERMINED

Figure 4. Pacific Region Plans and Planning Organization

prospects in the Region. Prospect-specific scenarios will continue to be developed to define internally consistent sets of actions which, if taken by the various key entities, will lead to the achievement of goals depicted in the scenarios. The scenarios are aggressive projections or plans that provide a context for detailed planning and serve to identify critical issues and the near-term actions which are most critical to successful commercial development. The scenarios also serve as a basis for providing "reference" time lines to be used to focus discussion among the various organizations and help lead to a coordinated set of activities. In addition, the scenarios provide a basis for DGE, in its crucial role as coordinator of the entire Federal program, to assess Federal manpower requirements in areas such as leasing and to recommend staffing and budgetary priorities to other agencies on the basis of potential impact on development. Specific examples of scenarios which have been developed for the Heber, California and Puna, Hawaii sites are presented in Appendix III.

In addition to generating the scenarios as products, the process of developing them provides other benefits. As issues and interfaces are identified during the process, the responsible Federal, state, local, or industrial entity is made aware of the situation in general and their role in particular, often prompting action to be taken much sooner than would normally have been the case.

2. Market Analysis and Penetration Studies

To supplement and provide a basis for achieving the scenarios, the primary near-term emphasis will be on identifying the market and devising a strategy for

penetrating the market. Preliminary work has been done on each aspect of this analysis. Further work will pursue the analysis in more detail and provide a basis for refining the strategy. The current energy supply picture is being assessed. The market position of the primary competitors to geothermal energy (nuclear, coal, oil, natural gas, and hydropower) must be well understood so that an effective market strategy can be formulated.

In addition to expanding analysis of other energy sources which comprise the competition for geothermal energy, detailed analyses are being made of end use demands. Each class -- residential, commercial, industrial, and governmental -- will be analyzed to determine the end uses most appropriate for substitution or replacement with geothermal energy.

Further analysis is being performed on institutions involved in each of the primary end use areas. The decision-making process of users in each category, and the motivating factors and key parties to the process, are being examined. In addition, modes in which the market might be stimulated are being analyzed.

Based on the foregoing analyses, a strategy is being developed in collaboration with the industrial entities in the Region, as well as state and local governments.

In conducting the market studies, emphasis is being placed on involving those private sector organizations normally involved in performing this type of work. This is intended to maximize the relevance of the analysis to the real marketplace.

3. Regional Feedback and Information Transfer

It is essential that the regional planning process be fully integrated into the activities of the Region. A monitoring operation will be established to keep track of geothermal development activities in the Region and disseminate the information, so that unusual events or trends can be factored into the decision process in a timely manner. Extensive reviews and feedback cycles and mechanisms are also being established to ensure that the output of the regional planning process is most responsive to the needs of the key decision makers in the Region. Important mechanisms for this purpose are the state geothermal coordinating councils and the Region Geothermal Coordinating Committee. Industry advisers, developers and other federal agencies will all provide input to this Region Geothermal Coordinating Committee. As discussed above, it is the action of these key players, more than any independent actions by the PRT, that will determine the rate of geothermal development in the Region.

B. Commercialization Support

This program element includes those program activities involved with transforming the geothermal option from a technologically demonstrated alternative to commercial implementation. The activities in this program are focused on working side by side with the potential developers and users of geothermal energy. These activities, interactions, and relationships take several forms, such as cooperative programs and tests, technical and financial analytical support, and education and technology transfer.

1. Cooperative Programs and Tests

It is sometimes appropriate to provide substantial DOE assistance and support, so that an industrial partner is able to take the last few steps leading to commercial deployment. The industrial entity has a lead role, with PRT's program objective being to have the industrial partner become self-sustaining. Two current examples include:

- Geothermal Loop Experimental Facility (Niland, CA)

  An industry-coupled, cost-shared facility operated by the industrial partner (San Diego Gas & Electric), the GLEF is intended to provide information and experience leading to the resolution of problems associated with the production of power at the Salton Sea KGRA. It is anticipated that information sufficiently definitive to enable commercial plant decisions to be made will be available in mid-1979.

- Hawaiian Geothermal Project (Puna, Hawaii)

  The HGP is a DOE-state-county-industry cost-shared effort which began as a well drilling project and is now to the point of design and installation of a wellhead generator. The project, which is using the hottest operational geothermal well in the world ($\sim$ 365°C), should demonstrate commercial viability by producing electrical power in late 1980.

Consideration is also being given to other industry cost-shared activities. Possibilities under consideration include obtaining technical and economic data on wellhead generators as a possible source of bootstrap

power for geothermal well drilling and pursuing further the options of hybrid power generation and cogeneration.

Another facility providing the opportunity to obtain pre-production or pre-commercial data on components and systems is the Geothermal Component Test Facility (GCTF) at East Mesa, CA. Selected components of the GCTF are being modified to increase flow rates and improve auxiliary equipment for pilot plant tests of the direct contact heat exchanger and other hardware.

2. Technical and Financial Analytical Support

Support to potential users, which has been somewhat limited in the PRT program in the past, is planned to be expanded. Technical support will be focused particularly on the small potential user of geothermal energy. In addition, expertise in the sometimes unfamiliar and cumbersome financial aspects of geothermal energy use will be made available. Close coordination will be maintained with the Geothermal Loan Guaranty Program (GLGP) to ensure that the assistance available from that program is properly disseminated and adequately understood.

3. Education and Technology Transfer

One of the most significant impediments to commercialization is the level of perceived risk in geothermal development. In collaboration with key organizations in the Region, mechanisms will be set up to ensure the rapid dissemination of information. As needed, conferences and workshops will be held not only to further disseminate information but to provide feedback from potential users on what information is needed for them to make decisions.

4. Direct Use Support

This program element will focus upon active dissemination of information and technology transfer activities that are designed to enhance the overall commercialization potential of direct use applications of geothermal resources. The information dissemination and technology transfer activities would be planned and implemented by a commercialization field team now under consideration (headed by a representative of the Department of Energy, San Francisco Operations Office, and comprised of selected principals in the Pacific Region), in order to ensure well integrated and focused information dissemination and technology transfer activities.

Major emphasis will be directed at technical assistance to users and potential users in an effort to reduce perceptions of risk, stimulate general interest in direct use applications, develop marketing tools, establish an interactive forum with the geothermal community, and accelerate the creation of a support industry. In implementing these functions, the team is expected to perform in the capacity of energy extension specialists and brokers in bringing potential users and developers together and providing potential users with opportunities for hands-on training. A subset of these activities includes the conduct of seminars and workshops, as well as the construction and utilization of display and mobile units. An inventory of loan equipment is also being considered in order to provide potential users with ready access to representative equipment for the conduct of site-specific critical experiments. Such an arrangement will enable the feasibility assessment of candidate applications with minimal capital outlay, as well as provide invaluable hands-on training.

Concurrently, a planning support contractor will perform analyses of the market, industry/user infrastructure, and institutional barriers. Results of previously completed engineering and economic studies can serve as a useful point of departure for these market oriented investigations. Results will include recommended policy actions, financial incentives, mechanisms for leveraging investment decisions, cost-benefit assessment, user-resource overlays, user profile assessment, and marketing strategies. These data will be compiled and synthesized with related data. Further synthesis of the data can be accomplished by the unification of economic analysis and project results.

Additionally, field experiments may be selected to serve as representative direct use projects exhibiting major industrial/developer involvement and private sector investment opportunities (e.g., via system expansion).

The goals of these field experiments are as follows:

- Promote sharing of technical and economic information gained during the experiment with interested prospective users, developers, lenders, and the public.
- Determine the most advantageous government and private sector roles on major direct use projects via documentation of participants' approaches to and analyses of critical decision points.

One goal of the commercialization program for direct use includes the development and maintenance of a regional inventory and information system which will serve as the focal point from which information dissemination activity is launched. The team will seek the assistance of appropriate agencies at a local level (e.g., state, university, county extension agency, state energy

office, industrial associations, or professional geothermal organizations) in order to determine the specific information needs of these organizations. During FY '79, the groundwork of such a system will be designed and constructed and the dissemination of existing data initiated.

C. Institutional Support

A substantial number of governmental agencies in the various states of the Region are involved in regulation of geothermal energy development. These agencies have either constitutional or statutory responsibilities defining the policies which the agency must pursue. Geothermal development, if it is to occur, must conform with these policies. One of the chief difficulties that has plagued development in the past has been the lack of coordinated policies and timely agency review of proposed industrial development activities. This problem has manifested itself primarily as substantial federal, state and local permitting obstacles and federal leasing delays. These delays are primarily the result of competing agency priorities and inconsistent policy implementation. The relevant agencies at the Regional level are listed below.

Federal Agencies:

- The Bureau of Land Management (BLM) which is responsible for the leasing of Federal lands
- The U.S. Forest Service which is responsible for establishing the bases for leasing decisions on the lands under their jurisdiction
- The U.S. Geological Survey (USGS) which is responsible for the enforcement of all pertinent regulations on Federal lands under a geothermal lease and decisions on the federal income to be derived from their use.

State Agencies:

The titles for these entities vary from state to state.

Each of the following exists in some form in each of the five states, however. They include public utility regulators, power plant siting regulators, land use planning/regulation agencies, environmental/air/water agencies, drilling regulators, geologist/resource assessment offices, taxation department, and the legislature.

Local Agencies:

Land use regulators, tax agencies, environmental/air/water regulators and local legislative and administrative governing boards of some sort, such as county commissioners.

Other:

In addition to the above governmental agencies, the public has a strong input on the acceptability of proposed geothermal projects via public interest groups.

The Pacific Region program recognizes the legitimacy of each of the organizations in fulfilling its responsibilities. It is the intent of this program to help provide a positive framework for the many interactions and interfaces to be properly accomplished without undue delay in the responsible yet accelerated development of geothermal energy.

1. Planning Support

It is clear that any institutional planning for geothermal development must involve all of the diverse but related entities involved. Financial support from PRT for state and local planning is already in place in California, with several grants involving the Conservation Department, Geothermal Resource Board, Energy

Commission, and Imperial, Napa, Sonoma, Mendocino and Lake Counties.

PRT is actively working with state and local governmental agencies in the other four states to develop coordinating committees and prioritize tasks which may be jointly undertaken, as described in Section IV D, below.

The Pacific Region Team is also assisting in planning legislative, regulatory and procedural changes in the Region. Under a DGE grant, the National Conference of State Legislatures (NCSL) is working with the legislatures of Oregon and Hawaii. This activity will soon be expanded to include Washington and Alaska. DGE is also working with the United Indian Planners Association to involve tribes, native corporations, and Native Hawaiians in the participative planning process.

2. Policy Analyses and Development

As the geothermal resources of the Pacific Region move into commercial development, policy matters take on added significance. While a few policy issues (e.g., federal tax treatment) also effect the other regions, most of these barriers are specific to the five states in the region. Although it is not always possible to quantify legal and institutional roadblocks as to the precise number of megawatts lost, etc., there is little doubt that a failure to alleviate these problems will hinder geothermal development in the Pacific Region. Some of the major issues are briefly described below.

- Federal Tax Treatment:

  Since the early 1970's, present federal tax treatment has been perhaps the most significant policy-related barrier to geothermal development. A certain amount

of activity takes place nonetheless, but it is not an adequate level of action, given even the most modest of "targets" for power-on-line. Congress has recently provided for the expensing of intangible drilling costs and for a percentage depletion. Such tax enactment will provide an extremely important stimulus for geothermal energy in the Pacific Region.

- Leasing:

  On Federal acreage in key prospect areas of the Region, there has been a substantial failure to expedite geothermal leasing. The wilderness study programs of both the Forest Service and BLM have contributed to delay, particularly in Oregon and California. Industry response to this problem has been masked somewhat by a shift to land plays on state and private land and a parallel shift to states outside the Region. The State of Hawaii presents a somewhat different set of issues in this respect. Despite a paucity of Federal land, there is an abundance of state land which is presently interpreted as being mineral-severed. If the Federal tax problem can be resolved, access to land will emerge as the pre-eminent legal issue in the Region.

- Permitting:

  This barrier, like that found in the leasing arena, has been obscured in great part by lack of available federal land and a favorable tax regime. In the more developed areas, there are also problems at the state and local levels involving the permitting of both wells and power plants.

- Utilization/Distribution:

  Although some of the problems associated with this phase are technical in nature (e.g., demonstrating utilization technology), there are also legal and institutional aspects. Utility concern over reservoir life may be susceptible to a policy solution (e.g., reservoir insurance). The dedication of transmission line corridors must be cleared through a maze of Federal, state and local land controls and classifications, as well as utility siting systems. Where existing lines with adequate excess capacity are located nearby, wheeling arrangements with their owners must be negotiated.

- Water Law:

  Though it has not, as yet, become a serious obstacle, state water law regimes may pose roadblocks to geothermal development rivaling those in the tax, leasing and permitting areas.

- Land Tenure and Access (Alaska only):

  This subject is currently in the legislative process and impacts will be developed later.

3. Direct Heat Use

In addition to the issues discussed above, direct use applications have numerous specific institutional issues associated with them, including:

-- Legislative definition of low- to moderate temperature geothermal resources

-- Regulation of exploration for low- and moderate- temperature resources

-- Land-use regulation associated with direct utilization

-- Formation of special utility districts

-- Reservoir conservation and management

-- Environmental protection of wilderness areas, hot springs and other fragile environments

-- Stimulating private sector investments; providing financial assistance via tax incentives, Geothermal Loan Guaranty Programs, intergovernmental coordination and resource advisory capability; information dissemination and federal cost-sharing

-- Future price regulation of hot water for direct uses

-- Hybrid systems

The impact of these problems on development of direct uses, along with needed actions, is being analyzed in detail, and plans and recommendations are being formulated.

D. Resource Definition and Development

The ultimate goal of resource definition and development is a reliable inventory of proven geothermal resources at each

site within the Pacific Region that is capable of supporting commercial production of electricity and/or direct heat use. At present, only a fraction of the resource has been identified, and very little of it has been characterized.

Two approaches are being pursued:

- Discovery and definition of geothermal reserves for post-1985 commercial development.
- Confirmation of "proven reserves" at sites capable of power and/or heat-on-line by 1985.

Determination and evaluation of the resource base includes the geosciences and engineering activities which begin with exploration at a regional scale, continue through the definition and delineation of geothermal prospects and specific sites, and end with an inventory of proven recoverable reserves at each site. Economic analysis of geothermal energy production costs versus the cost of competitive sources of power and heat at that site are an integral part of resource estimation. Resource definition is a heavily funded federal activity within the Pacific Region because resource uncertainty is the major initial barrier to geothermal energy development.

One of the major technical problems inhibiting the current development of geothermal energy is the degree of risk inherent in the prediction of resource magnitude, reservoir characteristics and performance, and longevity. Uncertainty as to the size, quantity, and lifetime of geothermal resources beneath specific leaseholds is a primary deterrent to private investment decisions by utilities and other users of electrical and thermal energy. Lack of financial commitment by potential purchasers of geothermal steam constrains the activities of geothermal exploration and drilling companies.

1. Resource Program Approach

The purpose of the geothermal resource assessment program is to locate, delineate and evaluate the energy potential of specific geothermal resource sites. To best accomplish this a comprehensive and systematic approach is required that incorporates geological, geophysical, geochemical and hydrological surveys to determine locations for a sequence of drill holes and well tests.

Results from the surveys are analyzed to justify the siting of shallow (<100m) heat flow holes. Those data, in turn, influence the location and depth of intermediate depth (500-1000m) calibration test holes. All information is then focused on the siting of one or more deep (1500-3000m) test wells. If successful, these deep wells will prove that commercial temperatures exist within economic drilling limits, and that the chemistry of the geothermal fluids can be handled by proven methods.

Well tests are then conducted to prove that commercial flow rates can be maintained without depleting the reservoir over the lifetime of the plant, and that scaling, corrosion and reinjection problems can be controlled within the economic limits of the project.

2. Resource Discovery and Definition

The DGE Pacific Region Team will fund within budgetary limits, resource data collection, compilation and analysis activities within the Region. This support includes:

- USGS national and regional resource inventories;

- Cooperative regional and site exploration surveys with industry and other government agencies;

- Cooperative resource exploration drilling through:

  - bottom-hole contributions which encourage geothermal leaseholders to test promising acreage by cost-sharing the drilling of exploratory wells, and to offer existing data for sale, thereby accelerating the gathering of reliable information on known geothermal reservoirs;

  - drilling DOE-funded exploratory wells in order to stimulate commercial interest in the Region and possibly discover new geothermal reservoirs; and

  - DOE cost-sharing of coring in exploratory wells, to provide essential core material for reservoir parameter measurement, testing of completion and production techniques (e.g., muds and pumping rates), and analysis of reservoir production and injection problems (e.g., injection plugging).

  - potential programs coupled with the GLGP whereby the Region Program may cost-share an exploration phase preceeding a loan guaranty.

3. Reservoir Confirmation

One of the most critical barriers to acceleration of the development of geothermal resources is the lack of reliable test and production experience from hydrothermal reservoirs. Extensive geologic and engineering information is needed to facilitate field development, reservoir operation, economic analysis, and financial investment.

Substantial funding is planned for cost-shared high-temperature reservoir confirmation under the Industry-Coupled Case Studies Program. This program offers

industry financial assistance for reservoir confirmation wells, while making geoscience, reservoir engineering and other data available to the rest of the industry. Requests for Proposals specify acceptance criteria for industry cost-sharing proposals. The successful industrial concern acts as project manager. PRT receives the contracted data package and initiates interpretation, additional data collection and compilation, and publishes integrated case studies through selected contractors.

Definition and confirmation of low- and moderate-temperature reservoirs will be accelerated by the State Cooperative Resource Program. This program provides funding for the state geologist or his equivalent in each state in the Pacific Region, working in cooperation with the U.S. Geological Survey, where desired, to conduct resource definition at specific sites of greatest potential for direct heat utilization. The USGS assimilates the data generated into the GEOTHERM resource assessment computer file, and helps to interpret the data. The Department of Energy's laboratories are funded to provide technical assistance where required. The National Oceanic and Atmospheric Administration (NOAA) is funded to compile the data and publish the final state geothermal resource maps.

The State Cooperative Program provides important input to PRT Program Opportunity Notices (PONs) for direct heat use by identifying geothermal sites that are ready for development. It is anticipated that these state projects may lead to the initiation of industry cost-shared projects at selected sites by 1982 to develop more low- and moderate-temperature geothermal reservoirs, once the resource base is better understood.

A paramount consideration in the reservoir confirmation program for direct heat use is matching the location of confirmation activities to the availability of potential users. The flexibility afforded electrical applications by being able to transmit the energy to the ultimate customer from a remote site is severely restricted in the case of direct heat applications. Studies augmenting currently available information will be performed to determine the correct balance between expected resource locations and availability of on-site customers, giving particular attention to potential retrofit customers. The study results will be used in setting priorities for the direct use reservoir confirmation efforts.

4. Resource Technology Transfer

The need to ensure timely transfer of the information and technology development through the PRT program is critical, and is reflected in the manner in which the resource program is organized. Primary emphasis is placed on joint efforts with industrial partners. Industry participates in the setting of site priorities and defining the problems to be addressed. To ensure transfer of information beyond the necessarily limited participants in joint cooperative programs, special care is taken to widely disseminate up-to-date information.

E. Environmental Support

Geothermal energy resource development (both electric and direct applications) can be accomplished in an environmentally acceptable manner by identifying environmental issues at an early stage, acquiring appropriate baseline data, coordinating all interested parties, and resolving environmental concerns. The

Pacific Region Team will meet these requirements through funded activities that include financial and technical support for environmental activities in the Region, control technology demonstrations, coordination of environmental assessments, and environmental technology transfer to industry, universities, government agencies, other institutions and the public.

1. Support to Regional Activities

Support by the Pacific Region Program to environmental activities in the region takes several forms:

- Overviews

  Within DOE, the responsibility for environmental overview and research is in the Office of the Assistant Secretary for Environment (ASEV). The ASEV program is coordinated with the Pacific Region programs through several mechanisms. A Geothermal Energy Environmental Overview Committee is set up to coordinate within DOE. The environmental program is also represented on the PRT to ensure a coordinated program through all of the implementation phases.

  Through consultation with key organizations in the region (e.g., industry, Federal, state and local agencies), the Pacific Region Team identifies high priority areas for environmental attention. Based on these priorities, the ASEV program conducts overview studies, from which environmental priorities are determined. These studies and related projects, are the vehicles used to evaluate the environmental acceptability of geothermal development and investigate such parameters as air quality, meteorology, water quality, noise, hydrology, seisimicity, subsidence, resource-use, demography, socio-economics, existing and future land use and archeology.

  "Overview studies" are actually a form of preliminary planning. They use locally available resources for development of preliminary assessments of available data in Known Geothermal Resources Areas

(KGRA's) and identification of information gaps and key issues requiring further study. The following list identifies present "overview studies," principal contractors and associated time frames:

ACTIVITY	PRINCIPAL CONTRACTOR(S)	START DATE	COMPLETION DATE
(a) The Geysers	LLL	Mid FY 77	Early FY 79
(b) Coso Hot Springs	Naval Weapons Center China Lake	Late FY 77	Early FY 79
(c) Long Valley	UCLA and U.S. Forest Service	Early FY 78	Mid FY 79
(d) Hawaii	HI Natural Energy Institute	Late FY 78	Late FY 79
(e) Oregon	Oregon Graduate Center	Late FY 78	Late FY 79

- Baseline Studies and Projects

  If overview studies or other program considerations indicate the need, baseline studies are undertaken to provide a more detailed basis for environmental assessment. These may be sponsored by either the DOE Environmental or Pacific Region programs. The Imperial Valley Environmental Project (IVEP), completed in FY 78 under the management of LLL, has been the major study to date. The continuing responsibility for data maintenance and follow-on monitoring activities should be transferred to a local entity.

