ENVIRONMENTAL DEVELOPMENT PLAN GEOTHERMAL ENERGY SYSTEMS

August 1979

MASTER

U.S. Department of Energy

Assistant Secretary for Energy Technology

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FOREWORD

Environmental Development Plans (EDPs) are prepared by the Department of Energy (DOE) to help fulfill the Department's responsibility for the development of environmentally acceptable energy technologies. The EDP provides a common basis for planning, managing, and reviewing all environmental aspects of the energy programs under DOE's jurisdiction.

The EDP is timed to precede key technology program decisions as the technology moves from the exploratory development stage to an engineering development or technology demonstration phase. To ensure that environmental, health, and safety (EH&S) considerations will be addressed adequately in the technology decisionmaking process, the EDP (1) identifies and evaluates EH&S concerns; (2) defines EH&S research and related assessments to examine or resolve the concerns; (3) provides a coordinated schedule with the technology program for required EH&S research and development; and (4) indicates the timing for Environmental Assessments, Environmental Impact Statements, Environmental Readiness Documents, and Safety Analysis Reports.

The initial EDP for Geothermal Energy Systems (DOE/EDP-0014) was published in March 1978. This EDP provides a substantial updating of the 1978 document. It draws on analysis contained in the Environmental Readiness Document (ERD) for Hydrothermal Electric and Direct Heat (DOE/ERD-0005). ERDs are assessments prepared independently by the Office of Environment to provide a critical review of the environmental readiness of a technology.

The revised EDP on Geothermal Energy Systems is being released under authority of DOE Order 5420.1 dated August 10, 1978. It was prepared jointly by the Division of Planning and Technology Transfer (ET) and the Technology Assessment Division (EV), with the assistance of the research and support divisions of the Office of Environment.

This EDP on Geothermal Energy Systems is being distributed so that everyone having interests and responsibilities with respect to geothermal energy systems may have the opportunity to review and provide suggested changes for future updates.

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for Environment

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ENVIRONMENTAL DEVELOPMENT PLAN
FOR
GEOHERMAL ENERGY SYSTEMS

1979

Department of Energy
Washington, D.C. 20545

Technology Program Office:	Office of Energy Technology
Technology Program:	Solar, Geothermal, Electric, and Storage Systems
Energy Technology:	Geothermal Energy Systems
Program Coordination:	Ronald Loose Division of Planning and Technology Transfer Office of Energy Technology Robert Blaunstein Technology Assessment Division Office of Environment

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I. SUMMARY

The Environmental Development Plan (EDP) system is designed to provide a common basis for planning, managing, and reviewing the environmental aspects of the various energy technology programs under the Department of Energy's (DOE) jurisdiction. For a specified technology development program, the EDP performs the following functions:

- Governs the nature and content of the Environmental Issues and Control Technology annex to the Energy System Acquisition Project Plan, which is the baseline management document for DOE project activities;*
- Summarizes the environmental concerns associated with technology development, demonstration, and commercialization identified and evaluated in the previous EDP and the Environmental Readiness Document (ERD)** if one has been prepared;
- Defines general requirements for environmental, health, and safety research and assessments to resolve these concerns and defines an implementation strategy;
- Provides a coordinated timing schedule for required environmental research and development (R&D), technology program activities, and decision points; and
- Indicates approximate timing for documents required in the National Environmental Policy Act (NEPA) process, ERDs, and safety analyses where appropriate.

The publication of an EDP is generally timed to precede key technology program decisions that result in program shifts from an exploratory development into the technology development, engineering development, demonstration, or commercialization phase. The time frame covered by an EDP generally encompasses all significant decision points relating to the technology program. Projects or subprograms that are likely to result in a demonstration or commercialization within the near term are presented in detail. Projects that will need to be considered in greater detail in the next EDP update are identified.

*"Program and Project Management System for DOE Outlay Programs," memorandum from Dale D. Myers, Under Secretary, Department of Energy, May 31, 1978.

**The ERD is an independent evaluation by the Office of Environment which analyzes a technology's environmental acceptability.

This EDP for geothermal energy systems covers all current and planned activities of the DOE Geothermal Energy Systems Program. The goal of this program is to provide those initiatives which are needed to accelerate commercial development of geothermal resources and to ensure environmental and social acceptability and operational safety. Major elements of this program include exploration of resources, confirmation of reservoirs, development of energy extraction systems, demonstration of utilization systems, identification and removal of institutional barriers, and a loan guaranty program.

Three types of geothermal resources are covered in this EDP: hydrothermal convection systems, geopressured systems, and hot dry rock systems. Of these three, only hydrothermal convection systems are considered ready for commercial development, and an ERD for these systems has been published. The other two systems show promise of future development, but current research is now oriented toward resource exploration and confirmation and toward small-scale experiments of heat extraction systems. The geopressured resource is projected to contain large amounts of dissolved methane. The recovery of this methane is part of the geothermal geopressured program.

Environmental concerns and requirements for resolution of these concerns are discussed at length in Section III. In terms of immediate need and importance in getting power online, the emission of H_2S is the most important concern and the demonstration of an effective abatement system is the most significant requirement. Demonstration of one such system is targeted for FY 1979 at The Geysers geothermal area. Other significant concerns are the management or disposal of spent geothermal fluids, the potential of land subsidence, questions of water availability for heat rejection systems, land use conflicts, and socioeconomic and cultural problems. The requirements to appropriately research and mitigate these and other concerns in time to permit orderly and timely development of geothermal energy systems are scheduled in this EDP.

II. TECHNOLOGY PROGRAM

A. TECHNOLOGY DESCRIPTION

Geothermal resources of near-term interest are of three types: hydrothermal, geopressured, and hot dry rock.

1. Hydrothermal Systems

Hydrothermal systems are convective systems of water and steam that are trapped in fractured rocks or permeable sediments by impermeable surface layers. Geothermal fluids may be released when such systems are tapped by drilling. A specific resource is classified as being either vapor- or liquid-dominated, according to the state of the fluid produced. Typical electrical power generation systems for high-temperature resources are shown schematically in Figures 2-1 (a) and (b). A closed binary system schematic for moderate temperature hydrothermal resources is shown in Figure 2-1 (c).

Hydrothermal resources have high potential for near-term commercial development. For example, vapor-dominated resources are presently being used for the generation of electricity in the United States, Japan, and Italy; liquid-dominated resources are in use in Iceland, Mexico, El Salvador, Russia, and New Zealand.

2. Geopressured Systems

Geopressured zones consist of highly porous sands saturated with saline water at very high pressure and temperature. The high temperature is thought to be the result of normal heat flow being trapped by uncompacted clays which serve as insulating layers. Waters derived from the compaction and dehydration of clays accumulate in the sands and greatly increase the fluid reserve. The marine sediments are under-compacted below depths of 6,500 to 10,000 feet, and the interstitial fluid carries part of the overburden load (i.e., the fluids are at pressures between the hydrostatic and the lithostatic head). Temperatures up to 290°C and pressures up to 1000 atmospheres have been measured in these systems. In the United States, the principal geopressured formations are located under the gulf coast of Texas and Louisiana. The magnitude of the resource is substantial, and its economic value is enhanced by the presence of natural gas dissolved in the geopressured fluid; however, difficult technical and economic problems must be solved before geopressured resources can be utilized commercially. A proposed system for generating electricity and recovering methane is shown in Figure 2-2.

3. Hot Dry Rock Systems

Hot dry rock resources are those geothermal reservoirs where the heat is contained in rock of low permeability. Hot dry rock systems are potentially the largest and most widely distributed geothermal resource in the

Figure 2-1. Electrical Power Generation From (a) a Vapor-Dominated Resource, (b) a Liquid-Dominated Resource, and (c) a Closed Binary System From a Hydrothermal Resource

Figure 2-2. Electrical Power Generation and Methane Production From Geopressured Resource

Nation. A large volume of hot dry rock (normal gradient resource) is located in the Earth's crust at depths in excess of 15 km (50,000 ft), which is beyond present drilling capability. However, the volume of hot dry rock at more shallow, accessible depths is also considerable. It is estimated that 95,000 square miles of the Western Heat Flow Province (the 13 Rocky Mountain and Pacific Coast States) are underlain by hot dry rock at temperatures greater than 293°C at depths less than 5 km (16,000 ft). Two specific promising areas are the Valles Caldera, near Los Alamos, New Mexico, and the Coso Hot Springs, near China Lake, California. Other potential sites being evaluated are located on the eastern coastal plain, the midwestern region, and the Pacific Coast.

Development of these resources requires drilling into the rock, inducing fractures, injecting fluid, and removing the resultant heated fluid through separate wells. Technical problems associated with fracturing and maintaining the fractures must be solved before these resources can be developed commercially. A system for extracting energy proposed for the Fenton Hill area near Los Alamos is shown in Figure 2-3.

B. PROGRAM DESCRIPTION AND MILESTONES

The DOE program management for geothermal energy research, development, demonstration, and commercialization is the responsibility of the Office of Energy Technology (ET) and the Office of Resource Applications (RA), with program implementation carried out by the Division of Geothermal Energy/ET and the Division of Geothermal Resource Management/RA. DOE has been established as the lead agency for coordinating the Federal geothermal energy program. The goal of this Federal program is to enable and stimulate commercial and industrial development and use of the Nation's geothermal resources in an environmentally and socially acceptable manner. This development and use are to encompass both generation of electricity and the direct thermal energy use of geothermal resources, as well as methane extraction from the gulf coast geopressured geothermal resource.

1. Federal Program

The Federal geothermal program is directed toward providing those initiatives that are needed to effect accelerated commercial development while maintaining environmental acceptability and operational safety. It involves the activities of several agencies including DOE, the Department of the Interior (DOI), the Department of Agriculture, the Environmental Protection Agency (EPA), and others. DOE has the responsibility for coordinating the program and for coordinating the formulation of national goals for geothermal development. Coordination is accomplished through the Inter-agency Geothermal Coordinating Council (Figure 2-4). The achievement of environmental acceptability and operational safety through laws and regulations is the responsibility of several agencies: DOE, DOI, EPA, the Council on Environmental Quality, and the Occupational Safety and Health Administration (Figure 2-5).

Figure 2-3. Electrical Power Generation From Hot Dry Rock Geothermal Resource

The DOE geothermal environmental program consists of several elements:

- Environmental aspects of projects directly supportive of DOE geothermal resource and energy conversion technology development;
- Projects addressing generic environmental, health, and safety (EH&S) issues, generally of longer term and more fundamental in nature, with applicability to geothermal as well as other technologies;
- Projects designed to support and enhance the geothermal resource development efforts of other Federal agencies; and
- Projects designed to support promising regional or area geothermal resource development activities outside the Federal program.

These elements support DOE and other agency projects for development, demonstration, and commercialization of geothermal resources. Schedules and milestones of the geothermal technology development and demonstration program are presented in Figures 2-6 through 2-9.

2. Geothermal Loan Guaranty Program

In addition to the research, development, and demonstration of geothermal energy technologies as provided for by the Geothermal Energy Research, Development, and Demonstration Act of 1974 (P.L. 93-410), a loan guaranty program was provided for encouraging and assisting the financing of geothermal energy development. A summary of activities covered by the Geothermal Loan Guaranty Program is given in Table 2-1.