  Expanded activities for baseline data collection are being considered, particularly in support of direct heat use commercialization activities.

- Special Studies and Projects

  As the need arises, special studies and projects are being undertaken where an opportunity exists to expedite the geothermal environmental process. For example, technical and financial support was provided to the USFS in preparing the Inyo National Forest (Mono-Long Valley KGRA) environmental assessment. Support is being provided to Sonoma County to study Peregrine Falcon behavior as part of

an environmental assessment. Similar opportunities will continue to be sought.

A significant study which is being supported by PRT jointly with the state and local governments is the Geothermal Resource Impact Projection Study (GRIPS), in the four-county (Napa, Sonoma, Mendocino, Lake) Geysers area. The planning phase has been completed and a Joint Powers Agency has been formed to help provide an environmental base for local permitting decisions. The planning phase was closely coordinated with the DOE Overview Project performed by LLL, since the two studies had similar objectives.

Finally, consideration is being given to other activities, such as the development of a rough terrain model to predict ambient ground level concentration of hydrogen sulfide at the Geysers. Consideration is also being given to compiling information in handbook form to provide assistance to users, particularly small organizations contemplating direct heat use which may be unfamiliar with geothermal related environmental issues.

- Environmental Assessments for Field Experiments

  It is often the case that direct heat users are unfamiliar with federal environmental assessment requirements and/or lack the technical capability to prepare adequate environmental reports. PRT provides support and active technical assistance to contractors preparing environmental reports. This arrangement helps to expedite the environmental review process and promotes better understanding of the environmental acceptability of geothermal systems.

2. Control Technology Demonstration

It is important that geothermal development is not impeded by the unavailability of proven environmental control technology. The need for demonstrating advanced technology is underscored by the standards and regulations currently being discussed by the California Air Resources Board, which require more effective abatement techniques. A cooperative program has been undertaken with the Pacific Gas and Electric Company (PG&E) to demonstrate at pilot scale the copper sulfate upstream

H_2S scrubbing process developed by EIC with DGE support. This process shows great promise of ensuring that further development at The Geysers will not be impeded by hydrogen sulfide concerns, and will be immediately applicable to flash steam applications at hydrothermal prospects.

3. Coordination

Close coordination among the various governmental entities at the Federal, state and local levels is a major aspect of the program. This coordination primarily relates to the preparation of environmental assessment documents for geothermal development in the Region. The preparation of joint environmental documents is being encouraged. Recent examples of successful coordination include assessments completed or underway in the Imperial Valley and in The Geysers. PRT is generally an interested external party in such coordination, except when DOE funding or a loan guaranty is involved.

The Pacific Region Team will continue to attempt to identify promising areas, particularly for direct heat use, to help ensure that other responsible agencies will appropriately reflect the priority of geothermal potential in planning environmental assessments.

Finally, PRT will continue to actively review environmental assessments issued by other agencies so that the impacts of geothermal development are fairly assessed.

4. Information Transfer

It is critical that fully open and effective channels of communication be established to disseminate information

and define information needs to feed back into the program. Technical environmental assistance, Environmental "Overviews" and "Projects" will be transferred to the appropriate state or local agencies. Input to the regulatory processes at all levels of government will be maintained to ensure geothermal commercialization is carried out in an environmentally sound manner. In particular, Federal agencies preparing EA's, EAR's and EIS's involving geothermal projects will be actively solicited as to their data needs and sent all relevant output of the "overviews" and "projects". This includes the Forest Service (at Mono-Long Valley), BLM (at The Geysers, Coso and North Salton Sea) and the USGS. A similar level of coordination and sharing of data will be set up with the various states and counties.

F. Technology Applications

Available technology is generally adequate for the commercial development of the more attractive geothermal reservoirs. However, there are some applications in which technology improvements are essential to accelerating near-term commercial development and enhancing the likelihood that the mid- and long-term goals will be achieved. Improved technology will result in the increased capability to utilize the resource, and in improved economics. By interacting with industry and obtaining more feedback on problems being encountered by industry at specific sites, development needs are being identified by the Pacific Region Team that will be used to focus the DGE Technology Development program. Development requirements which have been identified are summarized below.

1. Resource and Well Development Technology

Improvement in well drilling and completion technology would offer the most substantial economic benefits to

geothermal development. While the costs incurred by a developer in these areas are substantial, there does not appear to be one single cost component whose reduction would have a major impact on the total cost. However, a steady incremental cost improvement over the entire range of factors can have a significant aggregate effect. In particular, it has been found that some technological improvements, such as higher penetration rate, longer lived rock bits, higher temperature drilling fluids, improved completion techniques and improved directional drilling techniques, have the potential for significantly reducing geothermal well costs.

Increased emphasis will be placed on securing industry's specification of needs for technology and information critical to geothermal development at specific sites, particularly in the resource/geosciences area. It is intended that a much more specific and prioritized set of development needs will be assembled and communicated to the appropriate DGE Technology Development program.

2. Geochemistry

Based on experience in the field, an improved understanding of the chemistry and methods of handling and managing geothermal fluids is desirable to improve the economics of geothermal energy use. Presently, the most significant geochemical problems requiring development attention at the various sites are:

Salton Sea - Silica deposition in injection system
- Corrosion due to low pH fluid
- Sulfide scale in inlet lines
- Disposal of waste material

East Mesa - Calcite scale
- Carbon dioxide gas

Puna - Sulfide scale
- Calcium scale

In addition, there is a need to develop the capability for on-line monitoring of geochemical conditions as they vary with time.

These development needs are being addressed in the DGE Geochemistry program element.

3. Extraction Technology

Once wells have been completed, there is a strong economic incentive to enhance production and avoid the expense of premature well replacement. In addition, it is often desirable to maintain sufficient pressure in the geothermal fluid system to avoid flashing (e.g., for binary cycles) or minimize plugging and scaling. The development of pumps capable of operating in the well for long periods of time under geothermal fluid conditions will be required to address these considerations. Development of more effective reservoir stimulation techniques will also be required to enhance fluid extraction from geothermal wells. The state-of-the-art for production strategy planning is such that improved understanding of two phase flow in geothermal well bores can significantly improve production. Techniques, such as the Equilibrium Flash Production (EFP) system, whereby relatively small quantities of CO_2 are injected into the well, which can increase production rates while minimizing calcite scaling, are also needed.

Each of these development needs is being addressed in the DGE Extraction Technology activity.

4. Conversion Technology

A substantial fraction of the resource in the Region is in the moderate-temperature range. This segment of the resource must be utilized as fully as practical in order to enhance the prospects of achieving longer range goals. The most significant development need is the development of the binary heat conversion system. This includes requirements for the development and demonstration of improved heat exchange equipment. The economics of exploring the moderate-temperature resources can be improved significantly by enhancing the effectiveness the heat exchangers, reducing cost, and reducing uncertainties in estimates of heat exchange size required for a given application. In particular, the direct contact heat exchange concept appears to be capable of improving cycle efficiencies, reducing costs, and reducing fouling problems. A significant amount of development remains, however, for that concept. Use of the hydrocarbon binary system also permits advantage to be taken of lower condensing temperature, thus leading to a need for improved condenser equipment. Finally, further development of devices to use the total flow from wells, particularly wellhead power generation devices, such as the helical screw expander, has a strong potential for enhancing geothermal development.

These needs are being addressed in the DGE Conversion Technology program element.

5. Direct Use Hardware Development

This activity provides the mechanism that will enable the sponsorship of industrial concerns for the design, development, and testing of components. Programmatic

scope will include cost-sharing with equipment suppliers. For equipment tested at the GCTF, staging of projects will be considered to maximize the utility of the test site.

Where appropriate, solicitations for R&D of critical components and new system processes will be issued (e.g., low temperature absorption refrigeration units, low cost heat exchangers, low cost effluent treatment and disposal techniques, and innovative concepts of energy cascading and byproduct recovery). Emphasis will be placed on those devices and systems that show promise of yielding significant overall energy savings, improving system economics, or enabling the utilization of a wider range of resource temperatures (e.g., suppressing the lower temperature threshold so that lower quality heat resources might be utilized for a given application).

Consideration is also being given to instituting independent research and development programs under government contracts and grants that are discrete and dedicated to energy related research. Such an allocation should spur equipment and service industry organizations to expand their product lines and build upon the capabilities of a support industry to better serve the needs of the geothermal community.

4. MANAGEMENT STRUCTURE

The specific roles and responsibilities of those entities involved in the management and coordination of the Pacific Region Geothermal Commercialization Plan are described below.

A. Roles of DOE Organizations

The Division of Geothermal Energy has assigned responsibility on a regional basis to three teams: Eastern Region, Rocky Mountain/Basin & Range, and Pacific Region.

The Pacific Region Team (PRT) manages programs in the areas of planning and policy development, resource definition, engineering applications, environmental conformance and facilities. The PRT is responsible for developing regional commercialization and development plans. It has the programmatic responsibility for coordinating with other Federal agencies, state and local governments, developers, financiers, industry and users. This commercialization plan is a first step in the process of developing a realistic, coordinated program that addresses the resources, goals and responsibilities of all parties.

Development of the PRT goals and objectives, program planning and execution, interface with other Government agencies and industry, budget formulation and defense, and detailed project planning and project management are the responsibility of the Pacific Region Program Manager as the Pacific Region Team Leader. Members of the team are located in the Division of Geothermal Energy, Washington, D.C., and the Geothermal Energy Division of the San Francisco Operations Office, Oakland, California. Specific functional responsibilities for each member and for support from the DOE Regional Offices are being developed

in Management Agreements for approval by the Director of the Division of Geothermal Energy and the Manager of the San Francisco Operations Office.

B. Industrial Coordination

The PRT recognizes the critical role played by industry in implementing geothermal energy utilization. Presently, structured input is given to DGE by the Advisory Committee on Geothermal Energy on which industry has representation. This channel of input could be expanded if the Pacific Region formed under the joint auspices of the ORR's in Region IX and X, a Regional Industrial Review Panel within the framework of the Advisory Committee on Geothermal Energy. This Panel could provide input, focusing on the unique industrial experience in the field to make the program as responsive as possible to the needs of the geothermal industry.

C. Federal Agency Coordination

By statute, DGE is responsible for leading the coordination of geothermal policy formulation and program management among the Federal agencies involved in geothermal activities. The formal mechanism for accomplishing this is the Interagency Geothermal Coordinating Council (IGCC), made up of Assistant Secretary-level members of the various agencies. This has proven to be a particularly effective coordination tool, due in large part to the extensive staff work accomplished in the periods between formal Council meetings.

D. State and Local Coordination

In addition to the assistance to state and local planning described earlier, working relationships have been established with state and local government bodies and public

organizations in the Region. PRT's role is to foster communication and identification and good faith resolution of issues, and to serve as a resource for information. Formal mechanisms are being set up to provide for state and local input into DGE's program activities in areas in addition to the planning program element.

Alaska has formed an Interagency Geothermal Working Group, to be supported by a Geothermal Advisory Board. California's Energy Commission, in concert with the Geothermal Resources Board, works regularly with its Technical Advisory Committee to develop geothermal policy and pursue urgent actions. Washington State has established an Interagency Geothermal Development Council, supported by a Technical Advisory Group, and has regular meetings to develop policy and plans, and to exchange information. Oregon has formed the Oregon Interagency Geothermal Coordinating Council which is supported by an advisory group and expects to pursue a vigorous program. Hawaii is expanding its state project activity to include additional state agencies in a Geothermal Coordinating Council.

The PRT and the state geothermal committees are working jointly to develop state planning and to direct and monitor the work of the regional site-specific planning contractors. In addition, they are currently formulating a Pacific Geothermal Coordinating Committee to provide a forum for development and comparison of policies, legislation and plans, and for interaction with the regional officers of Federal agencies and the regional panel of the ACGE. This Pacific Geothermal Coordinating Committee will assist the PRT in prioritizing sites and geologic regions for the PRT and USGS resource assessment activities, areas for leasing by BLM and USFS, areas for industry-coupled drilling, market areas for direct use emphasis, etc. Input will be used from the regional panel of the ACGE and from the states' knowledge of user interest and commitment, and the likelihood of early field development, for the prioritization activities.

APPENDIX I

ENERGY SUPPLY AND DEMAND

PACIFIC REGION

The Pacific Region of the United States includes the states of California, Oregon, Washington, Alaska and Hawaii. Together these states had a total installed capacity for electric power generation of 64,000 MW in 1976. California accounted for 55% of the power, Washington 28.9%, Oregon 12.3%, Hawaii 2.1% and Alaska 1.6%. The annual percentage change in installed capacity for the region was 4.6% from 1970 to 1976. Residential use accounted for 34.3% of the power generated, commercial accounted for 27.1% and industrial use for 35.5%.

Natural gas consumption in the region amounted to 1.877 quads, 85% was consumed in California, 8.3% in Washington, 4.5% in Oregon, 1.6% in Alaska and .2% in Hawaii. Residential use accounted for 35.05%, commercial use for 14.28%, and industrial use for 50.2% of the natural gas used.

The Pacific Region's manufacturing industries purchased 1.013 quads of fuel and electric energy in 1976 for heat and power at a cost of $2.3 billion dollars. Some industries which may show particular promise for geothermal energy are the food processing industry, lumber and paper industries, chemical industry, and the petroleum refining industry, all of which use large amounts of process heat. It should be noted that these projections are for purchased fuels. Some industries may not have a purchase transaction for all energy. For example, lumber mills are using wood residue for fuel, oil companies produce much of the fuel that they consume and much of the chemical manufacturing is done by oil companies. Oftentimes a large energy using sector will want to produce its own energy in order that its price can be controlled.

The table below displays the purchased fuels and electric energy in terms of trillion Btu's (10^{12}) as well as the prices paid for them.

QUANTITY AND COST OF PURCHASED FUEL AND ELECTRICITY FOR HEAT AND POWER FOR SELECTED INDUSTRIES IN THE PACIFIC REGION*
1976

	TRILLION BTU	MILLIONS OF DOLLARS
FOOD AND KINDRED PRODUCTS	137.5	$304.6
LUMBER AND WOOD PRODUCTS	73.5	192.9
PAPER AND ALLIED PRODUCTS	142.4	469.9
CHEMICALS AND ALLIED PRODUCTS	82.2	183.2
PETROLEUM REFINING	149.0	302.3

Population growth for the Pacific Region from 1970 to 1976 was 1.3%

The Pacific region of the United States has a major share of the geothermal resources in the United States. There are currently over 500 MWe of installed capacity on-line at the Geysers, California, 60 MWt in operation in Oregon in the Klamath Falls area, and a large number of small direct uses (such as swimming pool heating and greenhousing) scattered throughout the Region. California has the highest potential for electric power generation. Mitre Corporation, the National Operations Research

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*Reference: Annual Survey of Manufacturers, 1976, Fuels and Electric Energy Consumed, U.S. Department of Commerce, Bureau of the Census.

contractor, has made projections of geothermal electric power generation on-line, as well as millions of BTU per hour for direct heat applications with Federal participation in development activities. The Federal government's participation in the development of geothermal energy has already contributed to an accelerated growth rate for geothermal energy in the Pacific Region.

Figure I-1 indicates the dynamic character of the evolving geothermal industry in Imperial County, California. Comparing the recent SAI scenario for development with the Mitre Corporation's projections of a year ago, it can be seen that significant progress has been made and the expectations for energy on-line have been accelerated by as much as 1 to 2 years. Without government interest in geothermal energy, this level of activity might be greatly reduced.

At the present time there are no firm plans for geothermal electric power generation in Alaska, Washington or Oregon. Washington and Alaska are just beginning to investigate the potential for geothermal energy. Reports are currently being prepared in each of the states by Operations Research Contractors in conjunction with State Energy Offices and a higher level of planning for energy needs is presently evolving.

Projections of technical energy development were made for each state by Mitre Corporation and are included in the discussion of each individual state. California appears to be the major target for electric power generation accounting for over 90% of the projected power on-line. Geothermal energy development in California can be used to displace petroleum, natural gas, and new nuclear plants. Fuel oil costs have been increasing, natural gas may face future curtailments, and nuclear energy is facing problems with power plant siting.

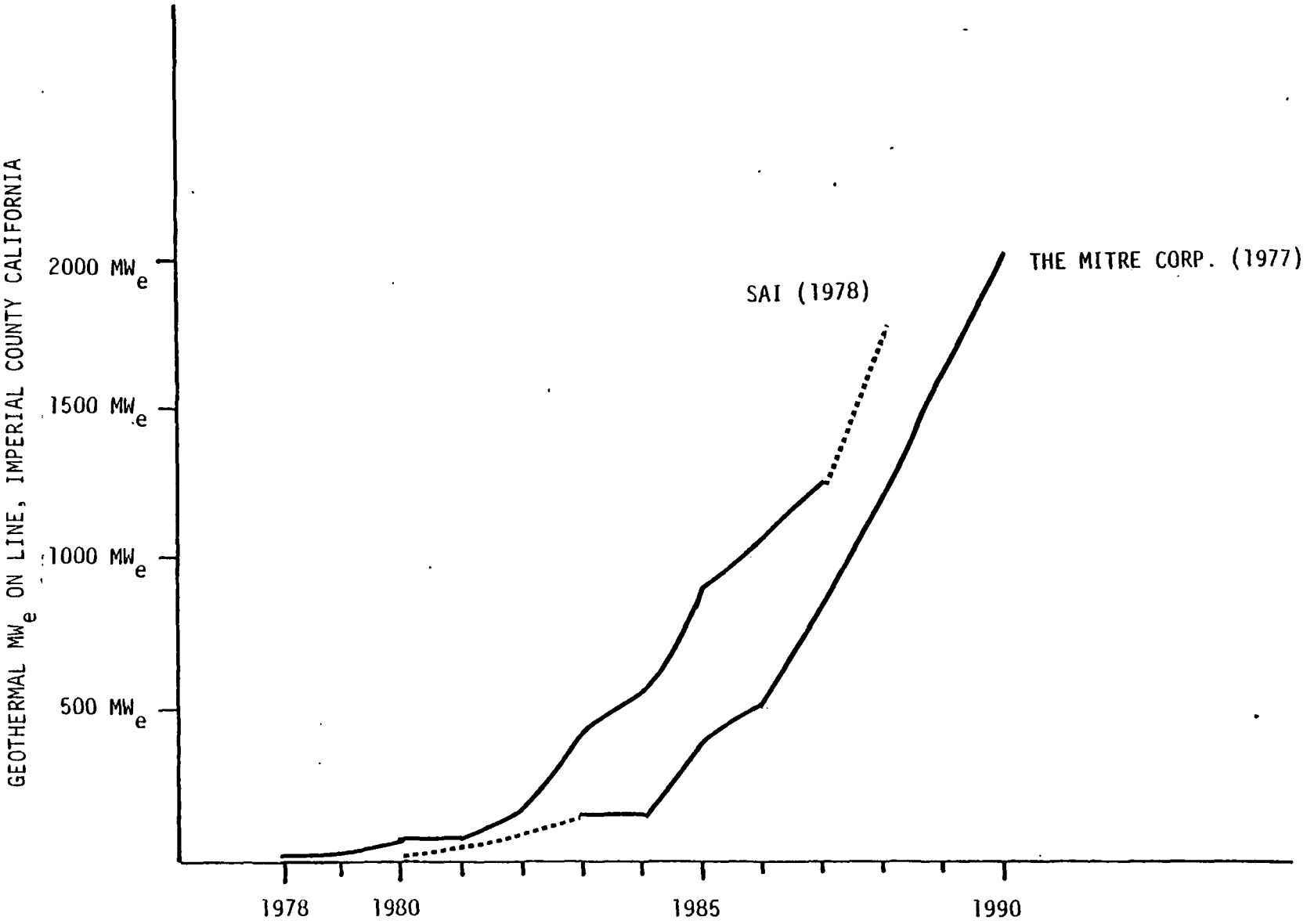


Figure I-1. Comparison of Updated Scenario for Imperial County, SAI (1978) with MITRE (1977), Installed Capacity, Geothermal MW$_e$ On Line

Washington and Oregon derive a large portion of their electric energy from hydroelectric systems which are very cost competitive and environmentally preferable. However, new hydro sites are limited and geothermal energy may help ease future reliance on a petroleum based energy supply.

Hawaii is heavily dependent upon petroleum products which account for 92% of the energy in the state. The state is actively involved in finding local alternative energy supplies to reduce the balance of payments pressure that oil places upon the state economy. At the present time the State and Federal government are participating in providing for a well head generator at the Puna site on the Big Island of Hawaii.

There is no projection of electric power on-line in Hawaii, Alaska, Washington and Oregon without Federal assistance.* The projection with Federal assistance is displayed in Figure I-2 with a potential 400 MW by 1990.

In the following paragraphs each state is addressed with regard to energy supply in the state and energy demand. A discussion is given of the electric power on line, as well as estimates of energy uses by commercial industries which are primary targets of geothermal process heat.

ALASKA

Alaska's energy is predominantly derived from petroleum and natural gas. Residents of Alaska use the largest amount of energy per capita partly due to the climate and partly to the long distances between centers of population. The components of energy supply and energy demand for Alaska* are given in Figure I-3.

*Reference: Result of discussions with officials of the State Energy Departments.

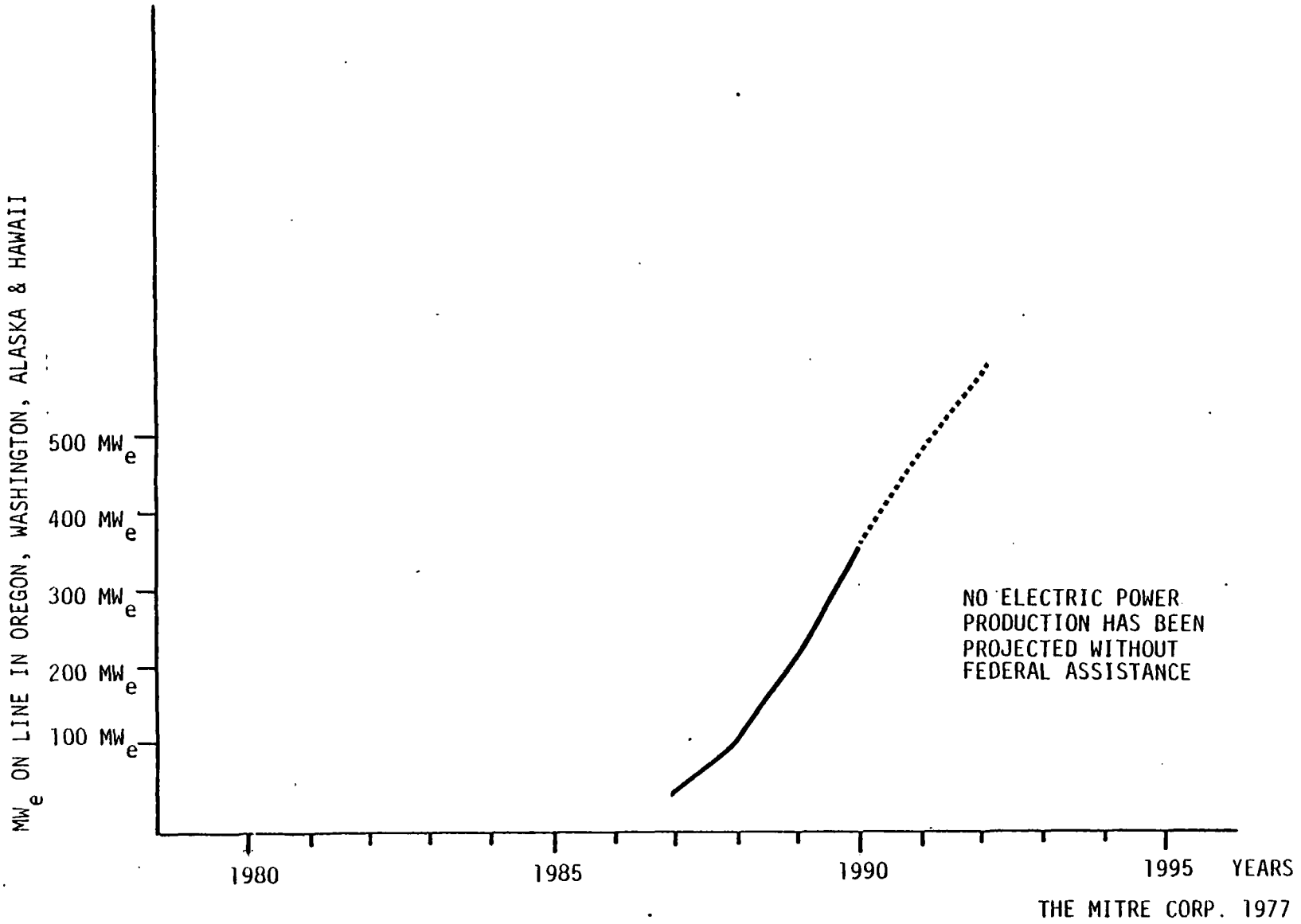


Figure I-2. Projection of Geothermal Electric Power Generation in Oregon, Washington, Alaska, and Hawaii

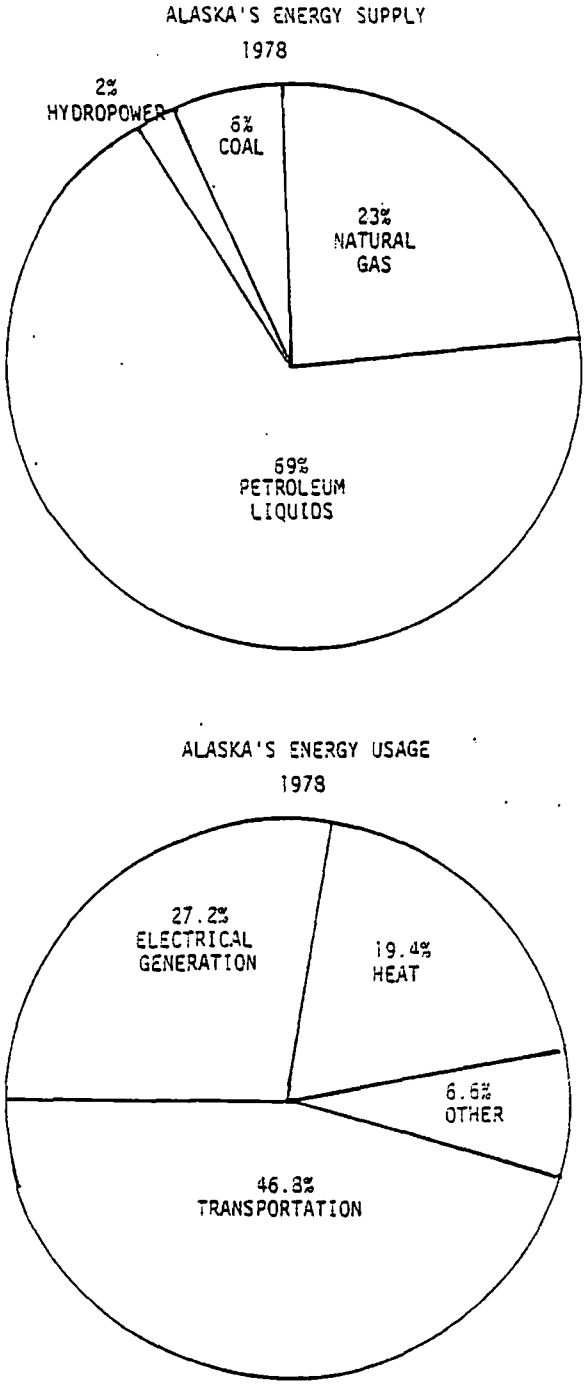


Figure I-3. State of Alaska Energy Supply/Usage

From 1970 to 1976, Alaska's installed capacity for electric power generation increased at a rate of 15% per year, the highest rate of the five states. Installed capacity in 1976 was 1,000 MW, the lowest of the five Pacific states. Of Alaska's electric power generation, 50% went to residential use, 36% went to commercial, and 9% went to industrial use.

Natural gas consumption in Alaska in 1976 was .031 quad: 19% went to residential use, 22.5% to commercial and 41.9% to industrial use.

Alaska's manufacturing industries consumed .0089 quad of fuel and electric power for heat and power purposes in 1976. Major industries in Alaska include only two of the industry groups: food & kindred products, and lumber and wood. The table below displays the quantity and cost of the energy purchased by these two industries.

QUANTITY AND COST OF PURCHASED FUEL AND ELECTRICITY FOR HEAT AND POWER FOR SELECTED INDUSTRIES IN ALASKA, 1976

	TRILLION BTU	MILLIONS OF DOLLARS
FOOD & KINDRED PRODUCTS	1.3	4.5
LUMBER & WOOD PRODUCTS	1.3	3.7

Since the oil embargo, Alaska has been growing at a much faster pace than was projected in earlier years. The OBERS Projections* have increased from a 3.9% rate of earnings growth

*OBERS: Office of Business Economics of the Commerce Department and Economic Research Service of the Department of Agriculture

to 5.6% per year. The population growth in Alaska from 1970 to 1976 was 3.9% per year, the highest of the five Pacific states.

There is no projection for geothermally produced electric power without Federal involvement at this time. Figure I-4 projects direct heat application at a relatively low level. Further investigations of the resources in Alaska may project a higher usage level as Alaska is in the process of evaluating its geothermal resources with the help of the Federal government.

CALIFORNIA

California's energy supply is heavily dependent upon petroleum (69%) and natural gas (25%). The components of energy supply and demand are given in Figure I-5. California consumes the largest amount of energy of the states in the Pacific Region. From 1970 to 1976, California's installed capacity for electric power generation increased at an average of 3.6% per year. In 1976, installed capacity was 35,300 MW. Of California's electric power production, 33.0% goes to residential use, 32.4% to commercial activity, and 31.0% to industrial uses. Natural gas consumption in California in 1976 was 1.618 quads: 37% went to residential use; 13.2% to commercial, and 49.56% to industrial use. Manufacturing industries in California purchased .624 quads of fuel and electric energy for heat and power purposes in 1976.

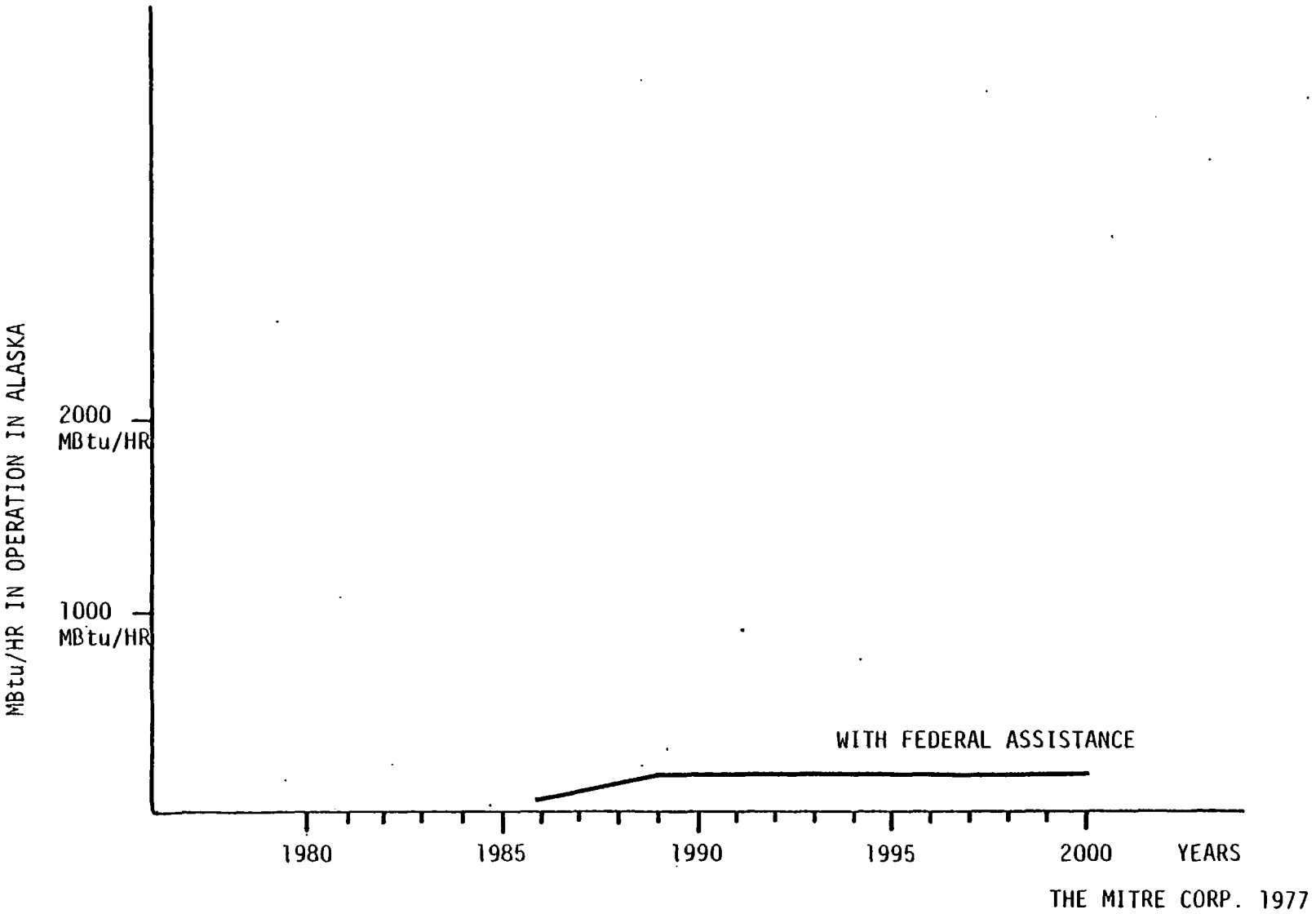


Figure I-4. Projection of Geothermal MBtu/HR in Operation for Direct Heat Applications in Alaska

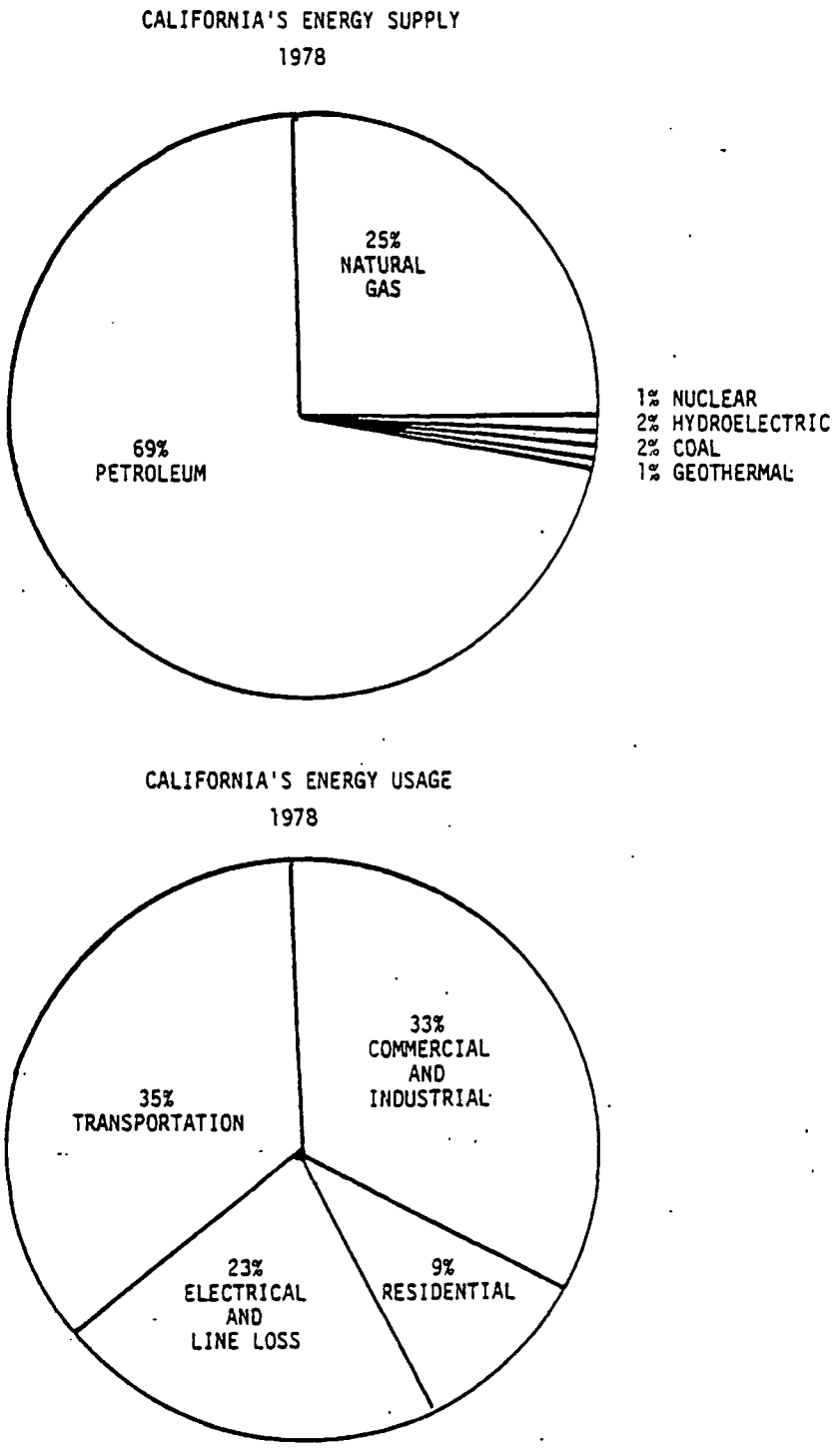


Figure I-5. State of California Energy Supply/Usage

The table below displays the energy purchased by major process heat users in the state.

QUANTITY AND COST OF PURCHASED FUEL AND ELECTRICITY FOR HEAT AND POWER FOR SELECTED INDUSTRIES IN CALIFORNIA 1976

	TRILLION BTU	MILLION OF DOLLARS
FOOD & KINDRED PRODUCTS	98.5	223.2
LUMBER & WOOD PRODUCTS	19.6	61.1
PAPER & ALLIED PRODUCTS	36.7	88.4
CHEMICALS & ALLIED PRODUCTS	60.9	147.8
PETROLEUM & COAL PRODUCTS	134.9	277.5

The OBERS Projections for earnings growth in California range from 3.7 to 4.2% per year. Population growth in California averaged 1.2% per year from 1970-76.

California is the only state that has projections of geothermal electric power on-line without Federal involvement. Figures I-6 and I-7 display projections of geothermal electric power production and direct heat in production.

The State of California has higher estimates of the potential power on line than does Mitre, projecting geothermal to be 12% of California's installed capacity by 1985, 19.9% by 1995 and 15.1% by the year 2000. Bringing about such an aggressive development schedule would require Federal assistance, enough to bring geothermal to parity with alternative fuels. Such issues as tax incentives are particularly important in California where geothermal energy is vigorously competing with oil, gas, nuclear, and coal for position in the utilities energy grid. Of the five states, California stands to gain the most from development of its geothermal resources.