LEGEND:

BLM—Bureau of Land Management
BuMines—Bureau of Mines
BuRec—Bureau of Reclamation
CEQ—Council on Environmental Quality
COMMERCE—Department of Commerce
DOE—Department of Energy
DOI—Department of the Interior
EPA—Environmental Protection Agency
FWS—Fish and Wildlife Service
OWRT—Office of Water Research and Technology

NavFEC—Naval Facilities Engineering Command

NASA—National Aeronautics and Space Administration
NSF—National Science Foundation
TREASURY—Treasury Department
USDA—Department of Agriculture
USFS—United States Forest Service
USGS—United States Geological Survey

*Denotes chairing function

Figure 2-4. Organizational Responsibilities Within the Federal Geothermal Program

Figure 2-5. Federal Environmental Laws for Geothermal Energy Systems

Symbols:

▲ Program Milestone

▼ Decision Point

— Activity Bar

Figure 2-6. Milestones for Hydrothermal Systems

Symbols:

▲ Program Milestone

▼ Decision Point

≡ Activity Bar

Figure 2-7. Milestones for Geopressed Systems

Symbols:

△ Program Milestone

▼ Decision Point

== Activity Bar

Figure 2-8. Milestones for Hot Dry Rock Systems

Symbols:

▲ Program Milestone

▼ Decision Point

≡ Activity Bar

Figure 2-9. Geothermal Technology Development

SYMBOLS:

△ Program Milestone

▼ Decision Point

= Activity Bar

Figure 2-9. Geothermal Technology Development (concluded)

Table 2-1. Geothermal Loan Guaranty Program
(Applications List)

Approval Goal or Status	Applicant	Project/Location	Goal	Loan Guaranty \$ millions
<u>FY 1978</u>				
Environmental assessment in revision (drilling site change)	Republic Geothermal Inc. and MAPCO	Westmorland Development Project: Explore, evaluate, and develop field/Westmorland, Imperial Valley, California	55 MWe	21.0 (Bank of America)
To DOE Hq. Sept. or Oct.	Honey Lake Hydroponic Farms	Honey Lake Farms Project: Heat greenhouses and packing sheds, refrigerate produce prior to shipment/Mendell-Amedee known geothermal resource area (KGRA), Susanville, California	(Nonelectric)	4.8 (Bank of Montreal)
In Review	O'Brien Resources Corp., Thermal Power Inc., Amax Exploration, Inc., and VTN Corp., Inc.	O'Brien Project: Verify reservoir and develop field/Roosevelt Hot Springs KGRA, Beaver County, Utah	55 MWe	12 (Bank of Montreal)
<u>FY 1977</u>				
Hold (added preliminary exploratory drilling)	Dry Creek Exploration, Inc., (Subsidiary of Geothermal Resources International)	Dry Creek Prospect: Explore, evaluate, and develop field/Lake County (Geysers), California	165 MWe	7.5 (Bank of America)
Approved	Republic Geothermal, Inc.	E. Mesa Development Project: Evaluate and develop field/ E. Mesa, Imperial Valley, California	48 MWe	10.0 (Bank of America)
Approved	McCulloch Geothermal Corp.	CU 1 Venture: Explore and evaluate fields/ Brawley, California	110 MWe	6.3 (Bank of Montreal)
Hold	Southern California Public Energy Corp. (City of Burbank)	Site selection appraisals/ Roosevelt Hot Springs, Utah	50 MWe to 200 MWe	25.0 (Dean Witter and Co.)
Approved	Geothermal Food Processors	Food Dehydration: Rehab. existing wells; Design and build dehydrator plant/ Brady's Hot Springs, Churchill County, Nevada	(Nonelectric)	3.5 (Nevada National Bank)
Hold	Diablo Exploration, Inc.	Select site, explore, evaluate, and develop field/Rio Grande Rift Valley, New Mexico	50 MWe	21.8 (Kidder, Peabody, Inc.)
Construction permit denied	Resource Funding Ltd. (Northern California Power Assoc., a con- sortium of cities)	Explore, evaluate, develop field/Cob Valley, Lake County (Geysers), California	66 MWe	14.5

III. ENVIRONMENTAL CONCERNS AND REQUIREMENTS

A. INTRODUCTION

Environmental changes have been observed to accompany development of hydrothermal resources in various parts of the world. The magnitudes of the associated EH&S impacts have varied widely and depend upon the site, the character of the resource, the nature of the utilization system or process, and the success of control or mitigation efforts. This experience with hydrothermal systems provides a rational means of defining potential problems that must be resolved before significant additional development of hydrothermal systems occurs. Priorities have not been set for these concerns, however, because their relative importance is so dependent upon the resource characteristics (noncondensable gas content, total dissolved solids, etc.) and the nature of the regional setting (land use, socioeconomic structure, water availability, etc.). Thus, while the emission of hydrogen sulfide is the most important issue at The Geysers geothermal resource area, the potential for land subsidence and water use conflicts are more significant issues in the Imperial Valley.

For geopressed and hot dry rock systems, there is no experience with fully developed systems, and the initial feasibility experiments are not yet completed. Therefore, it is possible at this time to predict the EH&S concerns and requirements in only a general way. Appendix A briefly discusses factors which, when considered in conjunction with site-specific screening criteria, constitute a reasonable and methodical technique for defining, setting priorities for, and scheduling the environmental research required to resolve environmental concerns. This technique will be applied as more experience with geothermal energy systems permits.

Important outputs of the DOE EH&S program include recommendations concerning the degree of control that should be maintained over effluents and other undesirable impacts associated with the development of geothermal resources. These recommendations will be in the form of DOE environmental policy and design criteria and may subsequently provide the basis for regulatory actions by other agencies.

B. ANALYSIS OF CONCERNS AND RESEARCH REQUIREMENTS

Concerns related to geothermal energy production were developed by including all conceivable EH&S problems within a general framework related to emissions, physical changes, land and water use conflicts, socioeconomic issues, and system safety. Research requirements were then generally developed for each concern so that the following factors were included where appropriate:

- Identify and measure (such as rates of release)
- Determine effects (e.g., dose-response curves)

- Assess the impacts of effects
- Develop mitigation measures where needed
- Establish baseline and monitoring networks
- Assess the impact of accidents

Emissions associated with vapor- and liquid-dominated geothermal resource applications are well defined for current technology. Most of the available data are from experience with electrical powerplants located at The Geysers area in Northern California. Additional information on residuals is related to precommercial operation of geothermal facilities in the Imperial Valley. Tables 3-1 and 3-2 list typical hydrothermal powerplant resource requirements and production residuals and chemical discharges, respectively. Because advanced H_2S abatement systems are still either in laboratory development or small pilot demonstrations, unabated values are given as a worst case. Values for residuals from geopressed applications are not given because actual operating experience is lacking.

C. HYDROTHERMAL SYSTEMS: CONCERNS, REQUIREMENTS, AND STATUS

As a result of recent analysis, the concerns listed in Table 3-3 have been generated for hydrothermal energy systems. In terms of timing and immediate impact on online power, the release of airborne effluents is the dominating concern. The continued operation and expansion of The Geysers is clearly dependent upon the resolution of this concern through the application of control technology. In other areas, more importance must be assigned to issues such as land subsidence and cooling system water availability. Cultural issues may even be the dominating concerns for development at Coso Hot Springs, California, and in Hawaii.

1. Release of Airborne Effluents

The fluids in hydrothermal reservoirs contain varying amounts of chemical species that do not condense during the heat extraction process. The fractional content of such noncondensed gases varies widely, from 0.4 percent by weight at The Geysers, California, to 30 percent at Monte Amiata, Italy. The major constituent of this fraction is typically CO_2 , with lesser amounts of NH_3 , H_2S , and CH_4 and with trace amounts of Rn, Hg, B, and other compounds. Most extraction and utilization techniques will result in the release of these chemicals to the atmosphere unless control devices are used. An exception would be the use of a down-hole pump to maintain pressure on the fluid through a heat exchanger and an injection well. In theory, a closed loop could be maintained. Such down-hole pumps are now used in Iceland and are undergoing tests in Imperial Valley, California.

The calculated unabated emission rates of these compounds at The Geysers are presented in Table 3-2. The collection of similar data for other reservoirs is a continuing requirement as development proceeds.

Table 3-1. Hydrothermal Powerplant Resource Requirements and Production Residuals^a

1. Powerplant size	
a. Capacity	110 MW
b. Operation factor	90%
c. Average power level	100 MW
2. Land area per powerplant for geothermal facilities	20 acres (0.03 sq. mi.)
3. Well field area per powerplant	1.25 - 2.50 sq. mi.
4. Average downhole resource temperature	285°C - 190°C
5. Geothermal fluid required	30 - 60 kg/kWh
6. Geothermal fluid residual	
a. Flashed steam system	21 - 45 kg/kWh
b. Binary flow system	30 - 60 kg/kWh
7. Steam condensate	
a. Flashed steam system	9 - 15 kg/kWh
b. Binary flow system	0 kg/kWh
8. Cooling water requirements	60 - 90 $\frac{\text{acre-ft}}{\text{MW-yr}}$
9. Hydrogen sulfide emissions to the atmosphere	
a. Flashed steam system	1.2 - 2.4 g/kWh
b. Binary flow system	0 g/kWh
10. Thermal efficiency	10 - 12%

^aD.L. Ermak, "A Scenario for Geothermal Electric Power Development in Imperial Valley," Energy, Vol. 3, 203, 1978.

Table 3-2. Measured or Calculated Unabated Discharge Rate of Several Chemicals to the Atmosphere at The Geysers Powerplant, as a Result of Producing 502 MWe of Power

Chemical	Discharge kg/day
H ₂ S ^a	21,700
CO ₂ ^a	313,000
NH ₃ ^a	18,500
CH ₄ ^a	18,500
H ₂ ^a	5,380
N ₂ ^a	5,060
As ^{a,b}	0.023
B ^{a,b}	48.6
Hg ^c	~0.12
H ₂ O ^a	8 x 10 ⁷
222 _{Rn} ^d	9 x 10 ^{-9e}

^aPG&E, "Environmental Data Statement," Geysers Unit 13, 1975.

^bBased on calculated cooling tower drift rates.

^cD.E. Robertson, Battelle, Pacific Northwest Laboratories, personal communication, 1978.

^dL.R. Anspaugh, Lawrence Livermore Laboratory, 1978.

^e9 x 10⁻⁹ kg = 1.4 Ci.

Table 3-3. Environmental, Health, and Safety Concerns and Requirements for Hydrothermal Energy Systems

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p>1. Release of Airborne Effluents</p> <p>Hydrothermal fluids typically contain a number of compounds such as CO₂, NH₃, H₂S, CH₄, Rn, Hg, and B. These and other chemicals such as salts in cooling tower drift may be released to the atmosphere; impacts may occur on local ecosystems and on human health. H₂S is of particular concern because of its disagreeable odor (above 5 ppb) and toxic effects (above 20 ppm).</p>	Characterization and Measurement	1.1. Identify and measure the levels of effluents that may be discharged during exploration, development, and utilization.	Current	Report for selected KGRAs to be developed.
	Monitoring	1.2. Establish baseline and monitoring networks for the most significant effluents, and develop new instrumentation as needed.	Current	Field Data Reports 1978 to 1981
	Physical and Chemical Effects	1.3. Develop models necessary to predict the transport, diffusion, and transformation of pollutants in complex terrain.	Current	Verified model 1981
	Health and Ecological Effects	1.4. Develop dose-response data for effects on native and agricultural ecosystems and on human health.	Current	Reports 1978 to 1981
	Environmental Evaluations	1.5. Assess the potential effects of effluent releases within a regional context for full-scale development, and develop environmental design criteria.	Current	Report for selected KGRAs to be developed.
	Control Technology	1.6. Develop control technologies as needed to meet regulatory standards and environmental design criteria.	Current	Proven control technologies. 1979 and continuing

Table 3-3. Environmental, Health, and Safety Concerns and Requirements for Hydrothermal Energy Systems (Continued)

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p><u>2. Release of Waterborne Effluents</u></p> <p>Large volumes of spent geothermal fluids and cooling tower blowdown will be generated. They may contain dissolved volatile compounds and large quantities of dissolved solids. The concern is for long-term disposal of such fluids so that beneficial sources of water are protected. Treatment may be required that results in solid waste generation.</p>	Characterization and Measurement	2.1. Identify and measure the levels of effluents that may be discharged during exploration, development, and utilization.	Current	Field Data Report for selected KGRAs to be developed.
	Monitoring	2.2. Establish baseline and monitoring networks for the most significant effluents, and develop new instrumentation as needed.	Current	Field Data Reports 1978 to 1981
	Health and Ecological Effects	2.3. Develop dose-response data for effects on aquatic ecosystems and human health.	Current	Reports 1979 to 1981
	Environmental Evaluations	2.4. Assess the potential effects of effluent releases within a regional context for full-scale development, and develop environmental design criteria.	Current	Report for selected KGRAs to be developed.
	Environmental Evaluations	2.5. Assess the consequences of accidental releases of effluents.	Current	Reports for selected KGRAs.
	Control Technology	2.6. Develop control technologies (surface and subsurface) as needed to meet regulatory standards and environmental design criteria.	Current	Report 1979. Proven control technologies 1979 and continuing.
<p><u>3. Noise</u></p> <p>Uncontrolled noise levels associated with exploration and drilling, well venting and testing, and operational processes can reach levels as high as 120 dBA at the site boundary and may have deleterious effects on human populations and local fauna.</p>	Environmental Evaluations and Control Technology	3.1. Develop noise abatement technologies as needed to meet noise ordinances and standards and environmental design criteria.	Current	Report 1979. Proven abatement technologies 1979 and continuing.