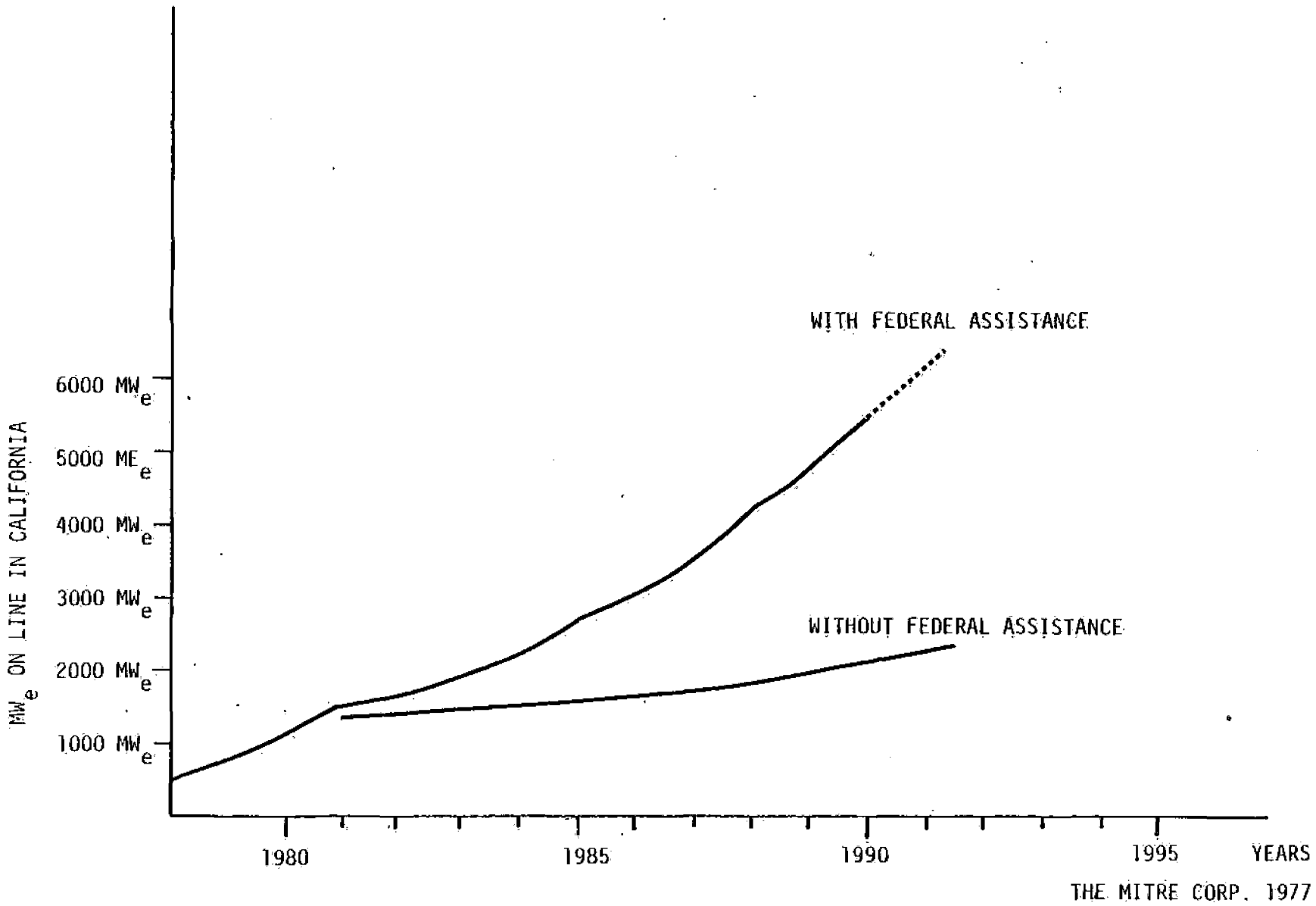


Figure I-6. Projection of Geothermal Electric Power Generation in California

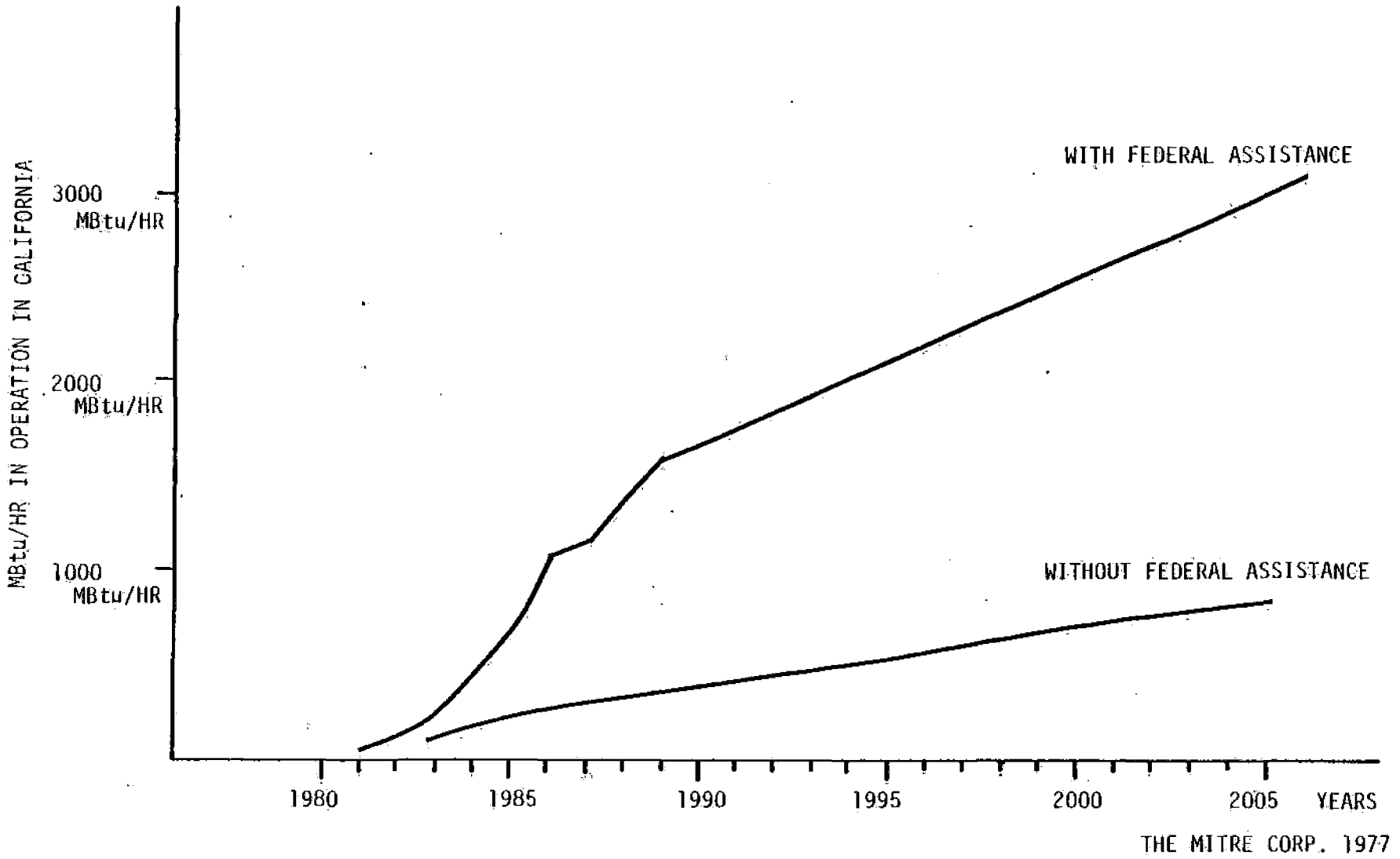


Figure I-7. Projection of Geothermal MBtu/HR in Operation for Direction Heat Applications in California

HAWAII

The energy supply in Hawaii is highly dependent upon petroleum products. All the petroleum is imported. Bagasse, the waste product from sugar refining is burned to generate electric power in the refineries. 7.8% of the energy in Hawaii is supplied by bagasse. There is also a very small amount of hydroelectric power supplying only .2% of the energy in the Islands.

Over half of the energy consumed in Hawaii goes for transportation (54.9%). Of this amount, 27.4% is taken for air transportation, 15.6% for ground transportation, 3.5% for water transportation and 8.4% for the military.

The breakdown of energy supply and energy usage are given in Figure I-8 on the following page.

At the present time (1978) petroleum is consumed in Hawaii at a rate of 112,000 bbl/day or about 225 x 10^{12} BTU/year. By 1985 it is projected that Hawaii's needs will be 140,000 bbl/day, a 25% increase in seven years. At this rate Hawaii would exceed an increment of 8.0 x 10^{12} BTU per year for each of the next seven years.

From 1970 to 1976 Hawaii installed capacity for electric power generation has increased at a rate of 4.3% per year. Installed capacity in 1976 was 1,400 MW. Of Hawaii's electric power generation 31.5% went to residential use, 20.4% to commercial use and 46.2% to industrial usage. There is very little gas consumption in Hawaii; as it must be manufactured from fuel oil, only .004 quad was consumed in 1976. Hawaii's manufacturing industries consumed .0096 quad in 1976, the main industries being sugar refining and pineapple processing. Sugar refining accounted for 44% of the fuel and electric energy used by the manufacturing sector, using 4.2 trillion BTU's at a cost of $10 million.

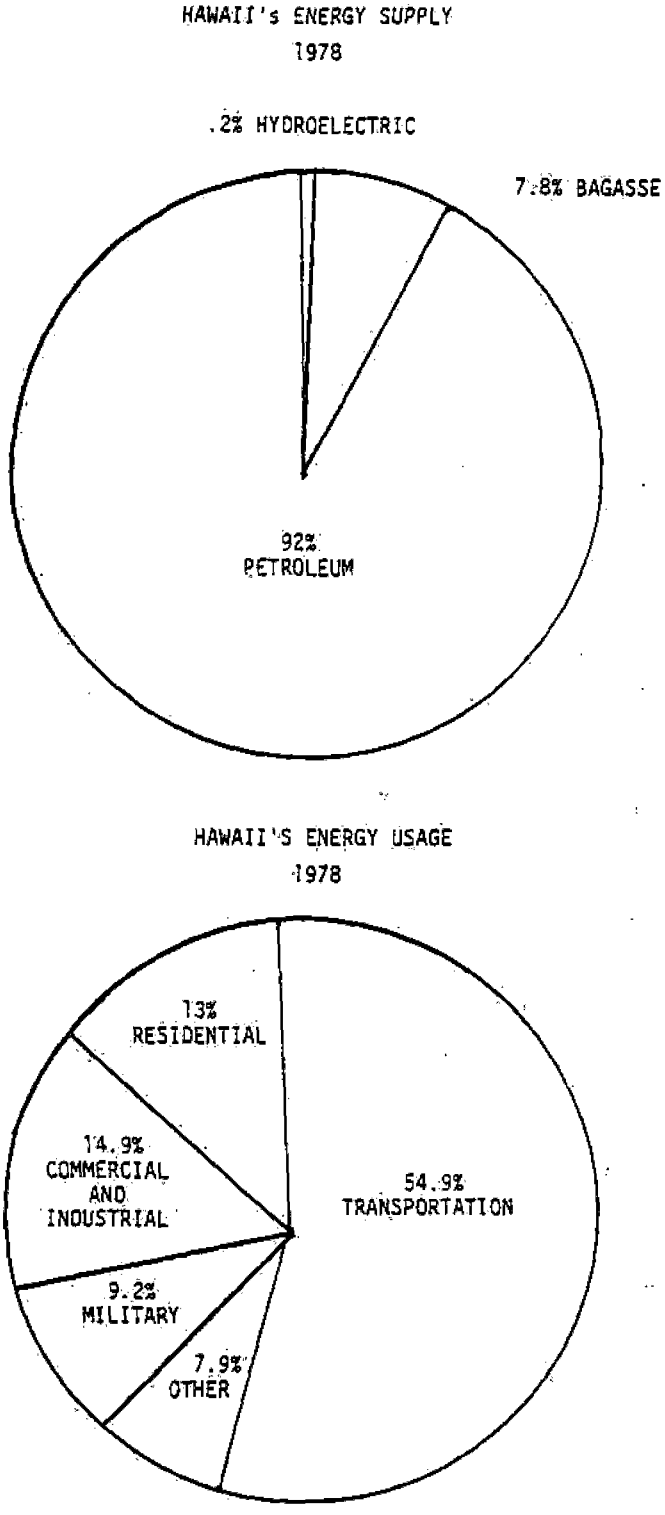


Figure I-8. State of Hawaii Energy Supply/Usage

Projections of direct use geothermal development in Hawaii with and without Federal government participation are found in Figure I-9.

OREGON

Oregon's supply and demand for energy is presented in Figure I-10, petroleum dominates with 55%. A substantial amount of electric power generation in Oregon is hydroelectric (85%). From 1970 to 1976 Oregon's electric power production increased 3.7% per year; installed capacity increased at an average rate of 5.6% per year. Installed capacity in Oregon in 1976 was 7,900 MW. Residential users consume 38.9% of the electric power production, commercial uses 28%, and industrial usage is 32.1%. Natural gas consumption in Oregon in 1976 amounted to .087 quads. Residential usage was 25.3%, commercial 17.2%, and industrial 57.5%. Manufacturing industries in Oregon purchased .130 quads in 1976 at a cost of $264.9 million. Major industry in the state includes lumber and wood products, paper and allied products and primary metal industries.

The table below displays selected industries that are major process heat users in the state.

QUANTITY AND COST OF PURCHASED FUEL AND ELECTRICITY FOR HEAT AND POWER FOR SELECTED INDUSTRIES IN OREGON, 1976

	TRILLION BTU	MILLIONS OF DOLLARS
FOOD & KINDRED PRODUCTS	9.8	20.4
LUMBER & WOOD PRODUCTS	32.1	81.5
PAPER & ALLIED PRODUCTS	36.6	73.8
CHEMICALS & ALLIED PRODUCTS	7.2	13.2
PETROLEUM & COAL PRODUCTS	2.5	4.4

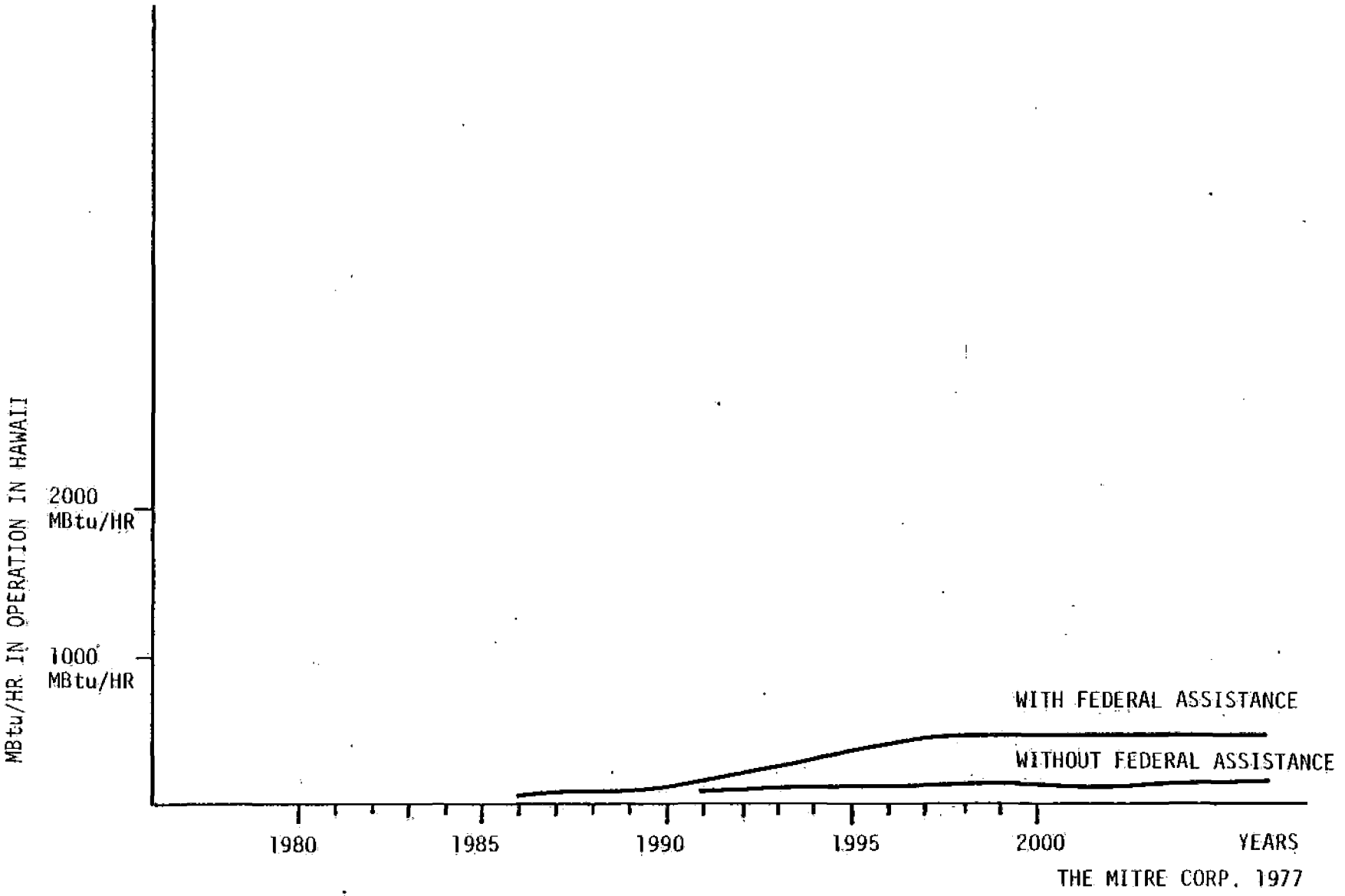


Figure I-9. Projection of Geothermal MBtu/Hr. in Operation for Direct Heat Applications in Hawaii

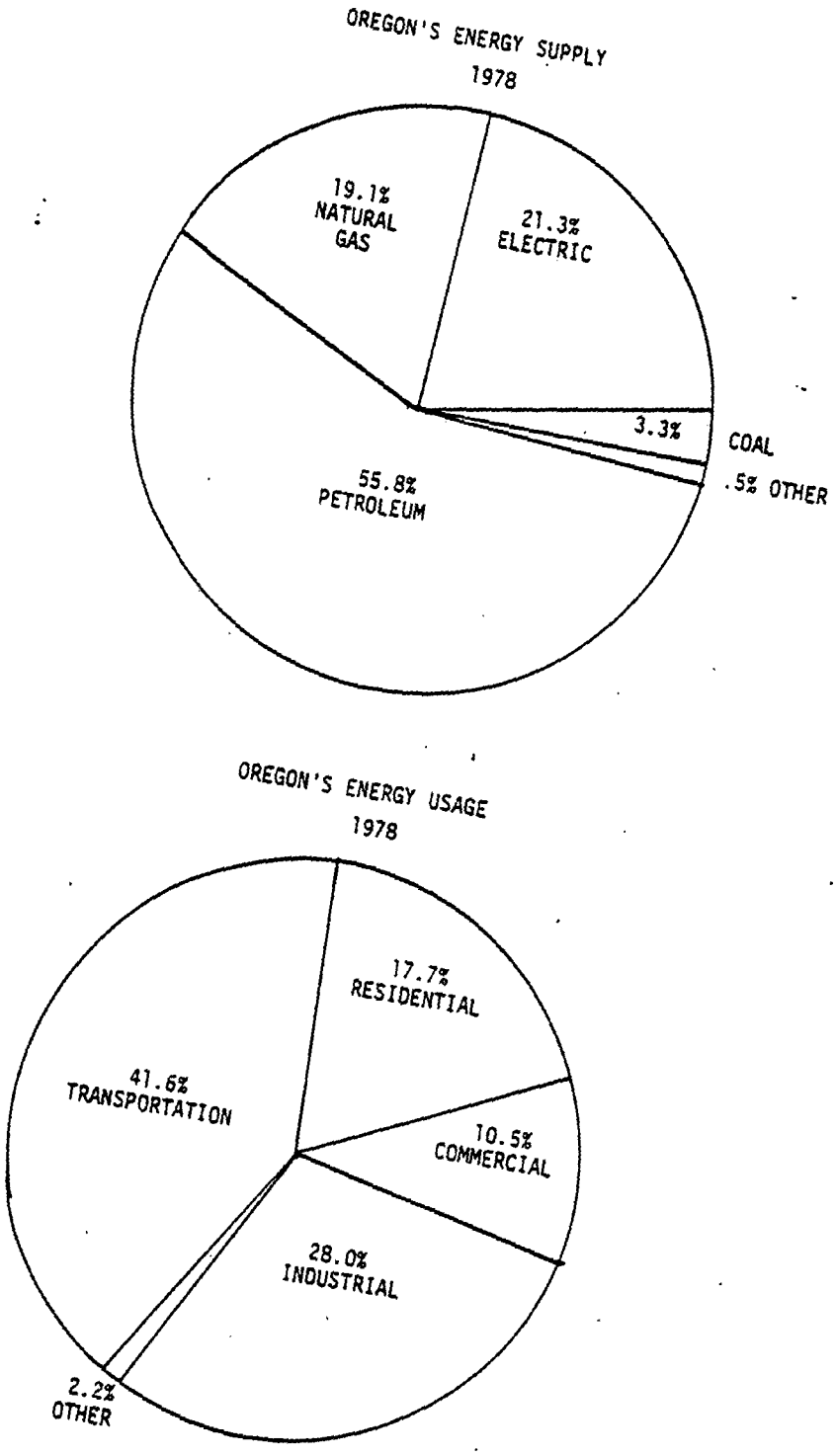


Figure I-10. State of Oregon Energy Supply/Usage

All of the industries above are potential users of geothermal energy, having process heat requirements. The OBERS Projections of earnings growth for Oregon range from 4.0 to 4.8%. The population of Oregon averaged a 1.7% per year increase from 1970 to 1976.

Klamath Falls, Oregon presently has 60 MWt in use and has been the location of several demonstrations of direct heat application. There are no projections as yet of electric power production without Federal involvement. However, Oregon holds great promise for further direct use development. The projection for BTU's in production with Federal participation are displayed in Figure I-11.

WASHINGTON

The energy supply and demand components for Washington are displayed in Figure I-12. From 1970 to 1976 Washington's installed capacity for electric power generation increased by 6.1%. 34.6% of Washington's energy sales go to residential consumers, 15.0% to commercial and 47.0% to industrial users. Installed capacity in 1976 was 18,500 MW. Natural gas consumption in Washington in 1976 amounted to .159 quads, 35% going to residential users, 14.3% to commercial, and 50% to industrial users.

Manufacturing industries in Washington purchased .240 quads of fuels and electric energy for heating and power at a cost of $393.2 million. The major industrial users include paper and allied products, primary metals, lumber and wood products.