Table 3-3. Environmental, Health, and Safety Concerns and Requirements for Hydrothermal Energy Systems (Continued)

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p><u>4. Subsidence</u></p> <p>The removal of large quantities of hydrothermal fluid may result in subsidence. The importance of subsidence will be site-specific; at locations such as the Imperial Valley, where the geothermal reservoirs are overlain with agricultural land, subsidence could have a significant impact.</p>	Monitoring	4.1. Conduct preoperational and continuing measurements to establish rates of subsidence.	Current	Field Data Reports 1978 to 1981
	Physical Effects	4.2. Conduct subsidence research program.	Current	Reports 1978 to 1980
	Control Technology	4.3. Verify efficacy of subsidence control techniques as needed.	Planned	Field Data Report 1983
<p><u>5. Induced Seismicity</u></p> <p>The withdrawal and/or injection of hydrothermal fluids may enhance the frequency or magnitude of seismic events.</p>	Monitoring	5.1. Conduct preoperational and continuing measurements to establish if seismicity is induced.	Current	Field Data Reports 1978 to 1981
	Control Technology	5.2. Develop and verify seismic control practices.	Planned	Field Data Report 1983
<p><u>6. Water Use</u></p> <p>Many proposed methods of utilizing hydrothermal energy will require exogenous sources of water for cooling systems. As many hydrothermal resource areas are in semiarid regions, conflicts may arise concerning the most beneficial uses of water.</p>	Socioeconomic Effects	6.1. Assess potential limitations on hydrothermal resource development due to water resource limitations.	Current	Report for selected KGRAs

Table 3-3. Environmental, Health, and Safety Concerns and Requirements for Hydrothermal Energy Systems (Continued)

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p><u>7. Land Use</u></p> <p>Some hydrothermal developments may cause land use conflicts. They may threaten pristine wilderness areas; impact upon habitat of endangered, threatened, or recreationally important species; or conflict with other beneficial uses such as agriculture or recreation.</p>	Baseline Ecology	7.1. Identify flora and fauna baseline conditions in development areas.	Current	Field Data Report for selected KGRAs. 1978 to 1981
	Ecological Effects	7.2. Assess impacts on flora and fauna.	Current	Field Data Report for selected KGRAs. 1978 to 1981
	Control Technology	7.3. Develop mitigation strategies if appropriate.	Planned	Strategy for each KGRA.
	Socioeconomic Effects	7.4. Assist local authorities to develop land use plans.	Current	Land use plan for each region.
<p><u>8. Social Services and Community Structure</u></p> <p>All hydrothermal developments will have an impact through the demand for workers and the influx of money. This impact may be considered positive or negative depending upon the existing community structure and life-style, and may range from negligible to major depending upon the size of the development and the size and diversity of the local economy.</p>	Socioeconomic Effects	8.1. Conduct baseline surveys of demographic, social, economic, and political aspects of resource areas.	Current	Field Data Report for selected KGRAs. 1978 to 1981
	Socioeconomic Effects	8.2. Assess labor requirements and secondary employment implications of full-scale development.	Current	Report for selected KGRAs. 1978 to 1981
	Socioeconomic Effects	8.3. Predict local population shifts and assess housing requirements and increased community services needed to support a mature development.	Current	Report for selected KGRAs. 1978 to 1981
	Socioeconomic Effects	8.4. Determine the relationship between expected revenues and expenditures for communities affected by development.	Current	Report for selected KGRAs. 1978 to 1981
	Socioeconomic Effects	8.5. Develop strategies to mitigate adverse impacts and achieve maximum enhancement of beneficial impacts.	Current	Report for selected KGRAs. 1978 to 1981

Table 3-3. Environmental, Health, and Safety Concerns and Requirements for Hydrothermal Energy Systems (Continued)

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p><u>9. System Safety and Occupational Health</u></p> <p>The safety of hydrothermal energy extraction and utilization systems could become a major issue if early significant accidents occur. Problems relate to proper handling of the high-pressure fluids and secondary and tertiary fluids such as isobutane and propane that might be used in powerplants.</p>	Occupational and General Safety	<p>9.1. Perform a system safety analysis of proposed methods for extracting and utilizing hydrothermal resources.</p> <p>9.2. Develop safety design and occupational protection criteria to ensure safety of all aspects of facility construction and operation.</p>	<p>Current</p> <p>Current</p>	<p>Report 1980</p> <p>Criteria 1980 to 1981</p>

The release of CO_2 by hydrothermal powerplants is significant only in a global context, and it is extremely unlikely that hydrothermal powerplants will make a significant contribution to the total flux of CO_2 to the atmosphere.

The release of H_2S is a substantial problem at The Geysers and has resulted in adverse reactions from the downwind communities. The odor detection threshold of humans for H_2S is about 0.005 ppm (by volume), and the California standard for ambient air is 0.030 ppm. The California standard is sometimes exceeded, and regulatory agencies have required the operator to develop a pollution abatement program as a condition for the expansion of the power production facilities. Health effects from exposure to H_2S at these low levels have not been unequivocally demonstrated but have been claimed by residents in The Geysers area. Effects of H_2S on vegetation have been demonstrated at concentrations in air of several parts per million. The presently available evidence indicates that vegetation damage from this mechanism will not occur due to hydrothermal operations, but more research is needed to confirm this with additional vegetation species and to examine the synergistic action of H_2S with other pollutants such as O_3 . In the atmosphere, H_2S is slowly oxidized to SO_2 and SO_4^{2-} . The formation of sulfate and other sulfur-containing particulates is therefore certain. However, the slow conversion rate of H_2S to other sulfur compounds indicates that this will probably not present an actual problem because considerable dispersion will have occurred while conversion is taking place. In actuality, it is very unlikely that any new, commercial-scale hydrothermal powerplant will be built in the United States without either H_2S abatement mechanisms or demonstrable proof that they are unnecessary due to the nature of the reservoir.

Present power units at The Geysers use direct-contact condensers. Because H_2S is soluble in water, about 70 percent of the H_2S is carried to the cooling tower with the condensate. Present environmental control technology consists of ducting the ejector off-gas to the cooling tower and adding an iron catalyst to the cooling water to oxidize H_2S to elemental sulfur. This method is not highly successful because of limited abatement, increased maintenance costs, and the need to dispose of large volumes of cooling tower sludge that contains unusable sulfur. New power units at The Geysers will have indirect contact condensers that will result in about 90 percent of the H_2S going to the off-gas ejector stream. This H_2S will then be oxidized to commercial quality sulfur by the Stretford process. The first unit of this design should be online in FY 1979 and may achieve 90-percent abatement while the units are in operation. However, this system cannot be retrofitted economically to the older units and will not have any effect when it is necessary to vent steam directly to the atmosphere. The required solution is an upstream scrubber that can remove H_2S from steam before it reaches the turbine. Such a scrubber is under development by DOE and others and will undergo 1/20-scale tests in FY 1979.

Substantial amounts of NH_3 are also released at The Geysers. Measurements indicate that emission rates of NH_3 are lower at other hydrothermal sites. The significance of ammonia release appears to be minor.

Ammonia is frequently used as a plant fertilizer and is probably nontoxic to vegetation and mammals at expected concentrations. Dissolved ammonia is toxic to aquatic life, but airborne releases of ammonia should not be significant. There may be complex interactions of ammonia, sulfur compounds, and particulates that produce potentially harmful pollutants. This possibility deserves further analysis, but it is not presently considered to be an important issue.

Although not presumed to be a reaction to H_2S , vegetation stress has occurred at The Geysers in the immediate area of the power-generating units. Presently available evidence indicates that this stress may be due to boron. This is a minor problem at The Geysers but could be of more importance at other reservoirs or with other adjacent land uses. More data are needed on the presence of boron in hydrothermal fluids.

Mercury emission rates have recently been reported for The Geysers and Cerro Prieto, Mexico. The airborne release rates are small, 90 micrograms per kilowatt-hour (g/kWh) and 30 to 70 g/kWh at three measured units at The Geysers. These releases appear to be inconsequential. Ambient air at The Geysers has the same concentration of mercury as was measured at background locations, although ambient air at Cerro Prieto was above background levels. Additional measurements at other sites are needed to resolve this issue for local conditions.

The release of radon-222 and other radionuclides has also recently been measured at The Geysers. The average emission rate of radon-222 is 130 nanocuries/kWh. Concentrations in ambient air of the short-lived radon-daughters at The Geysers are within the range of concentrations measured at background locations. Levels of other naturally occurring radionuclides in The Geysers area were also within normal background levels. Measurements of radon in fluids at other sites also indicate that the release of radionuclides at hydrothermal sites will not be an important issue. However, confirmatory measurements of emission rates and ambient concentrations in the vicinity of new uses, particularly nonelectric applications, will be necessary.

More detailed source-term measurements at sites of hydrothermal use are needed to determine the levels of some toxic trace constituents which may be released. In particular, information on compounds such as hydrogen fluoride, mercaptans, and volatile hydrides is needed. These compounds very likely exist in hydrothermal fluids, but very few measurements are now available.

Airborne effluents in the form of cooling system drift are also expected at all hydrothermal powerplants. The magnitude of this potential problem is very dependent upon technological options. In the Imperial Valley, for example, commercial powerplants will very likely be forced to maintain fairly high salinity levels in their cooling systems because high quality water is not expected to be available. If steam condensate is used as cooling water makeup, then the concentration of many ionic species in the cooling

system will be altered. Expected emissions will be in the form of particles composed of common salts and many trace contaminants including boron and cooling system additives. Cooling system drift may therefore stress surrounding vegetation. Studies and assessments of this problem are planned.

By far the largest of the airborne emissions from geothermal powerplants will be water vapor. Because the thermodynamic efficiency of such powerplants is low, the release rate per unit energy produced is higher than for other conventional power plants. In some locations, this water vapor release may result in local fogging and icing conditions.

2. Release of Waterborne Effluents

The management of spent hydrothermal fluids is one of the most important issues confronting development at many locations, although some hydrothermal fluids are so pure they have been used for irrigation and other beneficial uses. Some fluids in Imperial Valley, however, are very saline, and discharges to surface waters would not be desirable or permitted. The anticipated disposal scheme is to inject the spent fluids back into the geothermal reservoir. Injection of excess steam condensate has been carried out successfully for several years at The Geysers. Prior to injection, the excess condensate had been released into surface waters, but this was found to be detrimental to aquatic life, probably due to the dissolved ammonia.

Long-term injection tests are currently being conducted in the Imperial Valley with spent fluids of greater salinity. These tests appear to be successful although there are still serious concerns of scaling and well-bore plugging due to precipitation of silica. Preliminary results from high-temperature (above 145°C) injection of geothermal fluids have been encouraging. It may be realistic, therefore, to assume that hydrothermal powerplants utilizing many liquid-dominated reservoirs can be operated over long periods with no intentional release of spent hydrothermal fluids to surface waters or into underground aquifers of beneficial use. Research studies and long-term monitoring at selected sites are necessary, however, to ensure that unintentional contaminations do not occur. The accidental release of geothermal fluids could, in some areas, have a serious impact on aquatic and terrestrial ecosystems.

Some of the very saline fluids, constituting less than 5 percent of the U.S. hydrothermal resources, such as those in the Salton Sea known geothermal resource area (KGRA), cannot be injected directly back into the reservoir due to scaling, precipitation, and plugging problems and very high attendant maintenance costs. Treatment of the spent fluids will therefore be required prior to injection, leading to a need to dispose of large volumes of sludge in waste disposal sites and accompanying concerns of adequate disposal site selection and maintenance to avoid contamination of surface water and groundwater.

There are also problems with waterborne effluents during the well-drilling process. These problems are not unique to geothermal energy, but

contaminating events have occurred on several occasions at geothermal sites. These releases are of an accidental nature and are already covered by regulations. It is hoped that improved procedures will eliminate or greatly reduce such releases in the future.

Another potentially major issue involving waterborne effluents concerns heat rejection systems. There are many options for the design of such systems, but the options may be severely limited by available water quantity and quality and by cost. Most practical cooling systems will probably require the discharge of cooling water blowdown. This water will be brackish and may contain additives or geothermal fluid carryover if steam condensate is used as makeup water. For hydrothermal systems, it may be possible to inject this blowdown with the spent hydrothermal fluids, but there are serious questions whether the two fluids can be mixed without worsening the scaling problem in some liquid-dominated systems. The cooling system design of any proposed hydrothermal use must be evaluated carefully for possible effects on aquatic ecosystems, both by the dissolved solids and by the thermal discharge.

3. Noise

Noise has been a significant problem at The Geysers, with resulting complaints from nearby residents. Major noise-producing events are the venting during well completion and the discharge of mainline steam to the atmosphere when power-producing units are shut down. (This venting has been allowed to continue if the power unit is down for only a short period. The reopening of shut-in wells can dislodge damaging debris.) This problem has been reduced by the use of better mufflers and the installation of cross-ties between steamlines so that it is not necessary to release as much steam to the atmosphere when power units are shut down. Studies of the impact of noise on wildlife at The Geysers have been completed; results indicate that there is no discernible impact. There is a need, however, for portable mufflers to reduce noise levels when wells must be vented. A state-of-the-art study of this problem is planned.

The noise issue is expected to be much less important at liquid-dominated hydrothermal sites. Steam pressures are lower, and noise levels associated with well tests are much lower than at The Geysers. Measurement programs will be necessary, however, and mitigation measures will be employed if necessary.

4. Subsidence

The removal of large quantities of fluid from a geologic formation may result in subsidence, or sinking of the land. Such subsidence has been common following the withdrawal of water and oil. It has also been observed at the Wairakei, New Zealand, hydrothermal powerplant where a maximum rate of subsidence of about 1.3 feet/year has been measured. However, the injection of spent geothermal fluids back into the formation is not done at Wairakei; the spent fluids are discharged into surface waters.

It is hoped that the injection of spent hydrothermal fluids back into the reservoir will not only solve the liquid waste problem but will also eliminate or mitigate the subsidence problem. However, this is not known with certainty; localized sinking around withdrawal wells and uplifting around injection wells may occur.

A better understanding of geothermal reservoirs and the factors that control subsidence may eventually lead to the development of management strategies that can completely control subsidence. This is an area of active research and, in 1977, DOE established a subsidence research project at Lawrence Berkeley Laboratory. It is necessary to assess the problem by acquiring precise leveling data to measure actual rates of subsidence at geothermal facilities. Baseline data are also important because many geothermal sites can be expected to be undergoing tectonic subsidence. A naturally occurring subsidence of 13 centimeters was observed in the northern end of Imperial Valley during a recent 2-year period.

The importance of subsidence will be site specific. It may be of significant importance at locations such as the Imperial Valley where the geothermal reservoirs are overlain by agricultural systems using gravity-flow irrigation and drainage systems. Subsidence in naturally hilly locations may cause only minor or insignificant problems.

5. Induced Seismicity

Many hydrothermal reservoirs are located in regions with a high frequency of naturally occurring seismic events. A significant issue is whether the withdrawal and injection of geothermal fluids may enhance the rate of microseismic events, or even trigger a major earth movement. Although one study implicates the process of reservoir cooling, the most likely cause of induced seismicity is believed to be the injection process. Studies in Colorado have demonstrated that the frequency of microseismic events is increased as a result of the high-pressure injection of fluids.

It is not known what pressures will be required to maintain the injection of spent hydrothermal fluids over long periods of time at liquid-dominated sites, but field trials indicate that the pressures may be well below those demonstrated to cause induced microseismicity. The possible lubrication of a major fault and the resultant triggering of a major earthquake is another unresolved issue; careful site selection to avoid major faults should alleviate this concern.

Because these potential effects are unresolved, detailed microseismic studies must be conducted at geothermal sites. Baseline data on the frequency of seismic events and the depth at which they occur will provide valuable information in distinguishing between naturally occurring and induced events. In the Imperial Valley, for example, the depth of occurrence of nearly all naturally occurring seismic events is far below the depth of the

hydrothermal reservoirs. Any sudden shift in the depth of earthquake foci to the depth of the reservoir would be strong evidence that geothermal production had, in fact, induced seismicity.

In 1979, DOE established a new program to study induced seismicity. The program, which will be managed by the Nevada Operations Office, seeks ultimately to recommend guidelines for assessing the risk of inducing seismic events during geothermal development and production. The program will utilize existing and new data to evaluate the usefulness of prediction models.

6. Water Use

Nearly all proposed methods of utilizing hydrothermal reservoirs for the production of electricity will require exogenous sources of water for heat rejection systems. As most reservoirs are in the semiarid regions of the West, conflicts over the allocation of limited water resources are expected. Such a conflict has already arisen in the Imperial Valley where the agricultural community is limited by the availability of water imported from the Colorado River. Research is in progress to assess this problem fully and to suggest measures to resolve this conflict through a series of tradeoffs. Similar studies in other KGRAs are needed.

7. Land Use

Any human activity, including the exploration for and the development of geothermal reservoirs, can put pressure upon native flora and fauna. Because geothermal energy is extracted as heat, it cannot be transported over long distances but must be utilized close to the location where it is found. This may result in conflicts over land use. Such issues will be extremely site specific. The most significant issues are expected to arise when geothermal reservoirs are located on or adjacent to areas designated or nominated as critical habitat areas under the Endangered Species Act. Such issues may be expected not only at sites of exploration and energy extraction, but for powerline corridors as well.

It is therefore essential that information concerning the presence of endangered and threatened species be obtained prior to development. Because geothermal powerplants will probably be built in small incremental units and because limited flexibility in siting is possible, most major problems should be avoided by careful planning. There may, in fact, be excellent opportunities to enhance wildlife habitat in the vicinity of geothermal developments if potential problems and opportunities are recognized early. Studies aimed at resolving such issues are currently underway in several KGRAs, and they will be needed as development expands into new areas.

Land use conflicts have also occurred in The Geysers region where development is encroaching upon residential areas. This problem, in theory at least, could be resolved by comprehensive land use planning in advance of development, and Federal aid in this process might be appropriate. In

practice, however, this is a very difficult issue because land use management can result in major economic impacts on individuals and corporations, and local agencies have historically shown strong antagonism to State and Federal "assistance" in land use planning.

8. Social Services and Community Structure

Hydrothermal resources are located in a variety of areas with greatly differing socioeconomic resources. Many social, economic, cultural, and political issues may arise as geothermal energy uses are planned; these will be highly site specific. The Geysers powerplant has been opposed by some segments of the population in nearby communities because it threatens to alter a rural, retirement, and recreationally oriented lifestyle. The Imperial Valley resources are located within a highly developed agricultural system; however, a recent public opinion survey indicates that geothermal energy development is highly favored by more than 90 percent of the populace. Competition for land and water resources may ultimately develop between agriculture and geothermal energy unless the development is carefully planned to avoid such conflicts.

The development of geothermal resources will provide many positive impacts in the social and economic areas. Tax bases will be broadened and the economic base in affected communities will also be diversified. Early planning with affected communities could be effective in developing appropriate manpower resources so that positive steps can be taken to reduce local unemployment.

Geothermal projects will probably occur as phased development with exploration leading to the construction of power generating units, or non-electric uses, in modest size increments. (Typical power generating units have been added at The Geysers in increments of about 100 MWe.) These phased developments should not result, therefore, in the overwhelming of existing social services that has occurred where very large coal-fired powerplants have been built.

Cultural and religious conflicts may also arise. Some hot springs have been or are being used as part of a cultural tradition, and development may be opposed because it threatens such use. Development in Hawaii faces a unique problem because volcanoes (and geothermal energy) are considered by native Hawaiians to be physical manifestations of the Goddess Pele.

Because social, economic, cultural, and political issues may be significant in determining the acceptability of geothermal resource development, these potential issues must be identified and addressed. Development scenarios must be formulated and potential impacts identified. Effective mitigation of these issues will require working with or providing assistance to local communities so that the need for increased social services can be identified and planned, and the appropriate cultural and political issues can be identified and resolved in advance of development.

9. System Safety and Occupational Health

The health and safety issues that affect the operation of hydrothermal energy facilities include the need for measures to ensure that the operation of such facilities adequately provides for the medical and health surveillance and safety of the workers at the facility.

The safety of geothermal energy extraction and utilization systems could become a major issue if early significant failures should occur. Well blowouts have occurred at several geothermal powerplants including The Geysers, California, and Cerro Prieto, Mexico. These events apparently have not caused major damage due to the isolated locations of the powerplants; however, such events could be serious.

Many proposed geothermal plant designs include secondary or tertiary loops with working fluids such as isobutane and propane. Containment of such fluids is important as they represent potentially explosive mixtures. In addition, many geothermal fluids are corrosive and erosive to standard materials. Because of such potential problems, there is a need for a detailed examination of the overall safety of geothermal energy systems. This review is in progress with a final report expected in FY 1979. This should be followed by the adoption of safety design and occupational health protection criteria.

D. GEOPRESSURED SYSTEMS: CONCERNS, REQUIREMENTS, AND STATUS

Table 3-4 lists the concerns and requirements for geopressured systems. The most significant are expected to be the disposal of spent geopressured fluids and land subsidence.

1. Release of Airborne Effluents

Fluids in geopressured reservoirs contain large amounts of dissolved (and perhaps free) methane. This may, in fact, prove to be the most valuable part of the resource; it certainly will be recovered and used beneficially. In a recent geopressured well test, the dissolved gas contained, in addition to methane, about 1 percent CO_2 and trace amounts of H_2S , Hg , NH_3 , and Rn . Except for NH_3 , however, the concentrations found were quite low compared to noncondensable gases from hydrothermal systems. Results from other geopressured wells will be necessary before this potential problem can be assessed fully, but present results indicate that gas from geopressured wells can probably be added to other natural gas sources with no unusual treatment. Experience with some natural gas wells suggests that H_2S levels could be significantly higher in some areas and could constitute a problem. Large-scale development of the geopressured resource will result in the usual need for heat sinks and the accompanying problems of cooling tower drift, etc.

**Table 3-4. Environmental, Health, and Safety Concerns and Requirements
for Geopressed Energy Systems**

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p><u>1. Release of Airborne Effluents</u></p> <p>Fluids recovered from geopressed reservoirs are expected to contain substantial amounts of dissolved methane. This will undoubtedly be recovered. Whether substantial amounts of other volatile compounds might be released is an unknown. Any powerplants would undoubtedly have typical emissions of cooling tower drift.</p>	Characterization and Measurement	1.1. Identify and measure the levels of effluents that may be discharged during exploration, development, and utilization.	Current	Field Data Reports for several wells: 1978 to 1980
	Monitoring	1.2. Establish baseline and monitoring networks for the most significant effluents, and develop new instrumentation as needed.	Current	Field Data Reports 1978 to 1981
	Physical and Chemical Effects	1.3. Develop models necessary to predict the transport, diffusion, and transformation of pollutants in complex terrain.	Current for Hydrothermal Systems	Verified model by 1981.
	Health and Ecological Effects	1.4. Develop dose-response data for effects on native and agricultural ecosystems and on human health.	Current	Report: 1980
	Environmental Evaluations	1.5. Assess the potential effects of effluent releases within a regional context for full-scale development, and develop environmental design criteria.	Planned	Report 1980
	Control Technology	1.6. Develop control technologies as needed to meet regulatory standards and environmental design criteria.	Current	Report 1979. Proven control technologies 1979 and continuing.

Table 3-4. Environmental, Health, and Safety Concerns and Requirements for Geopressured Energy Systems (Continued)

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p>2. <u>Release of Waterborne Effluents</u></p> <p>Large volumes of geopressured fluids will be produced. It may not be economically feasible to inject these back into the reservoir, and other acceptable disposal means must be found. The fluids may contain substantial amounts of dissolved solids.</p>	Characterization and Measurement	2.1. Identify and measure the levels of effluents that may be discharged during exploration, development, and utilization.	Current	Field Data Reports for several wells. 1978 to 1980
	Monitoring	2.2. Establish baseline and monitoring networks for the most significant effluents, and develop new instrumentation as needed.	Current	Field Data Reports 1980 to 1981
	Health and Ecological Effects	2.3. Develop dose-response data for effects on aquatic ecosystems and human health.	Current	Report 1980
	Environmental Evaluations	2.4. Assess the potential effects of effluent releases within a regional context for full-scale development, and develop environmental design criteria.	Current	Report 1980
	Environmental Evaluations	2.5. Assess the consequences of accidental releases of effluents.	Current	Report 1980
	Control Technology	2.6. Develop control technologies (surface and subsurface) as needed to meet regulatory standards and environmental design criteria.	Current	State-of-the-Art Report 1979. Proven control technologies 1979 and continuing.
<p>3. <u>Noise</u></p> <p>Uncontrolled noise associated with exploration, drilling, well venting and testing, and operational processes may reach high levels and may have deleterious effects on human populations and local fauna.</p>	Environmental Evaluations and Control Technology	3.1. Develop noise abatement technologies as needed to meet noise ordinances and standards and environmental design criteria.	Current	State-of-the-Art Report 1979. Proven abatement technologies 1979 and continuing.

Table 3-4. Environmental, Health, and Safety Concerns and Requirements for Geopressed Energy Systems (Continued)

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
3. <u>Noise</u> (cont'd)	Characterization and Measurement	3.2. Measure noise levels associated with the drilling, completion, and testing of geopressed wells.	Current	Field Data Report 1979
4. <u>Subsidence</u> The removal of large volumes of geopressed fluid may result in subsidence. The effects may be severe on the gulf coast where lands overlying the reservoirs are only a few feet above sea level.	Monitoring	4.1. Conduct preoperational and continuing measurements to establish rates of subsidence.	Current	Field Data Reports 1978 to 1981
	Physical Effects	4.2. Conduct subsidence research program.	Current	Field Data Reports 1978 to 1980
	Control Technology	4.3. Verify efficacy of subsidence control techniques as needed.	Planned	Field Data Report 1983
5. <u>Induced Seismicity</u> The withdrawal and possible injection of geopressed fluids may produce seismic events.	Monitoring	5.1. Conduct preoperational and continuing measurements to establish if the testing of geopressed wells produces seismic events.	Current	Field Data Reports 1978 to 1981
6. <u>Water Use</u> The development of geopressed reservoirs will result in the consumption of water for heat-rejection systems.	Socioeconomic Effects	6.1. Assess potential limitations on geopressed resource development due to water resource limitations.	Planned	Field Data Report for each region 1980

Table 3-4. Environmental, Health, and Safety Concerns and Requirements for Geopressed Energy Systems (Continued)

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p>7. <u>Land Use</u></p> <p>Large-scale development of geopressed resources may result in land use conflicts. It may threaten estuarine areas; impact upon habitat of endangered, threatened, or recreationally and economically important species; or conflict with other beneficial uses.</p>	Baseline Ecology	7.1. Identify flora and fauna baseline conditions in development areas.	Current	Field Data Report for selected areas. 1978 to 1980
	Ecological Effects	7.2. Assess impacts on flora and fauna.	Current	Field Data Report for selected areas. 1979 to 1981
	Control Technology	7.3. Develop mitigation strategies if appropriate.	Planned	Strategy 1981
	Socioeconomic Effects	7.4. Assist local authorities to develop land use plans.	Planned	Criteria 1982
<p>8. <u>Social Services and Community Structure</u></p> <p>Any significant development of geopressed resources will have an impact through the demand for workers and the influx of money. This impact may be considered positive or negative depending upon the existing community structure and lifestyle, and may range from negligible to major depending upon the size of the development and the size and diversity of the local economy.</p>	Socioeconomic Effects	8.1. Conduct baseline surveys of demographic, social, economic, and political aspects of resource areas.	Current	Field Data Report 1979
	Socioeconomic Effects	8.2. Assess labor requirements and secondary employment implications of full-scale development.	Planned	Report 1981
	Socioeconomic Effects	8.3. Predict local population shifts and assess housing requirements and increased community services needed to support a mature development.	Planned	Report for selected resource areas. 1980 to 1983
	Socioeconomic Effects	8.4. Determine the relationship between expected revenues and expenditures for communities affected by development.	Planned	Report for selected resource areas. 1980 to 1983
	Socioeconomic Effects	8.5. Develop strategies to mitigate adverse impacts and achieve maximum enhancement of beneficial impacts.	Planned	Report for selected resource areas. 1980 to 1983