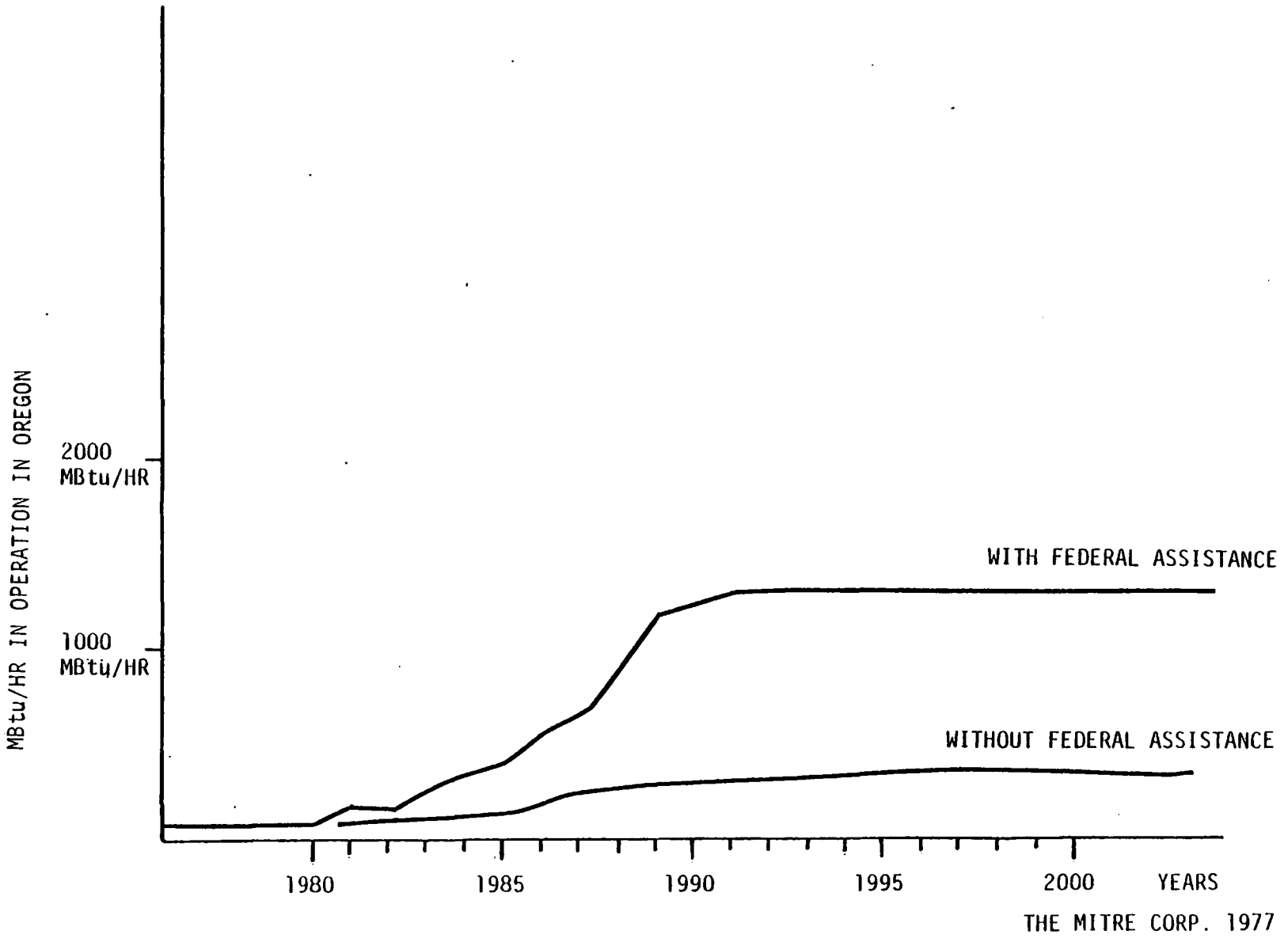
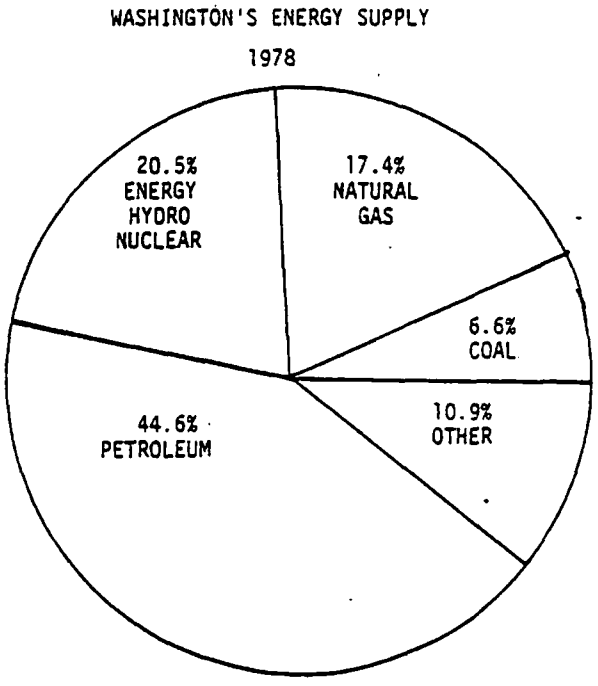


Figure I-11. Projection of Geothermal MBtu/Hr. in Operation for Direct Heat Applications in Oregon



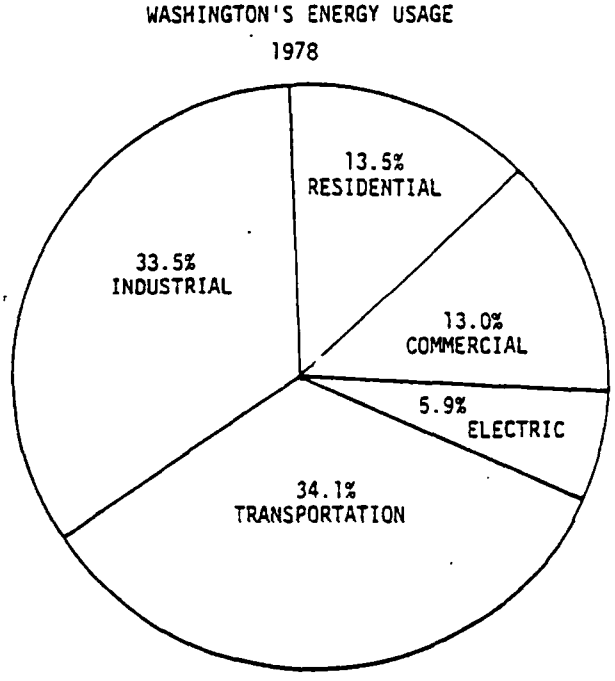


Figure I-12. State of Washington Energy Supply/Usage

The table below displays energy purchased for the main industries that could use geothermal process heat.

QUANTITY & COST OF PURCHASED FUELS AND ELECTRICITY FOR HEAT AND POWER FOR SELECTED INDUSTRIES IN STATE OF WASHINGTON 1976

	TRILLION BTU	MILLIONS OF DOLLARS
FOOD AND KINDRED PRODUCTS	21.8	41.2
LUMBER AND WOOD PRODUCTS	20.5	46.6
PAPER AND ALLIED PRODUCTS	69.1	114.8
CHEMICAL AND ALLIED PRODUCTS	14.1	22.2
PETROLEUM AND COAL PRODUCTS	11.6	20.4

The industries above are major users of process heat, and would be primary targets for geothermal energy usage. Growth rates for state earnings for Washington are projected at 3.7 to 3.9% per year by OBERS. The average percent change in population from 1970 to 1976 was .9% per year, the lowest of the five Pacific Regional states.

There is no projection for geothermal electric power production in Washington without Federal participation. Washington has the lowest projection for direct heat BTU's. This may reflect the fact that many of the resources are on protected lands. However, it should be noted that Washington's energy demand is second to California for the region and the resources have not been explored adequately. Figure I-13 displays the projection for direct heat usage in Washington with Federal participation at this time.

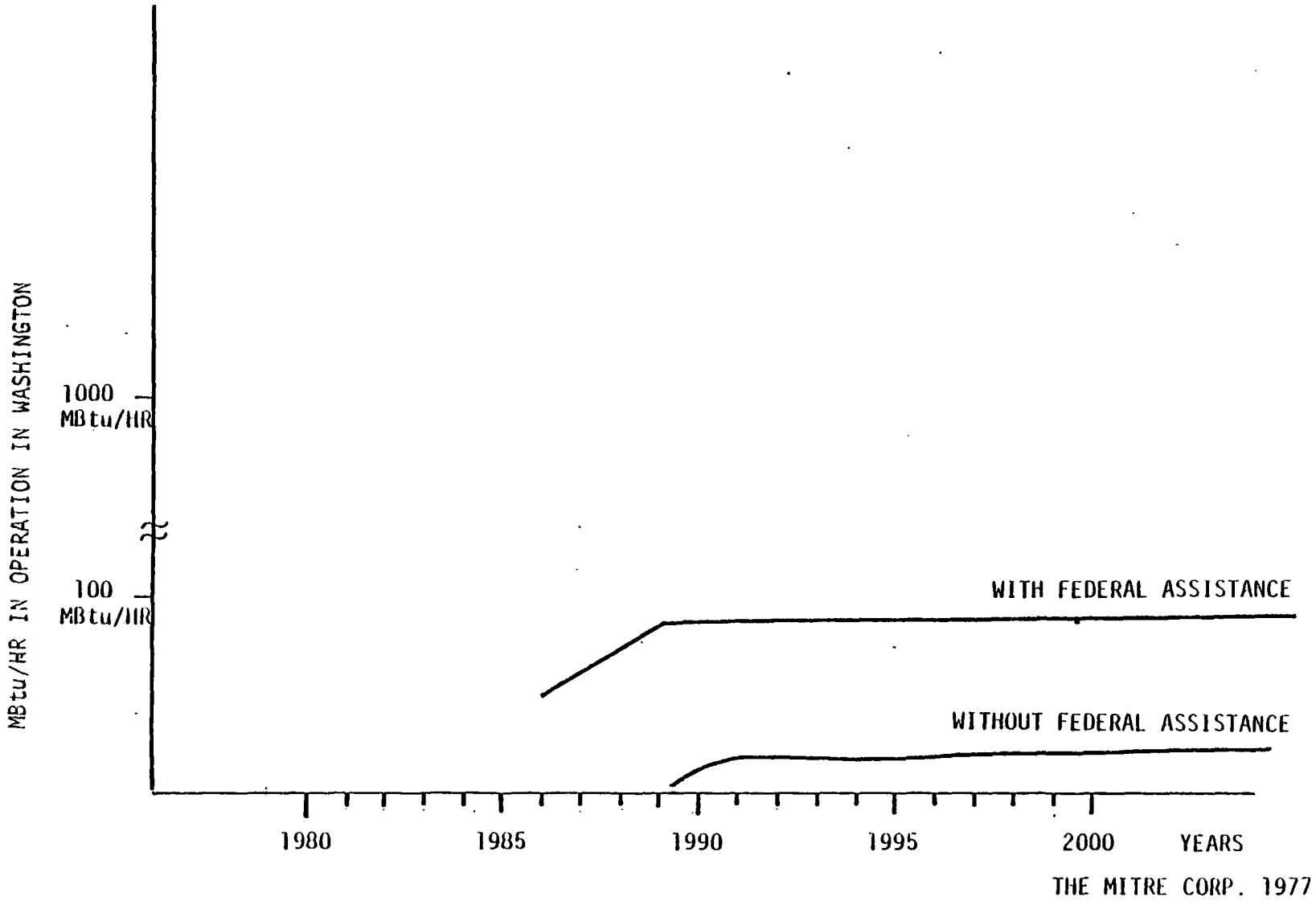


Figure I-13. Projection of Geothermal MBtu/Hr. in Operation for Direct Heat Applications in Washington

APPENDIX II. RESOURCES

The Pacific Region is an area which is rich in geothermal resources. Electrical power has been generated from a vapor-dominated reservoir at The Geysers in Northern California for years. Plans are being developed for the exploitation of geothermal reservoirs for future generation of electrical power in the Puna Rift Zone of Hawaii and the Salton Trough of Southern California. Direct use plans for geothermal reservoirs in the Pacific Region include space heating and cooling, bathing, and industrial processing of forestry and agricultural products.

The geothermal resources which exist in each of the five states that make up the Pacific Region are discussed in the following section.* It is clear that the Pacific Region needs more extensive exploration work in order to determine the full potential of geothermal resources in this area.

The five states making up the Pacific Region can be divided into sixteen physiographic provinces, as shown in Figure II-1. Those provinces which have associated recent volcanism and active fault zones were found to contain most of the geothermal reservoirs of the region. In this section, high-temperature resources (with the temperature exceeding 150°C) and low- to moderate-temperature resources (with the temperature less than 150°C) are discussed separately for each state.

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*More details will be given in USGS Circular 790, to be published shortly.

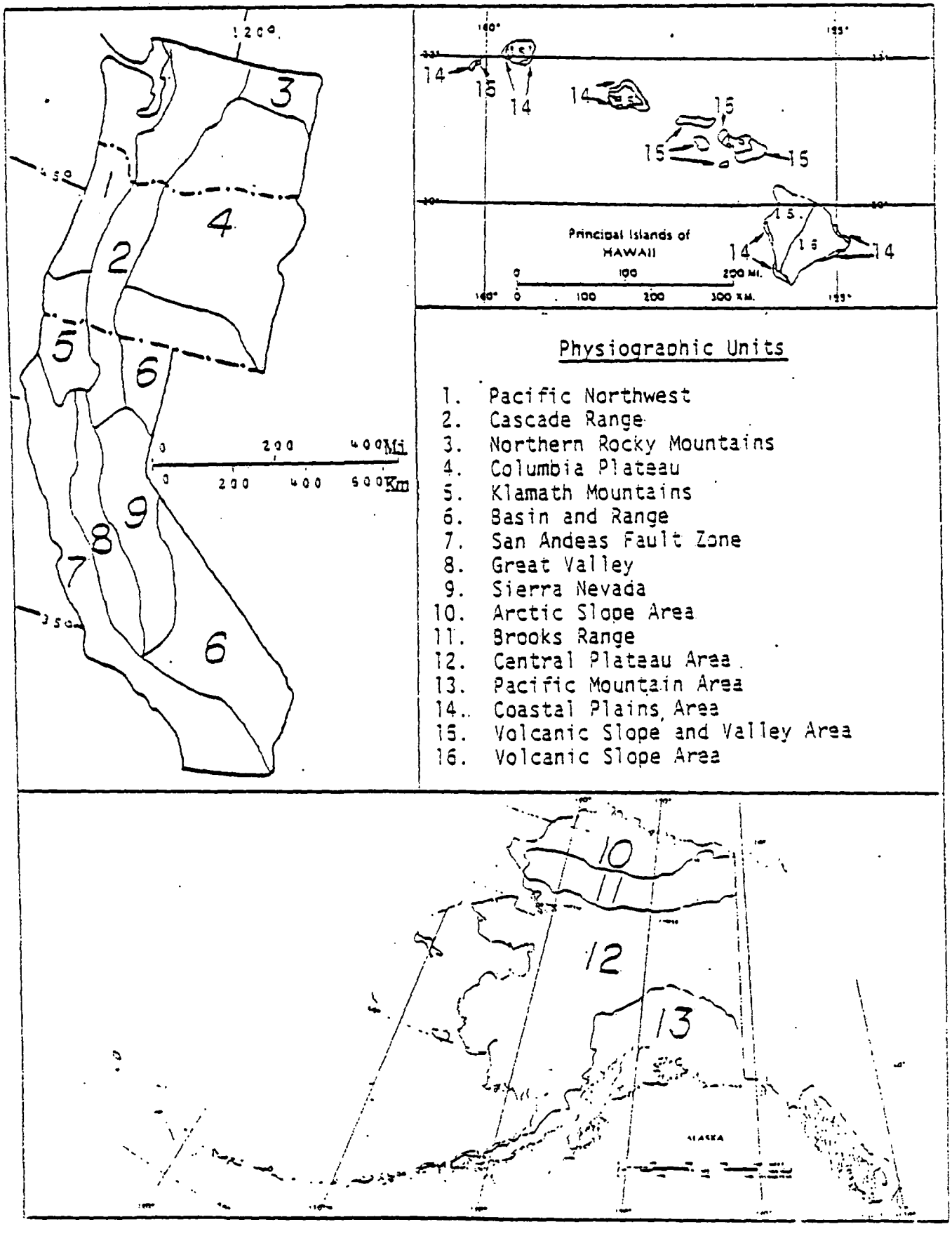


Figure II-1. Physiographic Provinces

ALASKA

INTRODUCTION

Alaska is divided into four physiographic provinces from north to south: the Arctic Slope, the Brooks Range, the Central Plateau and the Pacific Mountain Region (Fig. II-1). Most of the lands classified for geothermal resources are found in the Central Plateau and the Pacific Mountain areas. The Central Plateau in central Alaska, is located within the Yukon and Kuskokwim River Basins. The plateau has associated low hills and valleys and extends from the Brooks Range southward to the Alaskan Range.

The Pacific Mountain Region, which is part of the circumpacific volcanic belt and earthquake zone, includes the Coast Mountains of southeastern Alaska, the Alaska Range of south-central Alaska, and the Aleutian Range of southwestern Alaska. The Alaska and Aleutian Ranges are geologically equivalent to the Cascades of Washington and Oregon. Most of the Alaska Range is underlain by a granitic intrusion and Paleozoic and Mesozoic metasediments. Mesozoic fault lineaments extend parallel along the length of the range. The Aleutian Range is a chain of some 80 volcanic peaks on the crest of a submarine ridge. The Aleutians are formed of Mesozoic and Cenozoic marine sediments and granitic intrusions and Cenozoic volcanic rocks.

HIGH-TEMPERATURE RESOURCES

1. KGRA's

The KGRA at Geyser Spring Basin in the Aleutian Islands is a high temperature reservoir, whose subsurface thermal water temperature is 210^{o}C. This reservoir is a result of the active volcanic area in the Aleutians.

2. Other Prospects

The Pacific Mountain Region of Alaska is a good prospect for high-temperature resources. The Aleutian Islands and Alaska Peninsula have the greatest ratio of thermal springs to regional area of any other region in the state (Fig. II-2). The Aleutian Islands, themselves, have thirty-four of Alaska's 100 thermal springs and over forty active volcanos. The Coast Mountains of southeast Alaska is another prospect for high temperature resources. The area contains twenty of Alaska's 100 thermal springs. Geochemical curves have indicated that resource temperatures could be 170°C in parts of southeastern Alaska, so more exploration is needed in this area.

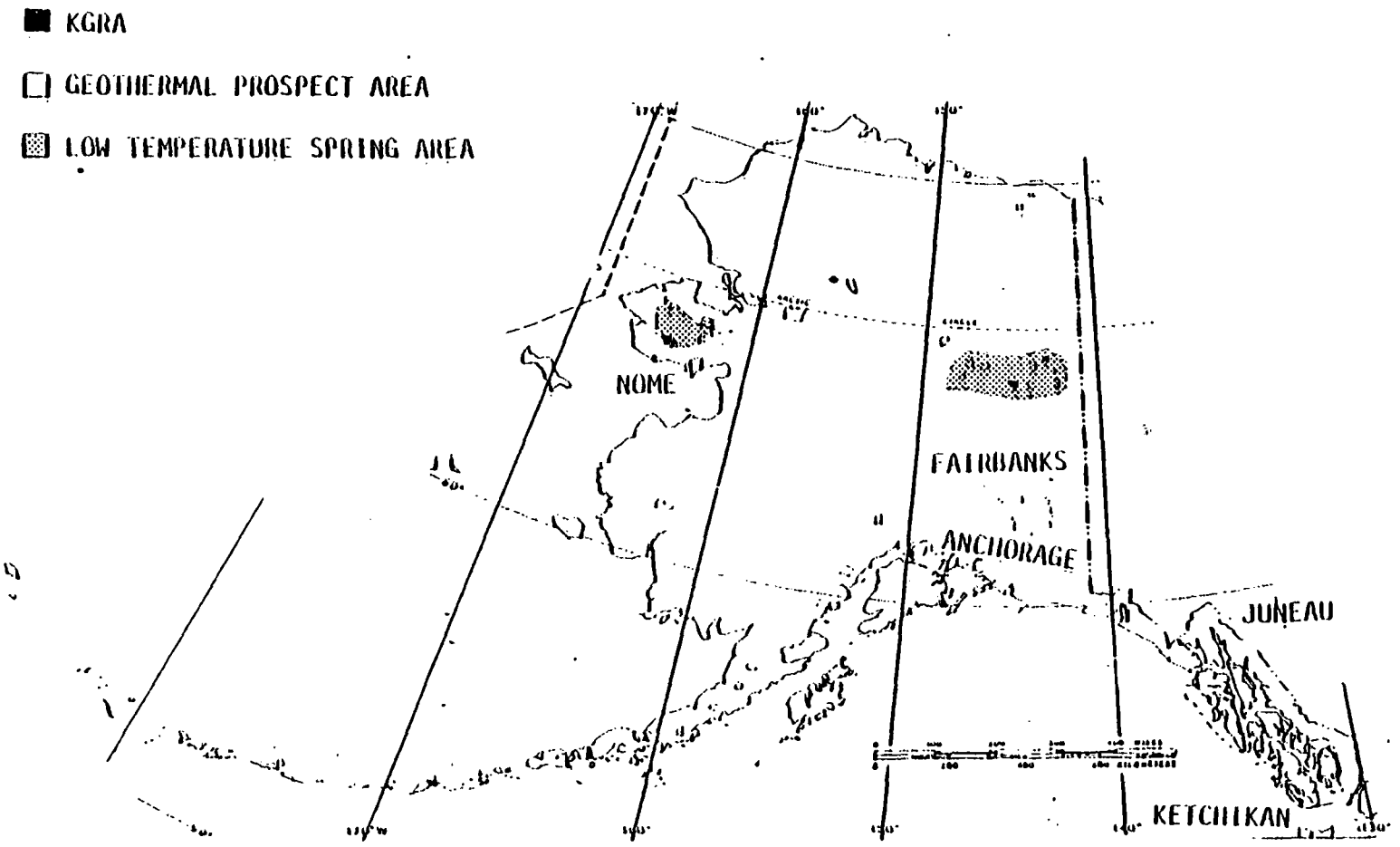
3. Potential for Discovery

The Brooks Range and Arctic Slope areas of northern Alaska may have geothermal potential, but because of the harsh climate and rugged terrain, very little geothermal exploration has been conducted.

LOW- AND MODERATE- TEMPERATURE RESOURCES

1. KGRA's

Okmok Caldera, on Okmok Isle in the Aleutian Islands, is a KGRA whose subsurface temperatures have been recorded at 125°C (Fig. II-2). Another low-temperature resource is at the KGRA of Pilgrim Springs, on the Seward Peninsula in the Central Plateau province, where subsurface temperatures have been recorded at 150°C. Primary non-electric usage of the resource at these sites would include commercial and residential space heating, greenhouse and soil heating, and bathing. It has been suggested that geothermal energy in Alaska might provide electricity generation for mines in remote areas of the state. For example, the KGRA's at Geyser Spring Basin and Okmok Caldera might be able to supply electrical power for the development of a deposit of zinc mineralization in a fault zone across Sedanka Island in the Aleutians.



(After USGS Circ. 647)

Figure II-2. Alaska Geothermal Resources

2. Other Prospects

The Central Plateau province is a good prospect, because several low-temperature geothermal convection systems are located in this area. Surface manifestations of geothermal activity are indicated by at least thirty-nine thermal springs in the Central Plateau province.

Southeastern Alaska is another prospect for low- and moderate-temperature geothermal resources, with several hydrothermal convection systems near the Pacific Ocean being located in this area.

3. Potential for Discovery

Discovery potential for low- and moderate-temperature resources appears to be high in the Alaskan Panhandle and the Central Plateau regions.

CALIFORNIA

INTRODUCTION

California has a rather complex regional composition which is made up of six physiographic provinces that include: the Klamath Mountains, the Cascade Range, the Basin and Range, the San Andreas Fault Zone, the Great Valley, and the Sierra Nevada provinces (Fig. II-1). Most of the geothermal resource areas of California are sited in the San Andreas Fault Zone along the Pacific Coast and in the Salton Trough, in the Sierra Nevada near the Nevada border and the Basin and Range province of Northeastern California.