Table 3-4. Environmental, Health, and Safety Concerns and Requirements for Geopressured Energy Systems (Continued)

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
8. <u>Social Services and Community Structure</u> (cont'd)	Socioeconomic Effects	8.6. Identify institutional barriers to development and remove them where possible by working with local, State, and Federal governments.	Current	Continuing liaison
9. <u>System Safety and Occupational Health</u> The safety of geopressured energy extraction and utilization systems could become a major issue if early significant accidents occur. Problems relate to proper handling of the high-pressure fluids and secondary and tertiary fluids such as isobutane and propane that might be used in powerplants.	Occupational and General Safety	9.1. Perform a system safety analysis of proposed methods for extracting and utilizing geopressured resources. 9.2. Develop safety design and occupation-protection criteria to ensure safety of all aspects of facility construction and operation.	Planned Planned	Field Data Report 1980 Criteria 1980 to 1981

2. Release of Waterborne Effluents

Disposal of spent geopressured fluids will be one of the most significant environmental problems. Available analyses indicate that the fluid will have a total dissolved solids content of 1,000 to 10,000 ppm, and boron concentrations of 20 to 60 ppm. Other than possible feedstock for mineral recovery, the fluids will not be suitable for beneficial uses. Because of the great depths and pressures, it may not be economically feasible to inject the fluids back into the geopressured reservoir. Possible means of disposal are to discharge into existing saline bodies of water or to inject into subsurface saline aquifers. Both methods appear to be feasible, but carry environmental risks that must be evaluated carefully.

Disposal to surface bodies of waters, such as the Gulf of Mexico, must be done without endangering the wetlands ecosystem, which is important to the region's economy. Subsurface disposal is currently being used with oil-field brines, but a fully developed geopressured industry would generate a substantially larger volume of brines. Long-term questions of reservoir acceptance without the contamination of aquifers of beneficial use must be answered, and monitoring networks will be essential.

As with some hydrothermal fluids, long-term injection may not be possible without the treatment of the brines to remove solids that would plug the wellbore or reservoir. If treatment is necessary, this may produce large volumes of solid waste that will require disposal. Tests scheduled over the next several years should define the extent of this possible problem. The discharge of cooling tower blowdown will probably also be required.

3. Noise

Because of the pressures involved, production facilities will be inherently noisy. However, noise levels should be substantially less than those associated with a freely venting well at The Geysers. Actual noise measurements will be required, and research on abatement systems may be needed.

4. Subsidence

The withdrawal of large volumes of fluid from geopressured reservoirs will result in compaction of the reservoir at depth. This compaction may be translated to the surface and result in land subsidence, but this is not known with certainty. If subsidence should occur, the results along the gulf coast are potentially very serious. This is because a large amount of land is presently only a few feet above sea level. Significant subsidence could result not only in the direct inundation of land but could also make large areas susceptible to flooding due to hurricane activity or freshwater flooding.

Regional and site-specific leveling networks are essential to measure this potential effect, and resurveying should be performed periodically. A better understanding of the process of subsidence, and the factors that control it, is essential.

5. Induced Seismicity

The induction of seismic events by the production of geopressured reservoirs is not considered likely, but cannot be ruled out. The gulf coast area is generally aseismic, and there appears to be a slow and continuous release of stress along the many growth faults in the region. The reduction of pore pressure in geopressured reservoirs could conceivably alter this process and cause stresses to accumulate. Seismic activity and fault movement should therefore be monitored closely during development.

6. Water Use

Large-scale development of the geopressured resource could result in competitive demands for the better quality water supplies. The required heat rejection systems are projected to be net consumers of water even if the condensate water is used for cooling water makeup. Careful advance planning should be able to resolve this problem, although in some areas it may be necessary to use saline water for cooling.

7. Land Use

A potentially serious issue concerns development in coastal wetlands. This wetlands area is sensitive to disruptions from human activities and is unusually valuable in terms of commercial productivity, recreation, and cultural and scientific interest. Coastal Zone Management Plans may be enacted that could have significant impacts on how the geopressured resource can be developed in these areas. A more thorough understanding of the biology and hydrology of the wetlands area will be required so that appropriate mitigation measures may be taken. More data on the presence of threatened and endangered species in these areas will also be required.

8. Social Services and Community Structure

A mature geopressured industry could have a significant impact upon regional economics and community structure. However, the gulf coast area has generally experienced large-scale industrial development and can probably accommodate the phased type of development that would occur. Some exceptions may arise where community assistance would be appropriate.

Major political and legal problems will arise if subsidence should actually occur or if there is significant disruption of wetlands ecosystems. The development of appropriate regulations in advance of large-scale activities would help mitigate public concern.

9. System Safety and Occupational Health

Well blowouts and accidental spills of produced fluids could have substantial impacts. Due to the pressures involved, well blowouts may be very difficult to control. A thorough assessment of the safety of any proposed geopressured fluid utilization facility must be carried out.

E. HOT DRY ROCK SYSTEMS: CONCERNS, REQUIREMENTS, AND STATUS

Concerns and requirements for hot dry rock systems are presented in Table 3-5. These concerns are somewhat speculative due to the very limited experience even with experimental systems. The most significant concerns may be the induction of seismic events and water use conflicts.

1. Release of Airborne Effluents

The extraction of energy from hot dry rock systems will depend upon the use of an exogenous fluid. Current experiments at Fenton Hill, New Mexico, are using water which is being circulated through a fractured section of rock via two wells. In theory, a closed circulation loop is possible, but it is necessary to vent the fluid when circulation is restarted. In addition, because the water does dissolve some of the rock, it may be necessary to discharge blowdown from the circulation system to control the buildup of dissolved solids. These processes will also result in the discharge of dissolved gases that may be present in the fluid. Measurements at Fenton Hill indicate that CO_2 , H_2S , traces of NH_3 , and additional unidentified gases are present. The levels of H_2S and NH_3 found do not suggest that these releases will be a significant environmental problem, but more data are needed as extraction experiments in other areas progress.

As with any energy technology, cooling tower drift effects represent a potential impact that must be assessed if wet cooling towers are to be used. Initial experiments involve discharging the heat directly to the atmosphere.

2. Release of Waterborne Effluents

As discussed above, the circulating fluid will dissolve or leach material from the fractured rock. The experiments at Fenton Hill indicate that silica may build up in the fluid to such an extent that treatment may be required to remove the silica to eliminate fouling of the heat extraction system. One method might be to discharge blowdown from the system if makeup water is available. Another method might be to remove the silica; this would result in a solid or slurry waste disposal problem. Other chemicals such as fluorides and mercury might also be present in this waste.

3. Noise

Heat extraction processes are not anticipated to be unusually noisy. However, noise levels associated with drilling and general activity may be objectionable in some locations.

4. Subsidence

Fractured volumes will not be very large (several hundred meters thick) and will be created at great depth (about 3500 meters). Overlying competent rock is expected to provide sufficient support so that subsidence should

Table 3-5. Environmental, Health, and Safety Concerns and Requirements for Hot Dry Rock Energy Systems

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p>1. <u>Release of Airborne Effluents</u></p> <p>Exogenous fluids will be used to extract energy from hot dry rock strata. These fluids may leach volatile compounds from these strata or cause chemical reactions that will result in the presence of dissolved gases. It may be necessary to release these gases to the atmosphere; cooling tower drift would perhaps also be a problem.</p>	Characterization and Measurement	1.1. Identify and measure the levels of effluents that may be discharged during exploration, development, and utilization.	Current	Field Data Report for each experiment. 1978 to 1985
	Monitoring	1.2. Establish baseline and monitoring networks for the most significant effluents, and develop new instrumentation as needed.	Planned	Field Data Reports 1980 to 1985
	Physical and Chemical Effects	1.3. Develop models necessary to predict the transport, diffusion, and transformation of pollutants in complex terrain.	Current for Hydrothermal Systems	Verified model by 1981.
	Health and Ecological Effects	1.4. Develop dose-response data for effects on native and agricultural ecosystems and on human health.	Current	Report 1981
	Environmental Evaluations	1.5. Assess the potential effects of effluent releases within a regional context for full-scale development, and develop environmental design criteria.	Planned	Report 1985
	Control Technology	1.6. Develop control technologies as needed to meet regulatory standards and environmental design criteria.	Planned	Proven control technologies Post-1985

**Table 3-5. Environmental, Health, and Safety Concerns and Requirements
for Hot Dry Rock Energy Systems (Continued)**

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p>2. Release of Waterborne Effluents</p> <p>The working fluid in a hot dry rock system will probably be contained in a closed loop. However, dissolved minerals may build up to such an extent that the release of "blowdown" may be required. This and also cooling system blowdown must be disposed in an environmentally acceptable manner.</p>	Characterization and Measurement	2.1. Identify and measure the levels of effluents that may be discharged during exploration, development, and utilization.	Current	Field Data Report for each experiment. 1978 to 1985
	Monitoring	2.2. Establish baseline and monitoring networks for the most significant effluents, and develop new instrumentation as needed.	Current	Field Data Reports 1979 to 1985
	Health and Ecological Effects	2.3. Develop dose-response data for effects on aquatic ecosystems and human health.	Current	Reports 1981, 1985
	Environmental Evaluations	2.4. Assess the potential effects of effluent releases within a regional context for full-scale development, and develop environmental design criteria.	Planned	Report 1985
	Environmental Evaluations	2.5. Assess the consequences of accidental releases of effluents.	Current	Reports 1981, 1985
	Control Technology	2.6. Develop control technologies (surface and subsurface) as needed to meet regulatory standards and environmental design criteria.	Planned	Report 1985
<p>3. Noise</p> <p>Uncontrolled noise associated with exploration and drilling operations may reach high levels with deleterious effects on local fauna and human populations.</p>	Environmental Evaluation and Control Technology	3.1. Define the state-of-the-art of noise abatement systems in terms of effectiveness, cost, reliability, and inadequacies.	Planned (Part of hydrothermal)	Field Data Report 1979

Table 3-5. Environmental, Health, and Safety Concerns and Requirements
for Hot Dry Rock Energy Systems (Continued)

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
4. <u>Subsidence</u> Subsidence is not expected with hot dry rock systems, but confirmation is needed.	Monitoring	4.1. Conduct preoperational and continuing measurements to establish the lack of subsidence.	Planned	Field Data Reports 1981, 1985
5. <u>Induced Seismicity</u> Injection of exogenous fluids into hot dry rock strata is proposed as the technique for extracting the energy contained in these rocks. Studies in Colorado have demonstrated that increased seismic activity may be associated with fluid injection. In addition, spontaneous fracturing of the rock may occur as it cools. Such "microseismic" events are probably insignificant, but confirmatory data are needed.	Monitoring	5.1. Conduct preoperational and monitoring measurements to establish if seismicity is induced.	Current	Field Data Reports 1978 to 1985
6. <u>Water Use</u> Exogenous water will be required as a working fluid and/or a heat-exchange fluid. Many of the hot dry rock resource areas are in semi-arid regions, so conflicts over competing uses of water are possible.	Socioeconomic Effects	6.1. Assess potential limitations on hot dry rock resource development due to water resource limitations.	Planned	Field Data Reports 1981, 1985

Table 3-5. Environmental, Health, and Safety Concerns and Requirements for Hot Dry Rock Energy Systems (Continued)

EH&S Concern	EH&S Research Area	EH&S Requirements	Status of Requirements	Requirement End Item and Time
<p><u>7. Land Use</u></p> <p>Development plans may be opposed because of land use conflicts. They may threaten pristine wilderness areas; impact upon habitat of endangered, threatened, or recreationally important species; or conflict with other beneficial uses.</p>	<p>Baseline Ecology</p> <p>Ecological Effects</p> <p>Control Technology</p> <p>Socioeconomic Effects</p>	<p>7.1. Identify flora and fauna baseline conditions in development areas.</p> <p>7.2. Assess impacts on flora and fauna.</p> <p>7.3. Develop mitigation strategies if appropriate.</p> <p>7.4. Assist local authorities to develop land use plans.</p>	<p>Planned</p> <p>Planned</p> <p>Planned</p> <p>Planned</p>	<p>Field Data Report for each site. 1980 to 1982</p> <p>Field Data Report for each site. 1980 to 1982</p> <p>Strategy for each site. 1980 to 1982</p> <p>Criteria 1981</p>
<p><u>8. Social Services and Community Structure</u></p> <p>Significant development of the hot dry rock resource will have an impact through the demand for workers and the influx of money. This impact may be positive or negative depending upon the existing community structure and lifestyle, and may range from negligible to major depending upon the size of the development and the size and diversity of the local economy.</p>	<p>Socioeconomic Effects</p>	<p>8.1. Conduct preliminary assessments of potential impacts on social services and community structure.</p>	<p>Planned</p>	<p>Reports 1981, 1985</p>
<p><u>9. System Safety and Occupational Health</u></p> <p>The safety of hot dry rock energy extraction and utilization systems could become a major issue if early significant accidents occur. Secondary loops may contain isobutane or other explosive fluids which are a potential onsite hazard.</p>	<p>Occupational and General Safety</p> <p>Occupational and General Safety</p>	<p>9.1. Perform a system safety analysis of proposed methods for extracting and utilizing geopressured resources.</p> <p>9.2. Develop safety design and occupation-protection criteria to ensure safety of all aspects of facility construction and operation.</p>	<p>Planned</p> <p>Planned</p>	<p>Report 1981</p> <p>Criteria 1982</p>

not occur. However, significant experiments should include minimum subsidence detection networks to confirm this.

5. Induced Seismicity

Massive fluid injection and withdrawal with the accompanying cooling of rock may lead to increased levels of seismic activity. Measurements during the initial experiments at Fenton Hill have not detected any increase in seismic activity; however, measurements should be continued as the experiments increase in scope.

6. Water Use

Although other working fluids have received some consideration, water will probably be the fluid of choice. An initial volume of water will be required to establish circulation, and makeup water will be needed to compensate for fluid loss in the system. Additional water may be required if blowdown from the system is discharged or if wet cooling systems are used as heat rejection systems. Detailed assessments of water needs and of possible conflicts over water use will be required.

7. Land Use

Conflicts may arise over land use if proposed experiments or developments impinge on wilderness areas; impact upon habitats of endangered, threatened, or recreationally important species; or conflict with other beneficial uses. As significant development will not occur for several years, this problem should be avoidable by care in the site selection process for experimental sites.

8. Social Services and Community Structure

As with any energy development, potential impacts upon local communities may occur. Over the next several years, only a few experiments will be conducted and effects should be minor. As decision points for commercialization are approached, assessments of the impacts of large-scale development will be required.

9. System Safety and Occupational Health

As practical heat extraction processes become defined, a review of system safety and possible occupational health problems should be undertaken. No unusual problems are anticipated, but secondary loops containing isobutane or other combustible fluids may be utilized and will require special attention.

IV. ENVIRONMENTAL PROGRAM STRATEGY AND MANAGEMENT

A. PROGRAM GOAL

The goal of the DOE Environmental Program is to ensure that energy technologies developed, demonstrated, and brought to the commercialization phase by DOE are environmentally acceptable. In particular, ensuring environmental acceptability refers not only to meeting the present, immediate requirements of the law but also to identifying environmental problems and taking measures that will avoid or mitigate adverse effects of widespread and long-term use of these technologies.

Section III enumerated and discussed the various environmental concerns and the R&D required. This section describes the implementation strategy developed to address these needs.

B. PROGRAM STRATEGY

To accomplish the above-stated goal, DOE conducts a number of assessments to determine the EH&S implications of energy technology development and utilization. The results of these assessments provide the basis for the DOE program addressing the concerns and requirements described in Tables 3-3, 3-4, and 3-5. The current program is designed to

- Produce information that will define the nature and scope of potential EH&S impacts,
- Provide an information base for the establishment of EH&S standards and regulations,
- Ensure that environmental considerations are taken into account in the program decisionmaking process, and
- Define mitigation measures and develop appropriate control technology to minimize impacts and meet environmental standards at reasonable cost.

The EH&S program consists of numerous projects, which are generally grouped as follows:

- Baseline characterizations to identify potential impacts and to establish the environmental conditions before significant development takes place;
- Operational site measurements and monitoring to assess environmental conditions during resource development and energy production operations;

- Effects studies to evaluate the ecological, health, safety, social, and economic impacts of geothermal developments and to develop the capability to predict long-term consequences;
- Integrated assessment and evaluation of our knowledge concerning the issues;
- Environmental control and abatement research to limit emissions and reduce impacts to prescribed or acceptable levels; and
- Development of EH&S guidelines and performance criteria.

The current and planned research and assessment projects supporting the geothermal program are summarized in Appendix B. The projects listed have been developed, planned, and implemented in coordination with the Assistant Secretary for Energy Technology (ASET)/Energy Technology Solar, Geothermal, Electric, and Storage Systems (ETS), the Office of the Assistant Secretary for Resource Applications (ASRA), and the Assistant Secretary for Environment (ASEV) to address the concerns and requirements of Tables 3-3, 3-4, and 3-5.

Figure 4-1 presents the schedule for environmental R&D efforts and compliance activities, coordinated with the schedule of the geothermal energy systems technology program. The upper section of the figure summarizes the total technology program (Figures 2-6 through 2-9) and establishes a time frame for the completion of systems and general technology development projects. Research on potential environmental impacts associated with stages of technology development is scheduled to precede completion of major systems and technology development projects, except in rare cases where the environmental R&D is necessarily of long-term duration. Preparation of Environmental Assessments (EAs) and Environmental Impact Statements (EISs) is similarly scheduled in Table 4-1. Revisions to the EAs and EISs will be scheduled in updated EDPs.

C. PROGRAM MANAGEMENT

1. Responsibility

ASEV, ETS, and ASRA are responsible for preparing, reviewing, approving, and coordinating implementation of this EDP. The Office of Environment (EV)/Division of Technology Assessment, ETS/Division of Planning and Technology Transfer, and the Office of Resource Applications/Division of Geothermal Resource Management will coordinate in identifying and determining the priorities of major health and environmental issues and reviewing research and assessment activities for relevance and timeliness.

The primary responsibility for performing the environmental research and assessment activities related to geothermal technology development will be shared by ETS, RA, and EV. Each program office will initiate, fund, and manage its health and environmental research and assessment programs in support of high-priority needs enumerated in the EDP. Projects

Symbols: ▲ Program Milestones ▼ Decision Point — Activity Bar

*Supportive of all geothermal systems.

**Refer to Table 4-1 for NEPA compliance documentation.

1. Begin Data Collection in Imperial Valley
2. Begin Preliminary Assessment of Data on Measurements of Environmental Pollutants and Public Health
3. Complete Comparative Evaluation of Local Health Statistics
4. Begin Evaluation of Correlative Results
5. Complete Data Evaluation and Prelim Analysis of Implications and Shortcomings
6. Collect Data on Baseline Studies on Gulf Coast
7. Complete Studies: Jemez Mtns., HDR Site
8. Complete Snake River Plain Studies
9. Complete Evaluation of Environmental Impacts to Imperial Valley
10. Complete Valles Caldera Baseline Studies
11. Collect Data on Gulf Coast Pilot Plant
12. Start Subsidence and Induced Seismicity R&D
13. Initiate Air Quality Field Measurement Program at The Geysers
14. Initiate Development of Air and Water Quality Research Program for Valles Caldera, New Mexico
15. Complete Analysis of Air Quality Data for Imperial Valley

16. Initiate Environmental Studies for Direct-Heat Applications, Idaho
17. Interim Report on Air Quality for The Geysers
18. Initiate Environmental Studies for Geopressured Sources, Texas and Louisiana
19. Implement Subsidence R&D
20. Report on Air Quality in Geothermal Development
21. Complete Subsidence and Induced Seismicity R&D
22. State-of-Art Assessment on Liquid Waste Disposal
23. State-of-Art Assessment on Gaseous Waste Disposal
24. Noise Abatement: Advanced Control Assessment
25. Field Assessment of Environmental Controls
26. Initiate National Geothermal Environmental Readiness Assessments
27. Complete National Geothermal Environmental Readiness Assessments
28. Complete Preliminary Assessment of The Geysers Calistoga KGRA

29. Complete Preliminary Assessments of the Texas, Utah, Louisiana, Roosevelt Hot Springs, Mono-Long Valley, Raft River-Snake River Plain KGRAs
30. Complete Geothermal Technology Assessment of Imperial Valley
31. Complete Socioeconomic Study of The Geysers Calistoga KGRA
32. Complete Preliminary Assessments of the Oregon, Hawaii, Northern Nevada, New Mexico, Washington, South Dakota, Wyoming, Arkansas, and Atlantic Coast KGRAs
33. Complete Preliminary Assessments of the Arizona, Colorado, and Alaska KGRAs and the HDR Regions of Maryland, New York, Nebraska, and California
34. ERD-Published Hydrothermal Electric and Direct Heat
35. EDP Update

Figure 4-1. Coordinated Technology and Environmental Milestones

Table 4-1. Summary of DOE-Prepared NEPA-Related Documents

Project	Document Number	Date
Hawaii Well Flow Test (Puna District, Hawaii)	EIA/GE/76-1	Nov. 1976
Coso Geothermal Project (Coso Hot Springs, Calif.)	EIA/GE/77-1	Jan. 1977
Hydrothermal Subprogram	EIA/GE/77-2	March 1977
Geopressure Subprogram	EIA/GE/77-3	July 1977
Loan Guaranty Application Republic Geothermal	EIA/GE/77-4	May 1977
Geothermal Food Processors GLGP* (Brady Hot Springs, Nev.)	EIA/GE/77-5	Sept. 1977
Hot Dry Rock Subprogram	EIA/GE/77-6	Sept. 1977
CU-1 Venture GLGP (South Brawley, Calif.)	EIA/GE/77-7	Aug. 1977
CU-1 Venture GLGP (Beryl-Lund, Utah--Cancelled)	EIA/GE/77-8	Sept. 1977
Raft River Geothermal Flow Test Loop (Raft River, Idaho)	DOE/EA-0008	March 1978
Pleasant Bayou Geopressure Well (Alvin, Tex.)	DOE/EA-0013	March 1978
Eastern U.S. Exploration Program	DOE/EA-0015	April 1978
Geopressure Wells of Opportunity (Gulf Coast)	DOE/EA-0023	Feb. 1978
Coso Hot Springs Flow Test (Coso Hot Springs, Calif.)	DOE/EA-0036	April 1978
Republic Geothermal and MAPCO GLGP (Westmorland, Calif.)	EA Draft	June 1978
Raft River Geothermal Turbine (Raft River, Idaho)	EA Draft	June 1978
Sweet Lake Geopressure Well (Sweet Lake, La.)	EA Draft	Sept. 1978
Lafourche Geopressure Well (Lafourche Bayou, La.)	EA Draft	Oct. 1978
Preheat for Hospital Heating and Hot Water (Marlin, Tex.)	EA Draft	Oct. 1978
Hawaii Geothermal Wellhead Turbine (Puna District, Hawaii)	EA Draft	Nov. 1978
Baca Geothermal Demonstration Plant (Jemez, N. Mex.)	EIS	in preparation
O'Brien and others GLGP (Roosevelt Hot Springs, Utah)	EA	in preparation
Geopressure Wells (Gulf Coast)	EA	2 projected
El Centro Community Heating and Cooling (El Centro, Calif.)	EA	projected
Republic Geothermal and MAPCO GLGP (Westmorland, Calif.)	EIS	projected
Fenton Hill HDR Project Expansion and Operation (Sandoval County, New Mexico)	EA Draft	March 1979

* GLGP = Geothermal Loan Guaranty Program

implemented will be coordinated and reviewed by the Geothermal Environmental Coordination Committee (GECC) and its subcommittees, described below.

EV will concentrate on environmental and biological effects research and national impact assessments resulting from particular commercialization scenarios and assessment of control options; ETS will concentrate on resource assessment and development of environmental control technologies. ETS and RA will identify the need for and prepare appropriate NEPA documents at the earliest possible date to meet the intent of NEPA. EV will assist in determining the need for and the timing and will provide overall review and approval of the documents. EV, ETS, and RA will coordinate the activities of offices in DOE and other Government agencies to ensure that resources are employed optimally for geothermal-related environmental research and assessment. RA will be concerned with providing appropriate incentives for commercialization through such means as loan guaranties, direct grants, and occasionally through planning assistance to states with KGRAs.

2. Coordination

The Geothermal Environmental Coordination Committee is a special group constituted under authority of DOE Order 5420.1, composed of representatives of various DOE offices to assist in the implementation of the DOE Environmental Development Plan System. The primary function of GECC is to monitor and overview the status of environmental R&D programs, ensure that the intent of the EDPs is achieved, and promote regular information exchanges and coordination between offices responsible for environmental R&D. Specifically, GECC, through appropriate subcommittees,

- Participates in the preparation and review of EDPs and identifies the need for and recommends revisions in EDPs;
- Maintains a collective awareness of the content, status, and results of environmental R&D efforts and apprises management periodically of status and issues;
- Advises management of gaps, redundancies, and potential conflicts in the environmental R&D efforts and recommends corrective options for management considerations; and
- Coordinates between performing offices those necessary physical and institutional arrangements required for the conduct of respective environmental research efforts.