Much of California's geothermal resources are related to areas of Cenozoic volcanism and active fault zones which have shown displacement in Quaternary times. Northeastern California is such an area. It has Quaternary and Tertiary volcanic rocks and extensive northwest-trending Quaternary fault zones (Fig. II-3). Another geothermal resource area is north of the San Francisco Bay in the San Andreas Fault Zone where Mesozoic ultramafic plutonic rocks and metasediments of the Franciscan Formation, along with Tertiary volcanic flow rocks, are found in a region of extensive, northwest-trending, pre-Quaternary faults. The faulted granitic rocks of the Sierra Nevadas in eastern California, along with the associated volcanic systems of Mono Dores and Long Valley, is a region of geothermal interest. The Salton Trough in Southern California is a notable geothermal resource area, composed primarily of Quaternary sediments located in a zone of major Quaternary faults.

HIGH-TEMPERATURE RESOURCES

1. KGRA's

Most of the KGRAs in California have subsurface temperatures exceeding 150°C. One of the most noteworthy of the KGRAs is The Geysers in Northern California, which is a vapor-dominated source that is presently being exploited for the generation of electricity by PG&E. Figure II-4 shows California's KGRA's. The USGS has projected recoverable geothermal resources for power production in California of up to 6000 MWe-centuries. High temperature resources in Northeastern California include Glass Mountain, Lake City-Surprise Valley, and Lassen (Fig. II-4).

The Mono Valley and Bodie KGRAs in the Sierra Nevadas of east central California would also have direct use applications for distinct heating and in the lumber industry. The resource at

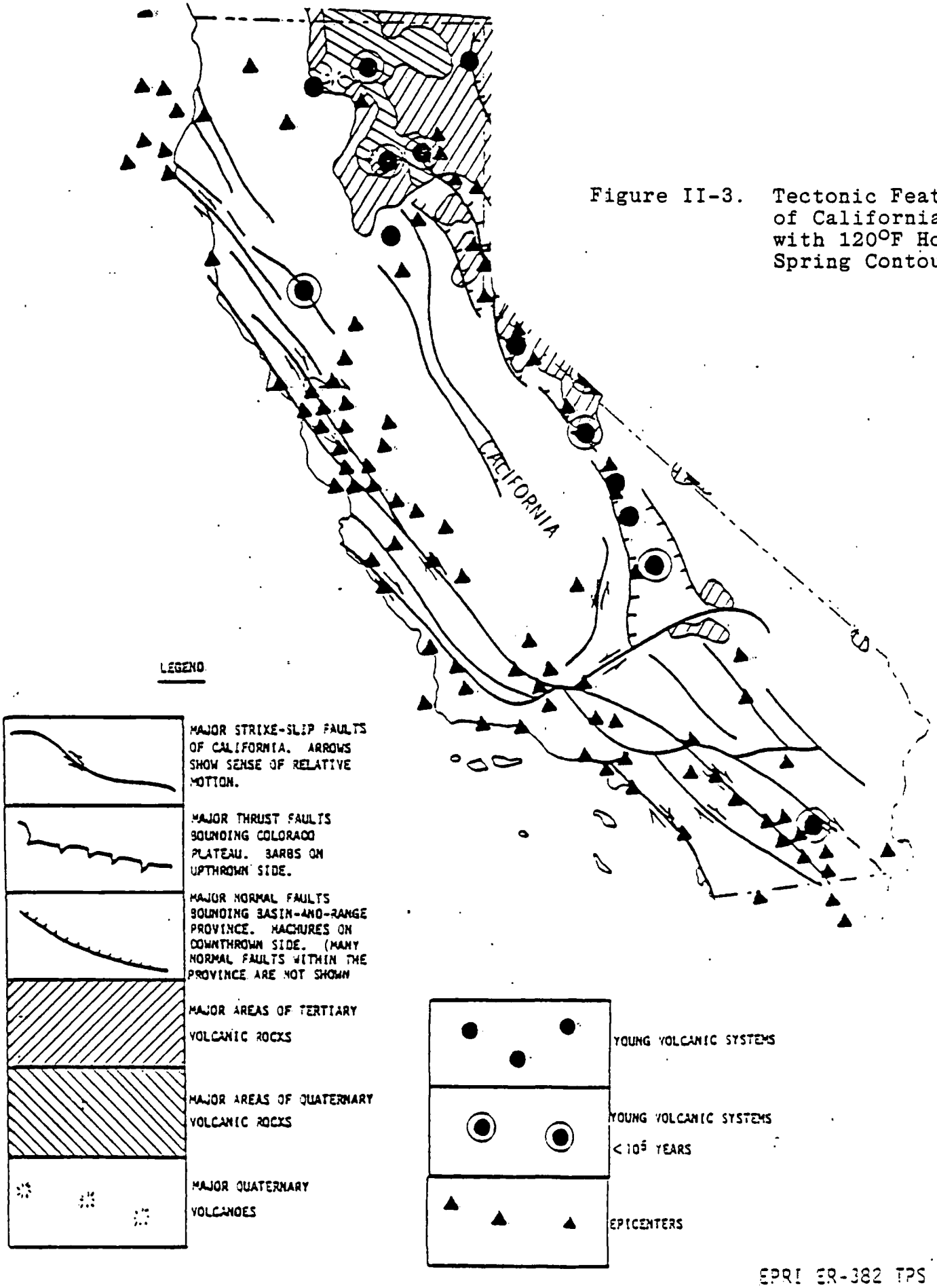


Figure II-3. Tectonic Features of California, with 120°F Hot Spring Contour

EPRI ER-382 TPS 76-638

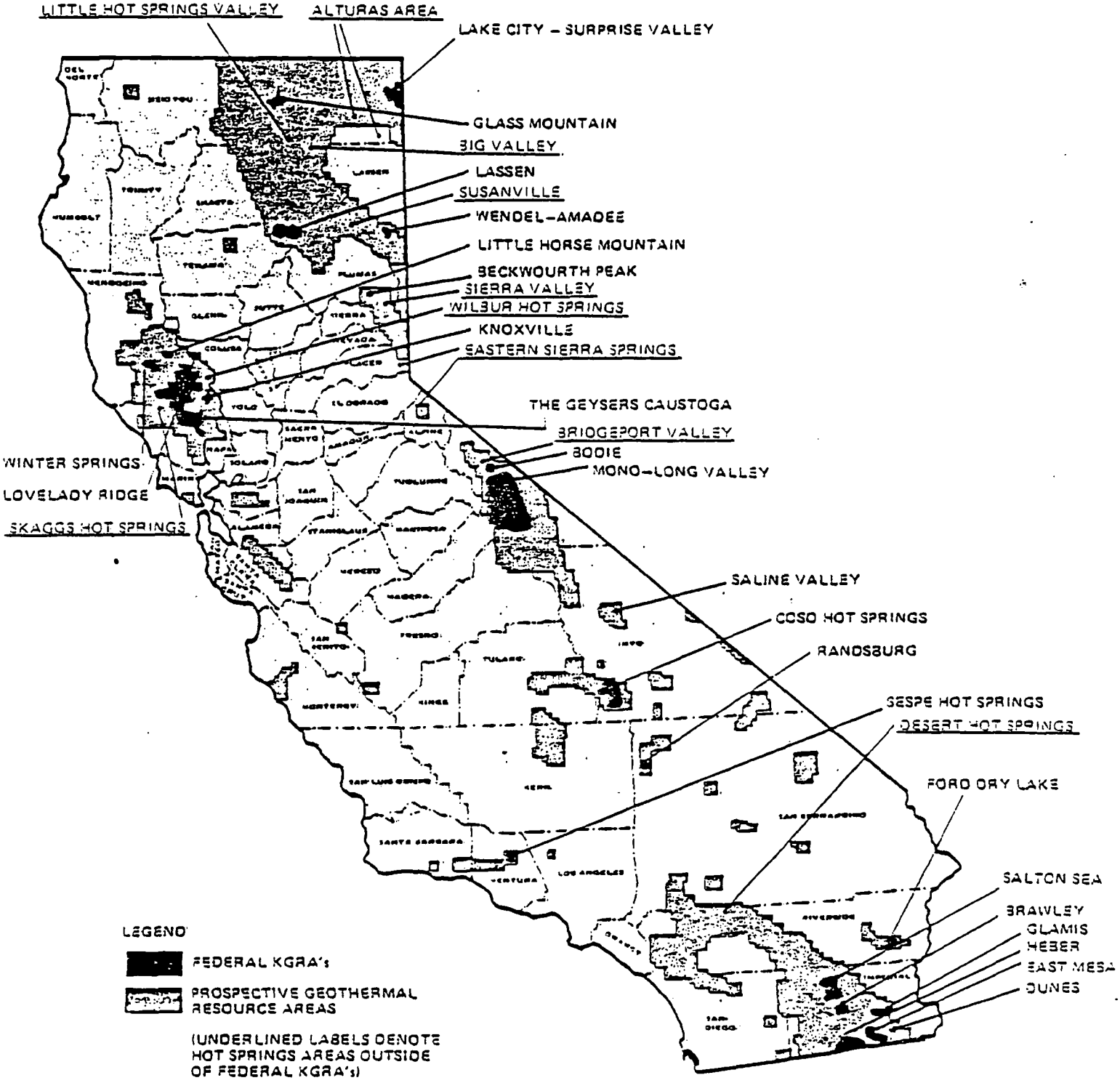


Figure II-4. Known Geothermal Resource Areas and Other Prospective Resource Areas in California

Coso Hot Springs in south central California has proposed non-electric usage for industrial applications, space heating and cooling.

The thermal resources found in the Salton Trough of Southern California have direct use applications for food processing, fertilizer manufacture, and possibly various agricultural applications.

2. Other Prospects

Little Hot Springs Valley, Big Valley, Susanville, and the Sierra Valley in Northeastern California (Fig. II-4) are all prospective geothermal resource areas that are associated with hydrothermal convection systems in the area. North California, with the associated thermal spring activity, is another good prospect.

3. Potential for Discovery

Potential for discovery of new resource areas in California is very high. Extensive vulcanism and tectonism give promise of many areas with deeply buried heat sources. While the most obvious resources have been identified, large areas remain to be explored.

LOW- AND MODERATE- TEMPERATURE RESOURCES

1. KGRA's

The Wendel-Amedee KGRA in Northeastern California has subsurface temperatures of about 140°C which classify it as a low temperature resource. Direct use applications for this resource include greenhouse heating. The KGRA at Glamis in the Imperial Valley of Southern California, with a subsurface temperature of about 135°C, is another low temperature thermal resource.

2. Other Prospects

The north end of the Imperial Valley and the Coachella Valley are good prospects for low- to medium-temperature geothermal resources. Low-temperature hydrothermal convection systems in these areas indicate the prospect of geothermal resources. Large areas of northern and central California may also have exploitable low-temperature resources, and California's coastal regions may not be totally devoid of potential; the Mt. Diablo and Sespe Hot Springs areas are good examples of such areas.

HAWAII

INTRODUCTION

A southeast-trending rift in the floor of the Pacific Ocean, through which molten lava has welled up in layers onto the sea floor over geologic time, was the beginning of volcanic activity in the Hawaiian Islands. The Islands are primarily composed of porous and fragmented vulcanic materials, which are partially mantled by alluvium (Fig. II-1). Today, the big Island of Hawaii is the only area of active volcanism in the Hawaiian Islands. There are five volcanos on the island of Hawaii: Kohala, Hualalei, Mauna Kea, Mauna Loa, and Kilauea, however,

only the last two are active at the present time. Each of these five volcanos has rift zones which are associated with them. The Puna area of Hawaii, which is traversed by the east rift of Kilauea, is characterized by eruptive vents and steam seeps, which show surface manifestations of hydrothermal activity at depth. In addition to the Island of Hawaii, other areas in the Hawaiian Islands which show some potential for possible geothermal resources include the islands of Maui (which contains the Haleakala volcanic system), Molokai and Oahu. The prospects on Kauai are not clear at this time.

HIGH-TEMPERATURE RESOURCES

1. KGRA's

The Puna Rift Zone in eastern Hawaii (Fig. II-5) has subsurface temperatures ranging from 250°C-350°C. Situated in an extremely active seismic area, the Puna Rift Zone is a forested plain with low mountains and sparse population. The lithology of the area consists primarily of Tertiary and Quaternary volcanic rocks. This resource, if developed, would probably have such direct use applications as space conditioning, industrial uses and agribusiness, in addition to electricity production.

2. Other Prospects

Areas of active volcanism, such as the Mauna Loa and Kilauea volcanos on Hawaii, are good prospects due to the high temperature of the deeply-buried magma associated with the region. Surface expressions of geothermal activity (hot springs) in the Hawaiian Islands are rare because heavy rainfall and a generally shallow water table dilute the thermal waters.

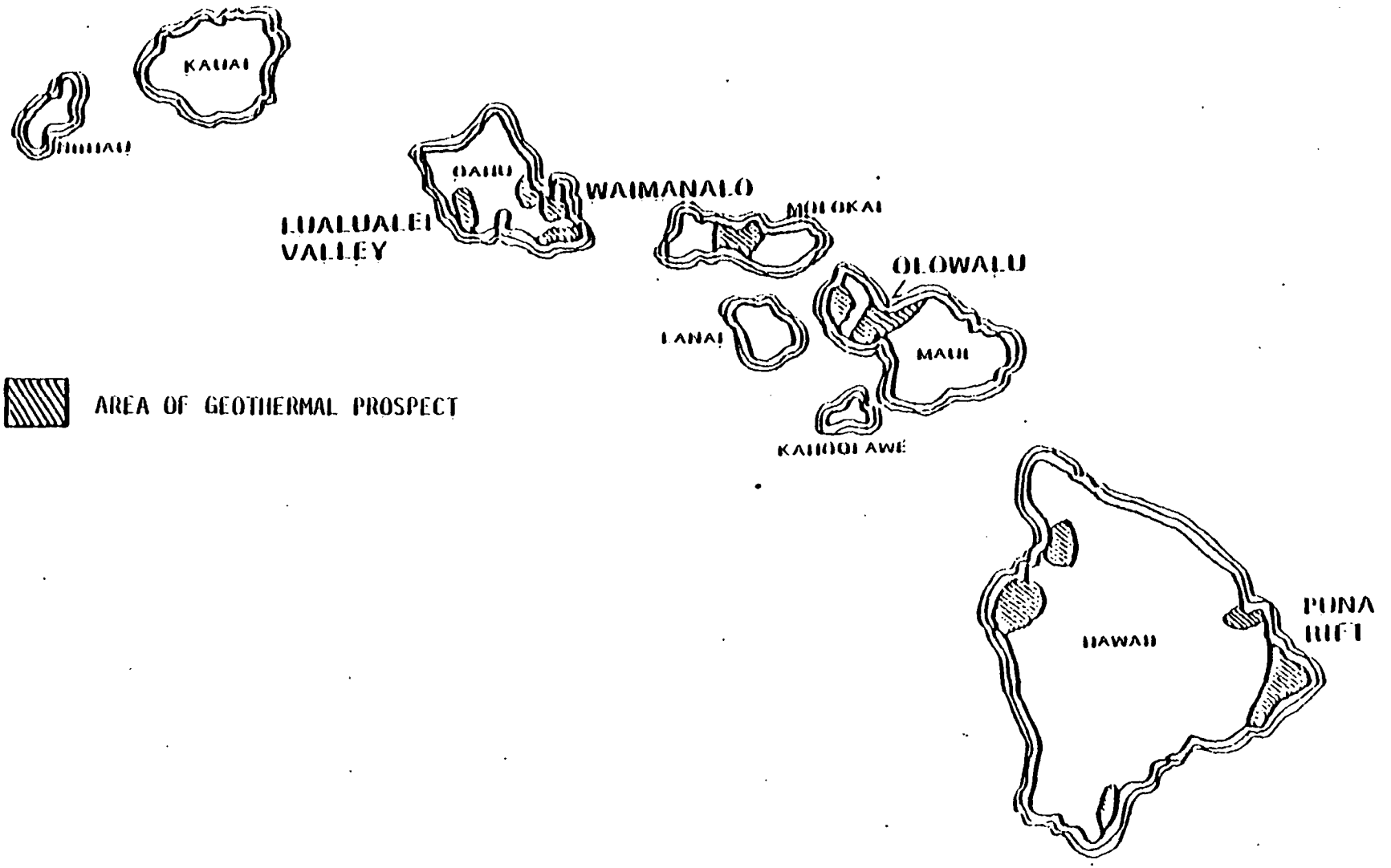


Figure II-5. Hawaii's Geothermal Resources

3. Potential for Discovery

More extensive geophysical studies in the areas of active volcanism on the island of Hawaii may further elucidate the possibility of greater high-temperature resource potential in that region.

LOW- TO MODERATE-TEMPERATURE RESOURCES

1. KGRA's - None

2. Other Prospects

The west and southwest coastal areas of the island of Maui, in particular the Olowalu Valley, contain shallow wells whose warm water temperatures have been recorded at 35°C. This area appears to be a prospect for low-temperature resources.

LOW-TEMPERATURE THERMAL SPRINGS AND WELLS IN HAWAII

Name	Water Temperature	Description
West Maui Island	36°C	drilled well
West Molokai Island	35°C	drilled well
Kawaihae, North Hawaii	Warm	on shore
Kailua, West Hawaii	Warm	near shore
Puu Kukae, East Hawaii	30°C	small pool
Puu Kukae, East Hawaii	30°C	small flow

Kapoho, East Hawaii	34°C	on shore
Waiwelawela Point, S.E. Hawaii	Warm	small flow

A warm water well found on West Molokai Island might indicate a low-temperature prospect here, too. The Puna Keaau area in eastern Hawaii is also a good prospect. The southwest shows warm spring activity.

3. Potential for Discovery

More exploration of geothermal potential is called for on the islands of Molokai, Maui and Hawaii (Fig. II-5), where warm water temperatures appear to indicate potential for geothermal resources at greater depths. The Island of Oahu, in particular the Lualualei Valley and Waimanalo Regions, also warrants exploration. The U.S. Navy hopes to do further exploration in the Lualuai Valley, where warm temperatures in the water table may indicate a geothermal resource at depth. The Hawaii Geothermal Resource Assessment Program of the Hawaii Institute of Geophysics is collecting data on springs and water wells and has found a large number with some degree of favorable geochemistry.

OREGON

INTRODUCTION

Figure II-1 shows that Oregon can be divided into five physiographic provinces: the Pacific Northwest, the Klamath Mountains, the Cascade Range, the Columbia Plateau, and the Basin Range provinces. The geothermal resources of Oregon are

primarily associated with the Cascade Range and the Basin and Range provinces. The Cascade Range is a heavily forested belt of rugged mountains, created by the arching and folding of meta-sediments and lavas, which makes a north-south line through western Oregon. Several peaks in the Cascade Mountains are of volcanic origin, including Mount Hood, Mount Jefferson, the Three Sisters, and Mount McLoughlin. The Basin and Range province of southeastern Oregon is a youthful, high lava plain which is distinguished by fault-block mountains, saline lakes, and rim escarpments.

HIGH-TEMPERATURE RESOURCES

1. KGRA's

Eastern and southeastern Oregon have some high-temperature KGRA's found in the Vale, Alvord, and Lakeview areas, as seen in Figure II-6. Vale, located in the Columbia Plateau province of eastern Oregon, has a high-temperature geothermal resource associated with a fault-controlled area of Tertiary sediments and lavas. Uses of direct geothermal energy at Vale include agriculture (sugar beets) and possibly residential heating. Alvord and Lakeview are both sited in the Basin and Range province of southeastern Oregon, which has Cenozoic basalt flows and faulting activity over parts of the area. Primary non-electric usage of the geothermal energy at Alvord and Lakeview include residential space heating, greenhouse heating, industrial processing of forestry products, and bathing.