3. Management Documents

In addition to EDPs, certain EH&S documents are prepared to assist management in conducting DOE's environmental program. The most significant of these are briefly described below.

Environmental Readiness Document - The ERD is an independent assessment report prepared by ASEV with the full cognizance of technology program line managers. It provides a state-of-the-art assessment of the environmental status of a technology at the phase of development being considered for management decisions, usually at the key decision points of the management system. The ERD presents the results of a critical review and analysis of environmental R&D results carried on in the preceding phase and provides further definition of concerns and research needs for the ensuing period. The ERD provides the basis for the ASEV position on the environmental readiness of a DOE technology at each key decision point.

Environmental Assessment/Environmental Impact Statement - The National Environmental Policy Act of 1969 establishes the requirements for EISs. An EA is a statement that provides the information on which to base a determination of the necessity for an EIS or a finding of no significant impact. EAs may be prepared for any action and at any time to assist Departmental planning and decisionmaking. EAs and EISs are prepared by program offices according to DOE procedures and are reviewed by the Office of Environment.

Safety Analysis - A safety analysis is prepared by program managers according to DOE procedures (Uniform Independent Safety Review System), early in the design phase of a proposed facility that DOE intends to procure and operate. The use of a safety analysis to identify hazards, eliminate and control identified hazards, assess residual risk, and document management authorization to a DOE operation applies equally to technology base activities and energy system acquisition projects. The purpose is to limit risks to the health and safety of the public and employees and adequately protect property and the environment.

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APPENDIX A

SETTING RESEARCH PRIORITIES FOR ENVIRONMENTAL, HEALTH, AND SAFETY RESEARCH

In addition to the rationale described in Section IIIA, three other factors require consideration in defining, setting priorities for, and scheduling environmental research. Each is discussed briefly below.

A. REGULATORY IMPETUS

When Federal, State, or local regulations or standards exist explicitly for new technologies, or implicitly through general regulation of some of the potential emissions or safety concerns, a ranking of possible impacts has already been performed by the regulating agency. High priority must be given to research directed toward determining the potential for compliance with existing or imminent regulations. Generally, when adequate regulations and standards exist, research is directed more toward identifying cost-effective compliance options (control technology) than determining impacts of alternative levels of control. Federal regulations concerning air and water emissions, their resulting environmental effects, solid waste disposal, toxic material handling, and occupational safety and health matters applicable to phases of geothermal energy systems technology include the following:

- National Environmental Policy Act
- Nonnuclear Energy Research and Development Act
- Clean Air Act
- Clean Water Act
- Safe Drinking Water Act
- Occupational Safety and Health Act
- Resource Conservation and Recovery Act
- Fish and Wildlife Conservation Act
- Endangered Species Act
- Toxic Substances Control Act
- Federal Hazardous Substances Act

In addition to such regulation on the Federal level, geothermal energy systems technology development will be impacted significantly by State and local regulations. These consist primarily of water law, zoning, and land use controls, all of which tend to be administered on the local and State level, except in those cases where geothermal energy resources are located on federally owned land. Zoning regulations restrict the ways in which owners may develop or use their land in the interest of the public health, safety, or general welfare. Water law, for example, appropriative and riparian doctrine, regulates and will determine the manner of water use in areas of geothermal resources development. Both of these regulatory mechanisms will explicitly or implicitly contribute toward setting environmental research priorities for geothermal resources development.

B. ENVIRONMENTAL RESOLUTION TIME VERSUS PUBLIC UTILIZATION TIME

A primary consideration for determining research needs is the schedule of deployment for the particular technology. The objective of the EDP is to plan environmental research so that issues are resolved before a technology is extensively utilized. Therefore, whenever it is estimated that the time required to resolve an environmental issue (environmental resolution time) through RD&D is greater than or equal to the time before the technology is available to the public, that issue has priority.

C. COST-EFFECTIVENESS

Another approach in determining priorities is to consider the commonality of problems among diverse technologies. Researching the problems of one particular technology may resolve similar problems involving other technologies. Such an approach is cost-effective.

APPENDIX B

SUMMARY OF COMPLETED, CURRENT, AND PLANNED ENVIRONMENTAL RESEARCH PROJECTS

Tables B-1, B-2, and B-3 summarize research that addresses the environmental effects of geothermal energy systems technology development. The projects described here address concerns as identified in Tables 3-3, 3-4, and 3-5.

Table B-1. Completed, Current, and Planned Research Projects for Hydrothermal Systems

Projects Listed are Keyed to Concerns and Requirements in Table 3-3

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE* PROJECT TITLE	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
1. Release of Air- borne Effluents	1.1,1.3,1.5	DOE/EV Air Quality Impacts of Geothermal Development in California (IVEP, Geysers)	LLL	Current	1975	1981
	1.1,1.2	Atmospheric Characterization	LLL	Completed	1977	1978
	1.1,1.3	Trace Metal Characterization and Speciation in Geothermal Effluents	UW	Completed	1978	1978
	1.1,1.2	Heavy Metal and Noxious Gas Emissions	PNL	Current	1975	1980
	1.1,1.3	Geothermal Tracer Experiment	ANL	Planned	1980	1980
	1.1	Pollutant Transport in Complex Terrain	LLL	Current	1979	1982
	1.1,1.2,1.4	Effects of H ₂ S on Vegetation	UC-Riverside	Current	1978	1980
	1.4	Toxic Effects of Geothermal Effluents	PNL	Current	1978	1980
	1.6	Evaluation of H ₂ S Control Technology for Geothermal Energy Sources	MRI	Current	1978	1979
	1.6	DOE/DGE H ₂ S Removal from Brine - Direct Oxidation	Dow Chem.	Completed	1976	1978
	1.5	Removal of H ₂ S from Geothermal Steam by Catalytic Oxidation	PNL	Current	1977	1982
	1.6	H ₂ S Control, CuSO ₄ Scrubbing	ETC	Current	1978	1980
	1.1,1.2,1.5	EPA Monitoring Guides for H ₂ S and Noncondensable Hazardous Gaseous Emission/Geothermal	EPA	Current	1976	1979

*Acronyms are listed in the Glossary.

⁺Fiscal Year

Table B-1. Completed, Current, and Planned Research Projects for Hydrothermal Systems (Continued)

Projects Listed are Keyed to Concerns and Requirements in Table 3-3

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE*	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
		PROJECT TITLE				
2. Release of Water-borne Effluents	2.3,2.4	DOE/EV Research Program Plan for Geothermal Liquid Waste Disposal	PNL	Current	1977	1980
	2.1,2.3,2.5	Properties and Impact of Submarine Geothermal Springs on the West Florida Continental Shelf	USF	Current	1977	1980
	2.1,2.2,2.3,2.4	IVEP Geothermal: Water Quality	LLL	Current	1975	1979
	2.5	Potential for and Control of Well Blowouts	Maurer Engineering	Completed	1978	1979
	2.4	Water and Geothermal Assessment	Cal. Tech.	Completed	1977	1978
	2.1,2.2	Trace Metal Characterization and Speciation in Geothermal Effluents	Univ. of Wash.	Completed	1978	1978
	2.6	DOE/DGE Downhole Cement Development	NBS, BNL	Current	1978	1979
	2.1	EPA Development of Sampling Plan for Geothermal Manifestations	TRW, Inc.	Completed	1977	1977
	3.1	DOE/EV Evaluation of Noise Associated with Geothermal Activities	Long/Davy	Current	1979	1979
	3.1	Geothermal Noise Effects	St. Mary's College	Completed	1978	1978
3. Noise	3.1	Impact Assessment of Geothermal Developments and Associated Human Activity on Nesting Ferruginous Hawks	INEL	Current	1978	1979

*Acronyms are listed in the Glossary.

+Fiscal Year

Table B-1. Completed, Current, and Planned Research Projects for Hydrothermal Systems (Continued)

Projects Listed are Keyed to Concerns and Requirements in Table 3-3

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE*	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
		PROJECT TITLE				
3. Noise (cont'd)		<u>DOE/DGE</u>				
	3.1	Noise Control Program	TBD	Planned	1979	1981
	3.1	Peregrine Falcon Study	GRIPS Commission	Completed	1978	1978
4. Subsidence		<u>DOE/EV</u>				
	4.1,4.2,4.3	IVEP - Geothermal Subsidence and Seismicity	LLL	Current	1977	1979
	4.1,4.3	Assess Effectiveness of Subsidence/Seismic Control Techniques	TBD	Planned	1980	1983
		<u>DOE/DGE</u>				
	4.1,4.2,4.3	Geothermal Subsidence Research Program	LBL	Current	1976	1984
		<u>USGS</u>				
	4.1,4.2,4.3	Geothermal Investigations, Subsurface Env. Impact	USGS, Calif.	Completed	1977	1978
5. Induced Seismicity		<u>DOE/EV</u>				
	5.1	Potential for Land Seismic Activity	TBD	Planned	1979	1980
	5.2	Assess Effectiveness of Subsidence/Seismic Control Techniques	TBD	Planned	1980	1983
	5.1,5.2	IVEP - Geothermal Subsidence and Seismicity	LLL	Completed	1977	1978
		<u>DOE/DGE</u>				
	5.1,5.2	Seismic Monitoring at The Geysers Geothermal Field	USGS	Completed	1977	1978
	5.1	Induced Seismicity - RHS Utah	Univ. of Utah	Current	1978	1982
	5.1,5.2	Induced Seismicity - The Geysers	USGS	Current	1977	1979
	5.1,5.2	Induced Seismicity - Cerro Prieto	LBL	Current	1978	1979
	5.1,5.2	Induced Seismic Research Program	Nevada Operations Office	Current	1978	1982

*Acronyms are listed in the Glossary.

+Fiscal Year

Table B-1. Completed, Current, and Planned Research Projects for
Hydrothermal Systems (Continued)

Projects Listed are Keyed to Concerns and Requirements in Table 3-3

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE*	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
		PROJECT TITLE				
5. Induced Seismicity (cont'd)	5.1	<u>USGS</u> Geothermal Investigations, Subsurface Env. Impact	USGS, Calif.	Completed	1977	1978
	6.1	<u>DOE/EV</u> Water and Geothermal Assessment	Cal. Tech.	Completed	1977	1978
6. Water Use	6.1	<u>USGS</u> Geothermal Investigations, Subsurface Env. Impact	USGS, Calif.	Completed	1977	1978
	7.4	<u>DOE/EV</u> IVEP Geothermal: Socioeconomic Assessment	LLL	Current	1976	1979
7. Land Use	7.2	Impact Assessment of Geothermal Developments and Associated Human Activity on Nesting Ferruginous Hawks	INEL	Current	1978	1979
	7.2	<u>DOE/DGE</u> Peregrine Falcon Study	GRIPS Commission	Completed	1978	1978
	7.4	<u>NSF</u> Evaluation of Alternative Energy Leasing Strategies and Schedules for Federal Lands	Cornell Univ.	Completed	1978	1978

*Acronyms are listed in the Glossary.

⁺Fiscal Year

Table B-1. Completed, Current, and Planned Research Projects for Hydrothermal Systems (Continued)

Projects Listed are Keyed to Concerns and Requirements in Table 3-3

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE* PROJECT TITLE	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
8. Social Services and Community Structure	8.1-8.5	DOE/EV IVEP Geothermal Socioeconomic Assessment	LLL	Current	1977	1980
	8.1-8.5	Socioeconomic Assessment of The Geysers - Calistoga Resource Area	LLL, LBL	Current	1979	1980
	8.1	NSF Evaluation of Alternative Energy Leasing Strategies and Schedules for Federal Lands	Cornell Univ.	Completed	1978	1978
9. System Safety and Occupational Health	9.1, 9.2	DOE/EV EH&S Standards for Geothermal Energy	PNL	Current	1977	1979
	9.1, 9.2	Potential for and Control of Well Blowouts	Maurer Engineering	Completed	1978	1979
Multidisciplinary (Generic)		Environmental Readiness Assessments - Geothermal	LLL	Planned	1980	1981
		Preliminary Assessment and Planning for Geothermal KGRA	LLL	Current	1977	1981
		Environmental Readiness Documents (ERD)	LLL	Current	1978	1980
		National Geothermal Information Resource (GRID)	LBL	Completed	1976	1978
		Imperial Valley: Integrated Assessment	LLL	Current	1977	1979
		IVEP Geothermal: Ecosystem Quality	LLL	Current	1976	1979
		IVEP: Health Effects	LLL	Current	1977	1980

*Acronyms are listed in the Glossary.