Other Prospects

Southeastern Oregon has a good prospect for finding more ermal potential, because 75% of the thermal springs in the are found here, where they rise along faults in the lava. ical analysis of thermal water from some of the springs d the occurrence of reservoir temperatures exceeding

Kapoho, East Hawaii	34°C	on shore
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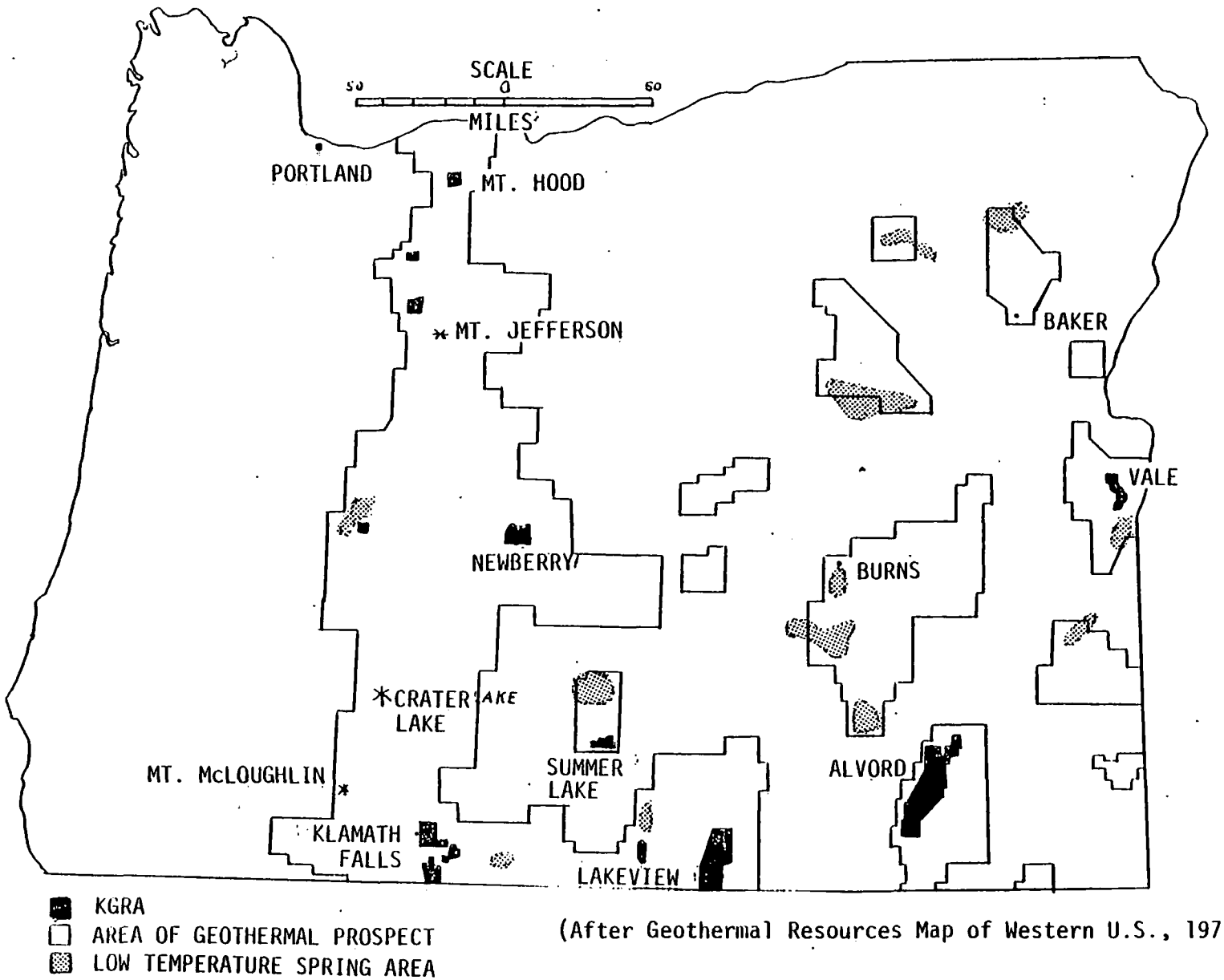


(After Geothermal Resources Map of Western U.S., 1977)

Figure II-6. Oregon Geothermal Resources

140°C, showing that there are high-temperature reservoirs existing in southeastern Oregon.

LOW- AND MODERATE-TEMPERATURE RESOURCES

1. KGRA's

The Cascades Range province contains several low temperature KGRA's, including Mount Hood, Carey Hot Springs, Breitenbush Hot Springs, Summer Lake, and Klamath Falls (Fig. II-6). The subsurface water temperature in these KGRA's ranges from 120°C to 150°C. The Mount Hood site in the Northern Cascades, is in a National Forest ski area. The country rock is a fractured, Quaternary lava. Primary non-electric usage of the geothermal resource at Mount Hood is for space heating of a ski lodge and snow melting on roads and parking lots in the ski area.

The geothermal resources at Klamath Falls in the Southern Cascades have been utilized for decades for space heating private residences, commercial buildings, and the Oregon Institute of Technology buildings.

2. Other Prospects

The Basin and Range province of Southeastern Oregon appears to have good prospects for low- and moderate-temperature resources. Southeastern Oregon is an intensely faulted region of Cenozoic volcanic and sedimentary rocks, in which many low-temperature thermal springs are located.

The Northern Cascades area around Mount Hood also shows prospects of low-temperature resources, as indicated by the existence of geothermal convection systems, with subsurface temperatures of up to 150°C in this region.

WASHINGTON

INTRODUCTION

Four physiographic provinces occur within the state of Washington: the Pacific Northwest, the Cascade Range, the Columbia Plateau and the Northern Rocky Mountains (Fig. II-1). The Pacific Northwest province follows the Pacific coast in Western Washington and consists of the Puget Sound, the rugged Olympic Mountains in Northwestern Washington, the flat-lying Puget Sound Lowlands, and the shallow slopes of the Wallapas Mountains in Southwestern Washington.

The Cascade Range province forms the backbone of the state, extending the length of the state of Washington, just east of the Pacific Northwest province. This region lies within the Pacific ring of fire, and several peaks in the Cascade Mountains are of volcanic origin including Mount Rainier, Mount Adams, Mount Baker, Mount St. Helens, and Glacier Peak.

The Columbia Plateau province in Central and Southeastern Washington makes up part of the largest lava plateau in the world, consisting of an elevated plateau of 15 million year-old Columbia River Basalts. The lava plateau is cut by occasional coulees and scablands and is partially covered by glacial alluvium.

The Okanogan Highlands, a branch of the Rocky Mountains in Northeastern Washington, make up much of the Northern Rocky Mountain province. This province consists of mountain ridges and valleys which contain commercial deposits of copper, gold, silver, lead, and zinc.

The primary region of geothermal potential in Washington is found along the Cascade Range province, where many prominent thermal springs emerge from the granites and basalts of the Cascades. The Mount St. Helens Known Geothermal Resource Area is also located in the Cascade Range province.

HIGH-TEMPERATURE RESOURCES

1. KGRA's

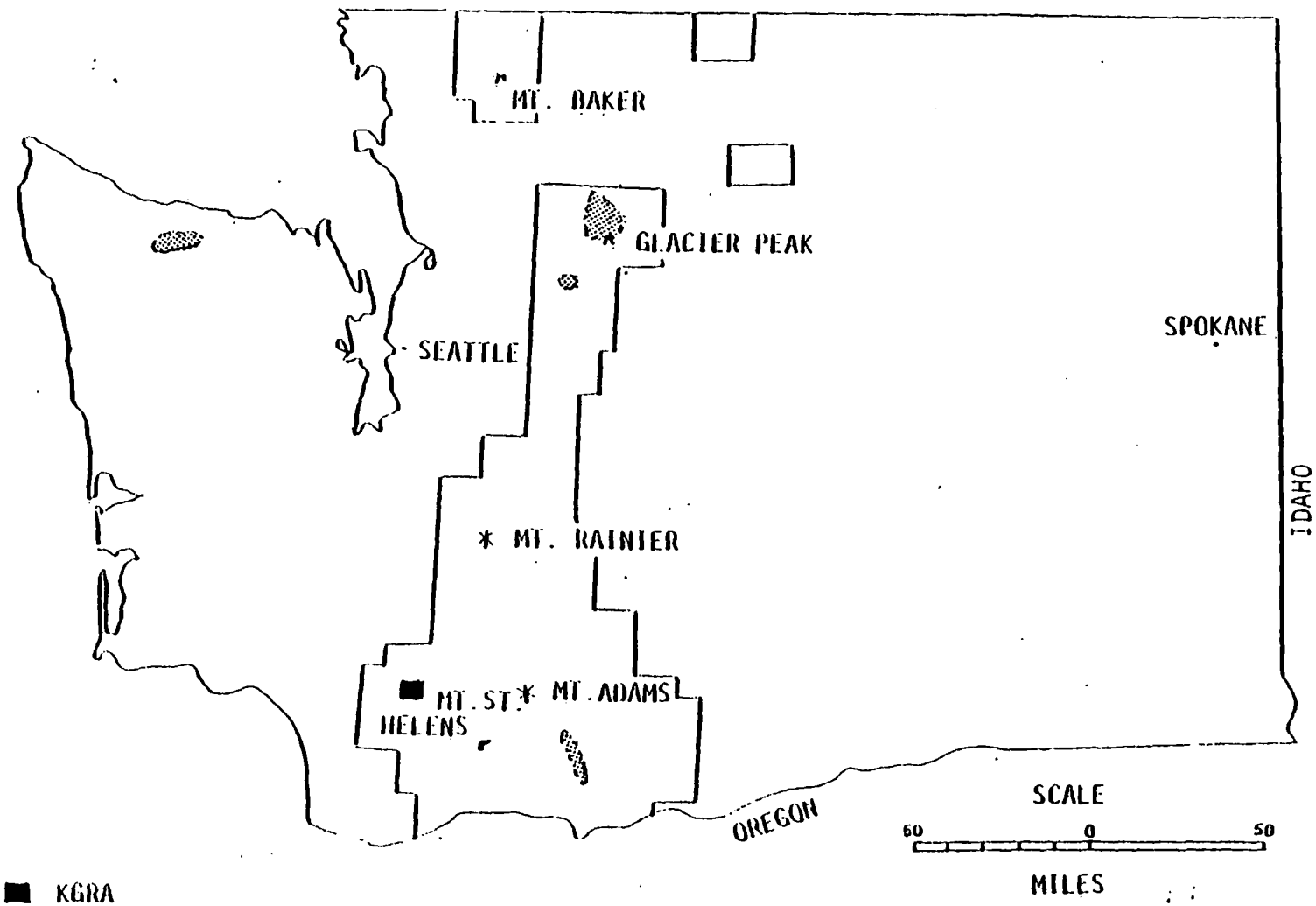
Geothermal convection systems with subsurface temperatures above 150°C are located in the Northern Cascades, near the Mount Baker volcanic system, and in the Southern Cascades, near the KGRA at Mount St. Helens, (Fig. II-7). The thermal resource is associated with the granitic and basaltic lithology of the Cascades, which has been complicated by periods of faulting and folding. The principal developmental problems associated with these geothermal areas are their location in scenic National Forests of high relief and sparse population density. The primary usage proposed for the geothermal resource at Mount Baker is for residential space heating and agricultural applications.

2. Other Prospects

The entire area of the Cascade Range province in Washington has been classified as having geothermal resource potential, due to the relatively recent volcanic activity there. The Glacier Peak volcanic system, just east of Mount Baker, may contain a high-temperature reservoir because of the location of a hydrothermal convection system at that site.

LOW- AND MODERATE-TEMPERATURE RESOURCES

1. KGRA's - None



(After Geothermal Resources Map of Western U.S., 1977)

Figure II-7. Washington Geothermal Resources

2. Other Prospects

The rocks of the Quaternary basalt field in the Southern Cascades Range, eastward of the Mount Adams volcanic system, have been found to have occurrences of thermal spring activity (Fig. II-7). Geochemical analysis of the thermal waters has shown an apparent aquifer temperature in the neighborhood of 140°C. Unusual gravity anomalies have been found here, and continued geophysical investigation of the area is planned for the future.

APPENDIX III

PROSPECT-SPECIFIC DEVELOPMENT SCENARIOS

Prospective development plans will be prepared on a state-by-state basis within the Pacific Region. These plans will be assembled by contractors under the direction of specific state representatives and the PRT. The process of preparing these development plans will include preparation of realistic prospect-specific scenarios for commercial utilization of geothermal resources, followed by preparation of developmental schedules and implementation plans for each prospect. These site-specific plans will then be integrated over each state to provide state-by-state development plans.

The resulting development plans will each contain a schedule of (electric or direct use) power-on-line, explanation of barriers to development, and programmatic recommendations which state and federal agencies should pursue in order to increase the likelihood of realization of development plans. Scenarios which have been prepared for electric power development at the Heber, California prospect, and for integrated electric power and direct use development at the Puna, Hawaii prospect are discussed below:

A. HEBER ELECTRIC SCENARIO

A typical prospect-specific electric power developmental scenario is included in Figure III-1 for the Heber, California, prospect. This scenario depicts development schedules for geothermal-electric power production at Heber.

Heber was selected as the initial step in a site-specific scenario development program for the following reasons:

- The Heber prospect - located between El Centro and the Mexican border - promises to be the site of the first commercial scale power plant on a liquid-dominated reservoir in the U.S. Several producing wells have been drilled and two major utilities have announced plans to construct separate 50 MWe plants at the site.

- The nature of the resource is well known. A capacity of 1000 MWe for 30 years is assumed. Development of the resource is within the state-of-the-art technology.

- Other aspects essential to development of power are at a relatively advanced state compared to other geothermal prospects such as Coso Hot Springs:

  - The county planning process is well underway;

  - environmental background data and impact studies have made good progress; and

  - utility commitment in principle has been obtained.

- A Heber scenario could serve as a starting point for the development of other scenarios in the Imperial Valley - East Mesa, Brawley, and Salton Sea/Westmorland. Logic and data generated here may be transferred to these other areas. Other plants are proposed or in process at these prospects.

Using JPL's previous work* as a point of departure, a detailed, site-specific scenario for the Heber prospect was created, utilizing a time-scaled, activity-oriented network approach to trace the developmental process of bringing geothermal power on-line. Each step in the detailed process was defined

*Reference: Fredrickson, C.D., Analysis of Requirements for Accelerating the Development of Geothermal Energy Resources in California, Jet Propulsion Laboratory, November 15, 1977.

and the requirements for completion of one step before initiating succeeding steps were laid out. Next, time estimates for the duration of each step were obtained. Finally, a time-scaled calculation of the entire network permitted the detection of rate-controlling activities and events.

The network approach makes possible the graphic display of the developmental process in such a manner as to aid analysis and understanding of the scenario. It also allows ready analysis of the effects of hypothesized program alternatives on the timing of the scenario. Whole plant developments were configured as modules capable of being moved in response to varying circumstances.

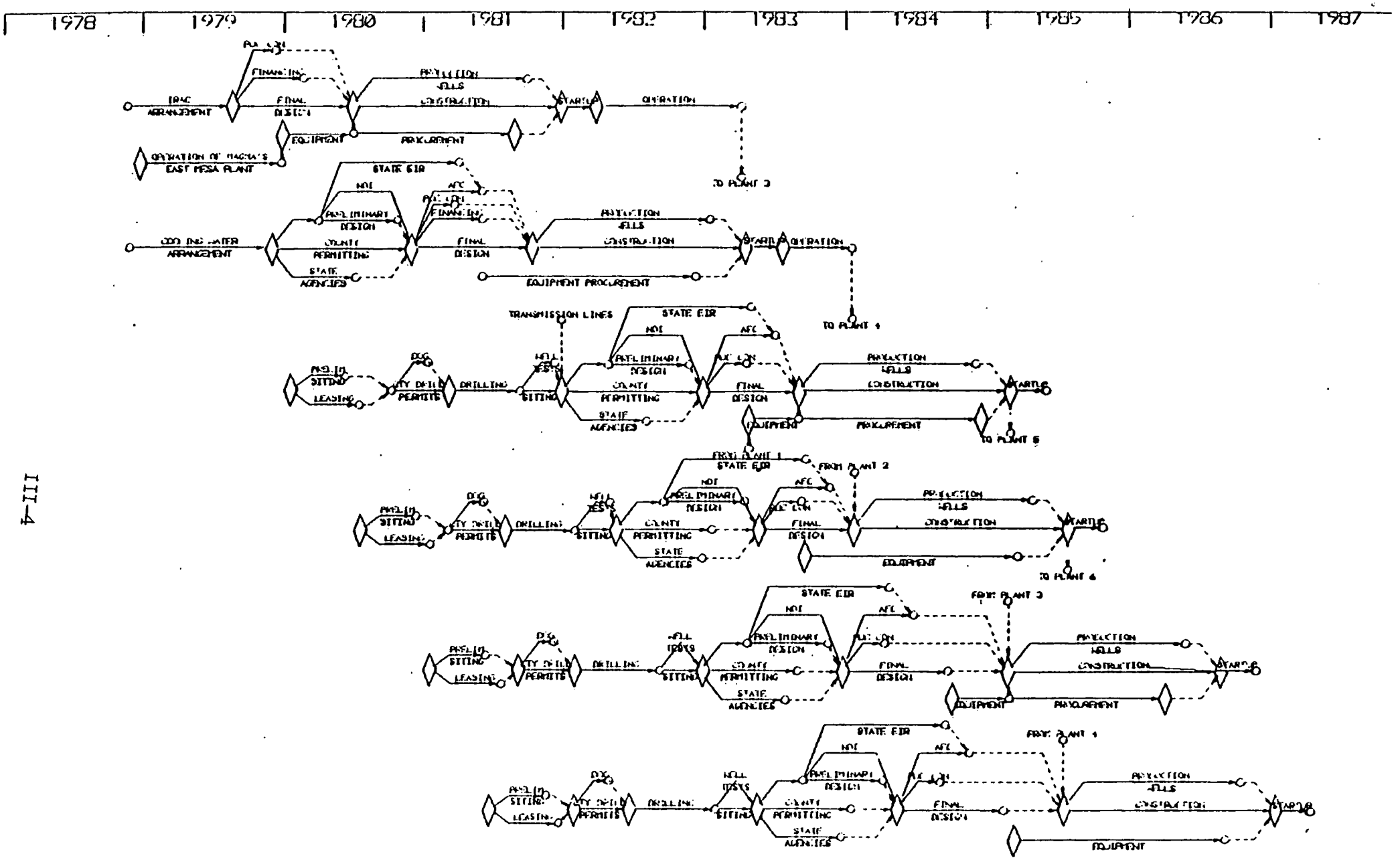
A portion of the scenario is presented in Figure III-1, which shows the sequence of activities from the present through 1987 with the completion of the sixth plant in the field. The actual working scenario on which this figure is based is considerably more detailed; however, for clarity of presentation, many subactivities have been combined to form the major activities displayed here.

In Figure III-1 the events which are shown as diamonds represent the milestones of the development process. They constitute, at least tentatively, the milestone events which will be used in monitoring the progress of geothermal electric energy development. Less significant events are displayed as simple circles in the figure.

The major activities in the development of each plant are presented as horizontal lines. The solid portion of the line represents the time needed for the activity. Dashed continuations of activity lines display the slack time available in the completion of that activity. The critical path in the development of each plant is shown by the activities which reach their terminal event with no dashed continuation.

Figure III-1.

HYPOTHETICAL HEBER SCENARIO WITHOUT FEDERAL PARTICIPATION IN FIRST PLANT



This revised scenario reflects the recent decision concerning the Heber demonstration plant. Without federal participation in the first plant, power-on-line is anticipated to be delayed one year. The resulting program need is to nourish the interim utility concept by special incentives.

Two factors impose constraints on geothermal development at Heber - cooling water availability and transmission lines and corridors. Cooling water availability must be determined by mid-1980 when the county permitting process for plant 2 commences. The second problem, dealing with transmission lines to transport power from Imperial County to markets in San Diego or elsewhere, must have a resolution by 1982, when the NOI process for plant 3 is scheduled to reach completion.

Reviewers of the scenario, which included the Imperial Irrigation District, agreed with the projections, stating that the resolution of both issues is absolutely vital to the large-scale development of the Imperial Valley geothermal resources. IID urged that a transmission plan that will utilize the existing transmission network to its fullest capability (including enlargement) be developed before full consideration is given to separate transmission corridors.

A further requirement that is clear from examination of the scenario is that a high level of early utility commitment to geothermal development will be required to realize the scenario.

It should be noted that construction of plant 3 does not begin until after plant 1 has been in operation for more than one year. While there is no fixed time requirement for operation of one plant before construction of the next (hence the "operation" activity is displayed on the scenario as a dashed line), this would be a desirable outcome.

The first four plants in the scenario are assumed to be 50 MWe capacity. It is felt that by the time plant 5 is begun, the site will be sufficiently developed to warrant commitment to power plants in the 100 MWe range - or alternatively, commitment to construction of two 50 MWe plants simultaneously.

Full development of the Heber prospect to 1000 MWe capacity - the value which has been used for the 30-year capacity of the field - would extend through 1996, according to the basic scenario. Figure III-2 (updated from a March 1978 draft) shows the generating capacity added in each year, and the cumulative total power-on-line for the scenario. All figures were based on discussions with various utility representatives. It must be emphasized that this represents an aggressive but achievable development goal.

Technical and institutional processes involved in the development of geothermal power were examined for their role in the scenario. The technical aspects addressed included subsidence and seismicity, power plant technology, cooling water, water use and availability, and comprehensive waste disposal. The most critical and rate-controlling institutional processes were identified with a view toward how they could be accelerated. As the scenario is a dynamic process, it will continue to change as new regulatory procedures are defined.

Findings in the area of institutional program needs fell into these categories: those actions needed by DOE, those pertaining to CERCDC and those pertaining to the Imperial County Planning Office. They may be summarized as follows:

- DOE
  - dissemination of information
  - EIR preparation done in common
  - grants to Imperial County

Figure III-2.

HEBER SCENARIO (JULY, 1978)

MW ON LINE

BASIC SCENARIO

YEAR	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97
MW ADDED	50	0	50	0	100	0	0	100	100	100	100	0	100	100	100	100
CUMULATIVE TOTAL	50	50	100	100	200	200	200	300	400	500	500	600	700	800	900	1000

POSSIBLE ACCELERATION

ACCELERATED	50	0	50	100	100	0	100	200	100	0	200	100	0	0	0	0
TOTAL	50	50	100	200	300	300	400	600	700	700	900	1000	1000	1000	1000	1000

- o CERCDC/GRB
  - allocate resources/manpower to county
  - use EA documents prepared in common with NOI/AFC
  - workshop on permitting procedures
  - Imperial County given lead in permitting

- o Imperial County
  - allow prospect-wide EIR's
  - serve as clearinghouse for permitting activities

Ten programmatic recommendations for realization of the scenario were also developed and are listed below:

- o Provide funds to expand Imperial County's ability to process geothermal permits
- o Increase sensitivity of Heber seismic baseline study
- o Provide for a long-term source of cooling water and/or reinjection make up water
- o Provide for routing of transmission lines out of Imperial Valley
- o Provide for sludge disposal
- o Coordinate ERCDC and County EIR efforts
- o Provide support to counties other than Imperial to facilitate rapid geothermal development
- o Consider the impact of the possible elimination of demonstration funding
- o Provide financial incentives for geothermal development

B. DIRECT USE SCENARIO

1. Introduction

The scenario format which worked well for the Heber electric scenario should also be well suited for developing a picture of the scenarios for direct uses. The format was utilized to develop the integrated Puna scenario, which is discussed later in this section.