⁺Fiscal Year

Table B-1. Completed, Current, and Planned Research Projects for
Hydrothermal Systems (Continued)

Projects Listed are Keyed to Concerns and Requirements in Table 3-3

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE*	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
		PROJECT TITLE				
Multidisciplinary (Generic) (cont'd)		IVEP: Assessment of Environmental Control Technologies	LLL	Current	1977	1979
		Geothermal Loan Guaranty Program: Assessment of Env. Control Technologies	LLL	Current	1977	1984
		Geothermal Planning for Snake River Plain	INEL	Completed	1978	1978
		Raft River Geothermal Ecology	Idaho Univ.	Completed	1977	1978
		<u>DOE/DGE</u>				
		Environmental Monitoring at Raft River	INEL	Current	1977	1984
		HGRA Site Environmental Monitoring	Univ. of Hawaii	Current	1978	1981
		High-Temperature Sensors for Geothermal Plant Control and Monitoring Instrumentation	PNL	Current	1978	1979
		Mineral Solubility Data Subcontracts	USGS & Universities	Current	1978	1979
		Hydrodynamics and Kinetics Effects on Scale Control	LASL	Current	1979	1980
		Fluid Characterization and State-of-the-Art Assessment of Instrumentation for Powerplant Monitoring and Control	PNL	Current	1978	1979
		Sampling and Analytical Technology	PNL	Current	1977	1979
		Injection Stimulation Chemistry	Vetter Research	Current	1978	1979
		EIA/EIS Support	ORNL	Current	1978	1982

*Acronyms are listed in the Glossary.

⁺Fiscal Year

Table B-2. Completed, Current, and Planned Research Projects for Geopressured Systems

Projects Listed are Keyed to Concerns and Requirements in Table 3-4

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE*	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
		PROJECT TITLE				
1. Release of Airborne Effluents	1.1	<u>DOE/EV</u> Trace Metal Characterization and Speciation in Geothermal Effluents	Univ. of Wash.	Completed	1978	1978
	1.1,1.2	Heavy Metal and Noxious Gas Emissions	PNL	Current	1979	1980
	1.1	Geothermal Tracer Experiment	ANL	Planned	1980	1980
	1.4	Toxic Effects of Geothermal Effluents	PNL	Current	1978	1980
2. Release of Waterborne Effluents	2.1,2.2	Trace Metal Characterization and Speciation in Geothermal Effluents	Univ. of Wash.	Completed	1978	1978
	2.4,2.6	Research Program Plan for Geothermal Liquid Waste Disposal	PNL	Current	1977	1980
	2.5	Potential for and Control of Well Blowouts	Maurer Engineering	Completed	1978	1979
	2.4,2.6	Water and Geothermal Assessment	Cal. Tech.	Completed	1977	1978
	2.3	Gulf Geothermal Water Quality	LSU	Completed	1977	1978
	2.6	<u>DOE/DGE</u> Downhole Cement Development	NBS, BNL	Current	1978	1983
3. Noise	3.1,3.2	<u>DOE/EV</u> Evaluation of Noise Associated with Geothermal Activities	Long/Davy	Current	1979	1979
	3.2	Geothermal Noise Effects	LLL	Current	1977	1980
	3.1	<u>DOE/DGE</u> Noise Control Program	TBD	Current	1978	1981

*Acronyms are listed in the Glossary.

⁺Fiscal Year

Table B-2. Completed, Current, and Planned Research Projects for Geopressed Systems (Continued)

Projects Listed are Keyed to Concerns and Requirements in Table 3-4

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE* PROJECT TITLE	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
4. Subsidence	4.2	<u>DOE/EV</u> Assess Effectiveness of Subsidence/Seismic Control Techniques	TBD	Planned	1980	1983
	4.1	Gulf Geothermal Seis/Subs.	GANGLIONS	Completed	1977	1978
	4.1,4.2,4.3	<u>DOE/DGE</u> Texas Gulf Const. Releveling Research Program Geothermal Subsidence Research Program	NGS LBL	Current Current	1977 1976	1981 1984
5. Induced Seismicity	4.1	<u>USGS</u> Geothermal Investigations, Subsurface Env. Impact	USGS, Calif.	Completed	1977	1978
	5.1	<u>DOE/EV</u> IVEP Geothermal Subsidence and Seismicity	LLL	Current	1976	1979
	5.1	Assess Effectiveness of Subsidence/Seismic Control Techniques	TBD	Planned	1980	1983
	5.1	<u>DOE/DGE</u> Induced Seismic Research Program	TBD	Current	1979	1982
	5.1	<u>USGS</u> Geothermal Investigations, Subsurface Env. Impact	USGS, Calif.	Completed	1977	1978

*Acronyms are listed in the Glossary.

⁺Fiscal Year

Table B-2. Completed, Current, and Planned Research Projects for Geopressed Systems (Continued)

Projects Listed are Keyed to Concerns and Requirements in Table 3-4

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE* PROJECT TITLE	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
6. Water Use	6.1	<u>DOE/EV</u> Water and Geothermal Assessment	Cal. Tech.	Completed	1977	1978
	6.1	Gulf Geothermal Water Quality	LSU	Completed	1977	1978
	6.1	<u>USGS</u> Geothermal Investigations, Subsurface Env. Impact	USGS, Calif.	Completed	1977	1978
	7.4	<u>NSF</u> Evaluation of Alternative Energy Leasing Strategies and Schedules for Federal Lands	Cornell Univ.	Completed	1978	1978
8. Social Services and Community Structure	9.1,9.5	<u>DOE/EV</u> IVEP Geothermal Socioeconomic Assessment	LLL	Current	1976	1979
	8.1,8.5	Socioeconomic Assessment of The Geysers - Calistoga Resource Area	LLL,LBL	Current	1979	1980
	8.1	<u>NSF</u> Evaluation of Alternative Energy Leasing Strategies and Schedules for Federal Lands	Cornell Univ.	Completed	1978	1978
	9.1,9.2	<u>DOE/EV</u> EH&S Standards for Geothermal Energy	PNL	Current	1977	1979
9. System Safety and Occupational Health	9.1,9.2	Potential for and Control of Well Blowouts	Maurer Engineering	Completed	1978	1979

*Acronyms are listed in the Glossary.

⁺Fiscal Year

Table B-2. Completed, Current, and Planned Research Projects for Geopressured Systems (Continued)

Projects Listed are Keyed to Concerns and Requirements in Table 3-4

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE*	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
		PROJECT TITLE				
Multidisciplinary (Generic)		<u>DOE/EV</u>				
		Environmental Readiness Assessment -- Geothermal	LLL	Planned	1980	1981
		Preliminary Assessment and Planning for Geothermal KGRAS	LLL	Current	1977	1980
		Environmental Readiness Documents (ERD)	LLL	Current	1978	1980
		National Geothermal Information Resource (GRID)	LBL	Completed	1976	1978
		Geothermal Loan Guaranty Program: Assessment of Env. Control Technologies	LLL	Current	1977	1984
		Gulf Geothermal Ecology	LSU	Completed	1977	1978
		ECT Implications of Geopressure Development	TBD	Planned	1981	1983
		<u>DOE/DGE</u>				
		Geopressure Environmental Studies	Univ. of Texas	Completed	1978	1978
		Louisiana Wellsite Environmental Monitoring	TBD	Current	1978	1981
		Environmental Assessment - Louisiana	LSU	Current	1978	1979
		Brazoria (Texas) Site Env. Monitoring	Univ. of Texas	Current	1978	1979
		EIA/EIS Support	ORNL	Current	1978	1982

*Acronyms are listed in the Glossary.

⁺Fiscal Year

Table B-3. Completed, Current, and Planned Research Projects for Hot Dry Rock Systems

Projects Listed are Keyed to Concerns and Requirements in Table 3-5

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE*	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
		PROJECT TITLE				
1. Release of Airborne Effluents	1.1	<u>DOE/EV</u> Trace Metal Characterization and Speciation in Geothermal Effluents	Univ. of Wash.	Completed	1978	1978
	1.1,1.2	Heavy Metal and Noxious Gas Emissions	PNL	Current	1975	1980
	1.1	Geothermal Tracer Experiment	ANL	Planned	1980	1980
2. Release of Waterborne Effluents	2.1,2.2	Trace Metal Characterization and Speciation in Geothermal Effluents	Univ. of Wash.	Completed	1978	1978
	2.5	Potential for and Control of Well Blowouts	Maurer Engineering Cal. Tech.	Completed	1978	1979
	2.4,2.6	Water and Geothermal Assessment		Current	1978	1979
	2.6	<u>DOE/DGE</u> Downhole Cement Development	NBS, BNL	Current	1978	1979
3. Noise	3.1	<u>DOE/EV</u> Evaluation of Noise Associated with Geothermal Activities	Long/Davy	Current	1979	1979
	3.1	Geothermal Noise Effects	St. Mary's College	Completed	1978	1978
	3.1	<u>DOE/DGE</u> Noise Control Program	TBD	Current	1979	1981
	4.1,4.2,4.3	Geothermal Subsidence Research Program	LBL	Current	1976	1984
4. Subsidence	4.1	<u>DOE/EV</u> Assess Effectiveness of Subsidence/Seismic Control Techniques	TBD	Planned	1980	1983

*Acronyms are listed in the Glossary.

⁺Fiscal Year

Table B-3. Completed, Current, and Planned Research Projects for Hot Dry Rock Systems (Continued)

Projects Listed are Keyed to Concerns and Requirements in Table 3-5

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE*	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
		PROJECT TITLE				
5. Induced Seismicity	5.1	Potential for Land Seismic Activity	TBD	Planned	1979	1980
	5.2	Assess Effectiveness of Subsidence/Seismic Control Techniques	TBD	Planned	1980	1983
6. Water Use		<u>DOE/DGE</u>				
	5.1	Induced Seismicity - RHS Utah	Univ. of Utah	Current	1978	1982
	5.1	Induced Seismic Research Program	TBD	Current	1978	1982
	6.1	<u>DOE/EV</u> Water and Geothermal Assessment	Cal. Tech.	Completed	1977	1978
7. Land Use		<u>NSF</u>				
	7.4	Evaluation of Alternative Energy Leasing Strategies and Schedules for Federal Lands	Cornell Univ.	Completed	1978	1978
8. Social Services and Community Structure		<u>DOE/EV</u>				
	8.1,8.5	IVEP Geothermal Socioeconomic Assessment	LLL	Current	1977	1980
	8.1,8.5	Socioeconomic Assessment of The Geysers - Calistoga Resource Area	LLL	Current	1979	1980
	8.1	<u>NSF</u> Evaluation of Alternative Energy Leasing Strategies and Schedules for Federal Lands	Cornell Univ.	Completed	1978	1978
9. System Safety and Occupational Health		<u>DOE/EV</u>				
	9.1,9.2	EH&S Standards for Geothermal Energy	PNL	Current	1977	1979
	9.1,9.2	Potential for and Control of Well Blowouts	Maurer Engineering	Completed	1978	1979

*Acronyms are listed in the Glossary.

⁺Fiscal Year

Table B-3. Completed, Current, and Planned Research Projects for
Hot Dry Rock Systems (Continued)

Projects Listed are Keyed to Concerns and Requirements in Table 3-5

CONCERN	REQUIREMENT NUMBER	SPONSORING AGENCY/OFFICE*	PERFORMING ORGANIZATION*	STATUS	START DATE ⁺	COMPL. DATE ⁺
		PROJECT TITLE				
Multidisciplinary (Generic)		Environmental Readiness Assessment - Geothermal	LLL	Planned	1980	1981
		Preliminary Assessment and Planning for Geothermal KGRA	LLL	Current	1977	1980
		Environmental Readiness Documents (ERDs)	LLL	Current	1978	1980
		National Geothermal Information Resource (GRID)	LBL	Completed	1976	1978
		Geothermal Loan Guaranty Program: Assessment of Env. Control Technologies	LLL	Current	1977	1984
		Geothermal Planning for Snake River Plain	INEL	Completed	1978	1978
		Raft River Geothermal Ecology	Idaho Univ.	Completed	1977	1978
		Dry Geothermal Hot Rock	LASL	Current	1976	1980
		<u>DOE/DGE</u>				
		Environmental Monitoring at Raft River	INEL	Current	1977	1984
		HGRA Site Environmental Monitoring	Univ. of Hawaii	Current	1978	1981
		Fenton Hill Site, Environmental Monitoring	LASL	Current	1978	1981

*Acronyms are listed in the Glossary.

⁺Fiscal Year

GLOSSARY

ANL	Argonne National Laboratory
BNL	Brookhaven National Laboratory
DGE	Division of Geothermal Energy
DOC	Department of Commerce
DOE	Department of Energy
DOI	Department of the Interior
EA	Environmental Assessment
EDP	Environmental Development Plan
EH&S	environmental, health, and safety
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERD	Environmental Readiness Document
ET	Office of Energy Technology
ETS	Office of Energy Technology, Solar, Geothermal, Electric, and Storage Programs
EV	Office of Environment
GECC	Geothermal Environmental Coordination Committee
GRIPS	Geothermal Research Impacts Project Study Commission
HSL	Health Services Laboratory, Idaho Falls
INEL	Idaho National Engineering Laboratories
KGRA	known geothermal resource area
LASL	Los Alamos Scientific Laboratory
LBL	Lawrence Berkeley Laboratory
LLL	Lawrence Livermore Laboratory
LSU	Louisiana State University
MRI	Midwest Research Institute
NBS	National Bureau of Standards
NEPA	National Environmental Policy Act
NSF	National Science Foundation
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Health and Safety Administration
PNL	Pacific Northwest Laboratory
RA	Office of Resource Applications
R&D	research and development
TBD	to be determined
UC	University of California
USF	University of San Francisco
USGS	U.S. Geological Survey
UW	University of Washington