In the electrical case, the focus was on presenting the activity of the developer with concentration on scheduling and the constraints that develop. Programmatic actions were defined from the constraints. The requirements of the direct use scenarios will be somewhat different, necessitating some modifications and reprogramming. For direct use, the problem of initiation increases in importance. Concurrently, the scale of many direct uses is such that government involvement in the performance of development is minimal. At the same time, for many areas, the steps that must be performed to initiate a direct use, and indeed even to evaluate whether a direct use will be profitable and desirable, are not clear. Scenario emphasis will therefore be on defining this phase. The analysis of the primary factors controlling development needs to be represented and the data used in the analyses will become part of the scenario. Thus, the various discriminating factors developed should follow from the scenarios. This in turn will make it possible to consider federal and state programs in terms of their impact on the scenarios. The change in the discriminators resulting from modifications in the scenario will provide a guide to the impact and importance of various programmatic alternatives.

Scenarios will have to include more than one possible application and the steps leading up to the various applications will have to be shown. In some cases, this may mean that government programs to encourage development, and even R&D programs will become key activities in the scenario. This impact and scheduling of some activities may be difficult to represent; it may become necessary to incorporate some features of decision analysis into the scenarios to represent probable outcomes and the effect planned actions have on changing the desirability of various programs.

The desirability of a particular program is proportional to the probability of success of that program. It is

essential to the large-scale acceptance and implementation of direct use applications of geothermal energy that the majority of proposed and ongoing programs have a high degree of desirability, and therefore, a high probability of success.

As soon as key information and data needs of the scenario have begun to come in, program needs or recommendations are identified and developed, which are designed to:

- o increase the desirability of various site-specific or region-specific programs;
- o accelerate the development at a particular site; and
- o accelerate the development of direct use applications in general.

These program needs generally fall into four categories: managerial, technical, institutional (regulatory/permitting), and economic. Any recommendations made take into account the present stage of development, and are designed to accelerate further development in a dramatic, but timely and feasible manner.

2. Puna Integrated Scenario

As a starting point for the development of an authoritative scenario for geothermal development on the Puna area in Hawaii, a "straw man" scenario was developed showing the processes leading up to placement of a wellhead generator at the existing well HGP-A and retrofit of the Puna Sugar Company's Keaau plant which appears to be located within a reasonable distance of viable resources. This scenario correctly reflects the State of Hawaii plans for a wellhead generator at HGP-A, but does not necessarily represent the thinking of the sugar company. Puna Sugar Company has shown a favorable response to discussions of the potential of geothermal utilization in the sugar industry, but there has not been sufficient discussion of this preliminary scenario with them to determine what thinking they may have done

regarding conversion of existing plants. One concern that has been expressed is whether or not the capital investments involved in geothermal development are compatible with the sugar industry in Hawaii. However, the possibility of integrated development of resources in the Puna Rift area might tend to lower projected capital costs for the sugar company.

The first case developed is shown in Figure III-3. Presentation is in the form of an activity or arrow network. The major steps in development, such as drilling wells or obtaining permits, are shown as arrows. The extent of the solid arrow on the time scale at the top shows the probable duration of the activity. The dotted lines represent "slack", unconstrained time. For example, in the scenario for the sugar plant retrofit, prior to starting drilling, both a special use permit and a grading permit must be obtained. These can be applied for in parallel; however, since the special use permit takes longer, there is slack time shown between the acquisition of the grading permit and the commencement of drilling. The diamonds show events which mark the beginning or end of important phases or steps in the development process. These are the milestones that can be used for monitoring. The small circles are for less important events.

The present condition of the wellhead generator (the upper part of the scenario) is as shown. A state EIS has been prepared and approved. A Federal EIS, based on the state's, is in preparation. Available information indicates that Puna Sugar has not begun any efforts, although they have carried out feasibility studies.

The wellhead generator line at the top of the scenario requires little clarification. However, it is not complete. What, if any, connection there will be between the wellhead generator and the sugar plant is not clear. This is partly due to uncertainty as to the use of the bagasse. The plans of the

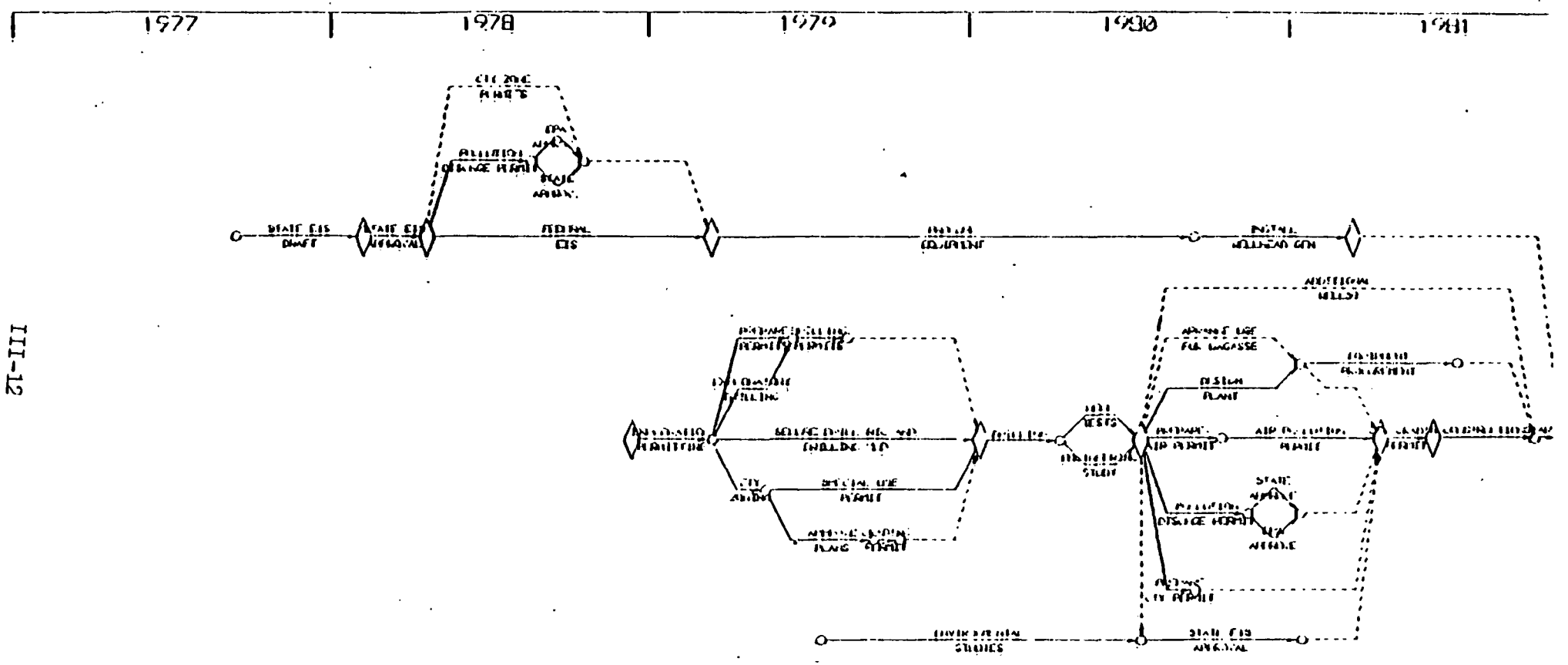


Figure III-3. Puna Wellhead Generator and Direct Use Scenario (Draft)

State for further development at Puna must be investigated and included in the scenario. Preparations for transmission of the power and disposal of the brine from the wellhead generator are not shown. These parts of the scenario must be developed. The time estimates for procurement and installation of the wellhead generator are also being revised.

The portion of the scenario dealing with the sugar plant shown in Figure III-3 is based on the fact that the Keaau Plant is located near some areas that may be potential resource areas. The scenario assumes that the Puna Sugar Company, or some other agency, begins this year with exploration of these resources, including drilling heat flow holes and follows up with a program to drill some wells. It is assumed that a resource with temperatures satisfactory for sugar processing (near boiling or above) is located and that the plant is retrofitted to use it. Since a retrofit is envisioned, it can be accomplished fairly rapidly. On this basis, the wellhead generator and the converted sugar plant could be in operation in 1981.

This scenario was constructed primarily as a way to begin approaching the question of what might be accomplished. However, it must be tied more closely to the realistic capabilities and options of the principals involved. The various permitting processes make up a large part of the scenario. The first thing that should be done is to check that the permitting processes have been appropriately interpreted. It may not be the case that the sequence in which permits are obtained is fixed. In that case, judgment must be exercised to construct, from discussion with appropriate officials, a probable, but optimistic, sequence. Similarly, best guesses of duration must be used; information on how much these may be exceeded can be given in accompanying descriptions, if necessary.

Efforts are underway to collect whatever data are available on resource potential in the vicinity of the Keaau Plant.

This will form part of the direct use overview for Hawaii. In addition, the Puna Sugar Company will be contacted. It must be determined if they have made any plans with regard to exploration for, or use of, geothermal heat. They are now engaged in feasibility studies for the use of geothermal brine in their operation. Rough estimates will need to be obtained from them for the time, expense, construction, and equipment requirements that might be involved in retrofitting the plant.

The Puna Sugar Company's energy requirements are largely supplied from bagasse, the fibrous waste from processed sugar cane. The plant uses about 2.3×10^{12} Btu in heat energy and about 10^{8} hp hours in mechanical energy per year. In addition, they sell electricity to the utility (HELCO). To meet their full commitment for electricity, however, they do use fuel oil to supplement the supply of bagasse. By supplying part of their energy from geothermal resources, they hope to eliminate their fuel oil usage and, also, if possible, increase their electrical output. Depending on the quality of resource that the sugar company is able to tap, they might, in fact, be able to displace a greater quantity of bagasse than could be used at the plant. For this reason, a dotted line labeled "Arrange Use for Bagasse" is shown in the scenario.

To fully present the potential for retrofit of the Keaau Plant, another alternative must be examined. Figure III-3, as has been explained, is based on exploration and development of an intermediate temperature resource near the sugar plant. However, Keaau is only about 18 miles from the present HGP-A. In view of the high temperatures that exist on the Puna Rift, it should not be impossible to consider transferring geothermal fluid from the present resource to the sugar plant. This might involve the brine from HGP-A as it emerges from the wellhead generator, although this alone would not provide all the plant's energy requirements. Perhaps, a new well, or wells, could be drilled in the known resource. Pump power for transmission of the fluids

could be provided by wellhead installation with steam turbines, or, if wells are to have downhole pumps in order to prevent flashing in the well (produce the fluid at higher temperatures), power could be provided from the wellhead generator on HGP-A.

For transfer of fluid from the HGP-A site, the scenario would not contain the parts dealing with exploration and drilling in the vicinity of Keaau. Instead, permitting for, and construction of pipeline for transferring the brine, would be necessary. There might also be additional drilling in the Puna Rift resource area. These questions are presently under investigation.

The original scenario has been refined by incorporating feedback received from industry representatives in Hawaii. The findings as related to HGP-A's Wellhead Generator Project are best seen by comparing Figure III-4 with the top activity network of Figure III-3. The major differences are:

- the activities of the engineering design and implementation processes comprise the main branches of the critical path to reach the "power-on" event;
- the introduction of a Federal Air Pollution Permit (to construct), as of June 19, 1978, that may require a review of the emitting source if 250 tons or more of any pollutant is discharged into the air, for example, hydrogen sulfide;
- a target date for completion of construction and power-on, during the 3rd quarter of 1980; and
- the identification and process time of all permitting/approval activities that can impact the design, construction and operation (demonstration) phases.

The first approximation of the direct use scenario for Puna which included both direct use and electrical generation, had been shown to representatives of the geothermal community in an effort to obtain their comments regarding current practices and expectations. The resulting scenario has not yet been reviewed by the local community. Cooperative efforts between the

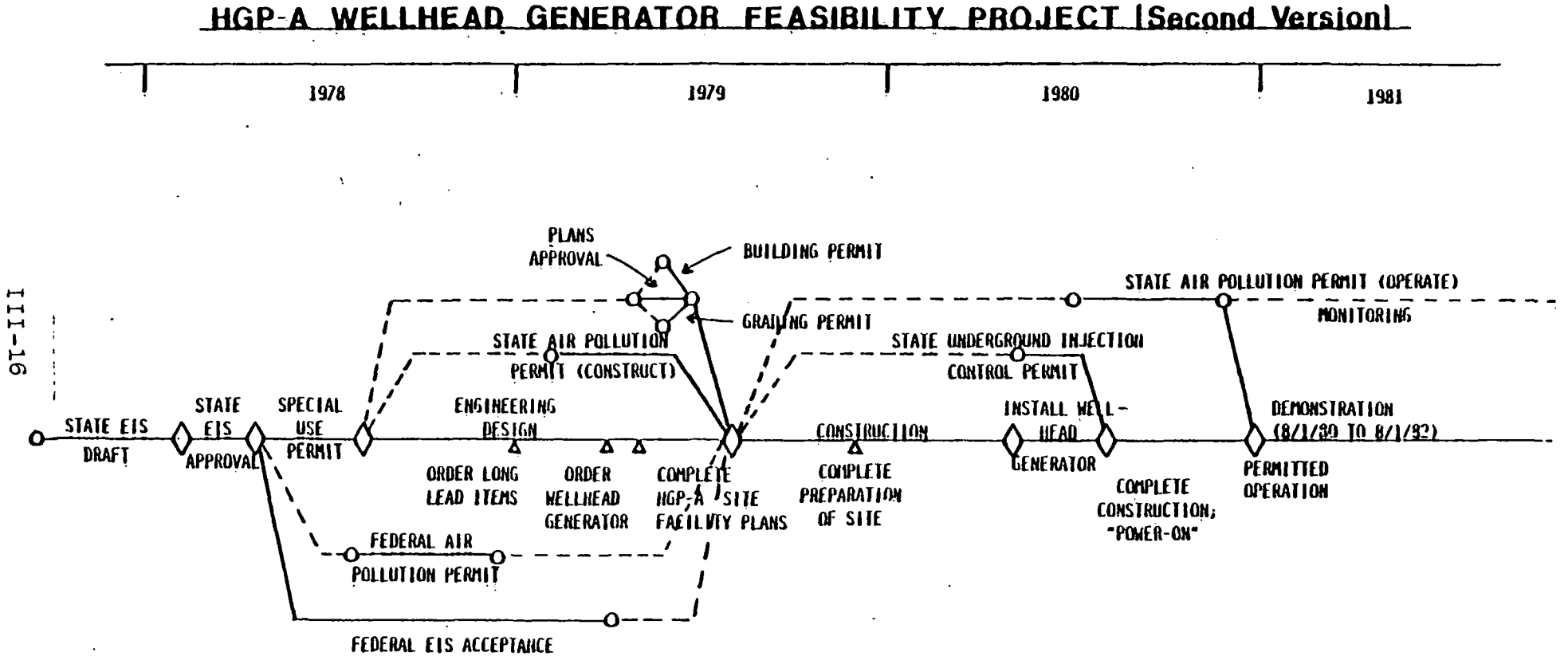


Figure III-4. Wellhead Generator Scenario

private sector and the state and county governments could potentially reduce the overall commercialization time by 12 months or 33%.

Specific measures identified to reduce the schedule are as follows:

- Use water well drilling for exploatory efforts, on private lands only, until the resource is identified (as regulations governing this type of drilling are less stringent, it is possible to shorten the schedule). Networks showing both the conventional approach and this alternative, applied to the direct use section of the scenario, are presented in Figure III-5.

- A more detailed analysis of the potential for obtaining permits in parallel, and of the engineering design and procurement schedule, resulting in compressing the wellhead generator scenario another three months.

- For larger developments, schedules could be shortened by obtaining a boundary change, thus bringing development under the regulations pertaining to urban areas, as opposed to conservation, agricultural or rural areas.

Several other important program needs for expediting geothermal commercialization in Hawaii were identified during the process of revising the scenario. The resource analysis must be tailored to support institutional and physical opportunities by designating the geothermal prospects and identifying process industries, candidates for energy complexes, secondary process uses, and institutional resources.

In order to effectively develop the geothermal resource on the Big Island, sufficient incentives must exist to make such development attractive. Several incentives were identified which would attempt to make geothermal development no less attractive than hydrocarbon development. These included taxation relief, such as subsidizing capital equipment, favorable financing and a moratorium on royalties.

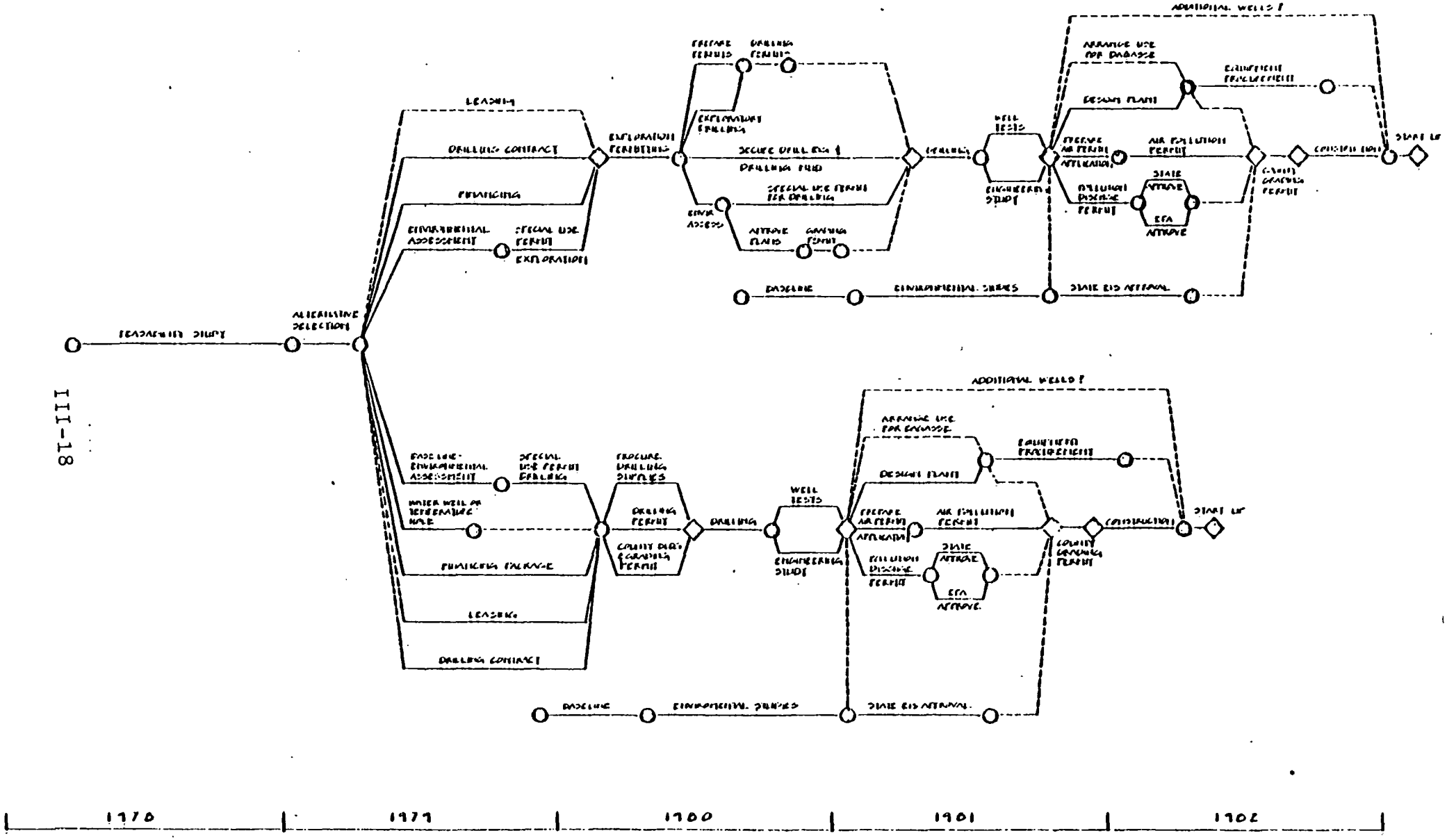


Figure III-5. Direct Use Scenario, Puna (2nd Version)

The next area identified was the removal of institutional impediments. Geothermal energy must be brought out of the "special case" role into a "normal course of business" role. This could be accomplished by streamlining land use rules, clarifying resource ownership, accelerating regulatory response, simplifying regulatory processes, and uniformity of regulations.

Finally, an expanded mission-oriented program with higher energy recovery goals must be implemented. Long range planning with established policy priorities must be developed, equity financing funds established, technology improved, and pre-cast baseline environmental data gathered.

Three future project needs were also identified:

- Assessment of the impact of native Hawaiian claims on the geothermal commercialization rate,
- identification of additional scenarios for direct use of geothermal resources in Hawaii, and
- further refinement and future extension of the Puna scenario.

APPENDIX IV

REFERENCES

The following listing represents a subset of some of the recent literature containing relevant data and information on the various phases of geothermal energy development in the Pacific Region. The information storage and retrieval system incorporates various aspects of the Digital Electronics Corporation (DEC SYSTEM-10) computer software package. Entries into a computer file are keyed by unique descriptors which are utilized in the organization and sorting of an output file. The present geothermal literature listing keys each entry by the following descriptors:

MATERIAL TYPE:

1. Bibliography
2. Books
3. Conferences--Proceedings
4. Journal Articles
5. Journals
6. Reports
7. Excerpts from any Material
8. Miscellaneous--Correspondence, Newspaper Clippings, etc.

GEOGRAPHIC AREA:

W - Western U.S.
U - U.S.
F - Foreign
C - California
H - Hawaii

The descriptors listed above do not appear in the bibliography which follows.

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