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SUMMARY REPORT

SOUTHWEST REGIONAL GEOTHERMAL OPERATIONS RESEARCH PROGRAM

First Project Year

June 1977 -- August 1978

Prepared For

U.S. DEPARTMENT OF ENERGY

Idaho Falls Operations Office

by

WESTERN ENERGY PLANNERS, LTD.

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EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

IDAHO OPERATIONS OFFICE UNDER CONTRACT EY-76-C-07-1570

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PREFACE

The Southwest Regional Geothermal Operations Research Program was instituted in June 1977, as a jointly sponsored project of the U.S. Department of Energy (DOE, formerly the Energy Research and Development Administration), the Four Corners Regional Commission (FCRC), and the State of New Mexico Energy and Minerals Department (formerly the Energy Resources Board). The project was conducted by the New Mexico Energy Institute (NMEI) at New Mexico State University and by five State Teams from the states of Arizona, Colorado, Nevada, New Mexico and Utah.

The overall objectives of the first year project were as follows:

- To develop realistic but agressive scenarios with certainty factors for the development of each identified geothermal resource area in Arizona, Colorado, Nevada, New Mexico, and Utah.

- To delineate the public actions, together with their schedules, required for the scenarios to materialize.

- To develop a computer-based data storage and retrieval system (i.e. a Regional Program Progress Monitor) of the level of a preliminary working model, which is capable of displaying program approach but is not loaded with all available data.

In addition, each sponsor had supplementary objectives aligned to its own programmatic goals. DOE sought to develop expertise and programs within the appropriate state agencies upon which future DOE development and commercialazation activities could be structured. FCRC sought to promote the utilization of geothermal energy throughout the five-state region for purposes of expanded economic development, increased employment, and higher citizen incomes. The goals of the five states varied from state to state, but generally included the following: development of alternative energy sources to replace dwindling supplies of oil and natural gas; economic and industrial development in rural areas; encouragement of industry and utility development of geothermal energy for electrical power generation; demonstration of the practical applications of energy research and development; and close interaction with business and industry for the commercialization of both electric and direct thermal applications.

During the first year of the project, NMEI concentrated its activities upon project management and definition, economic modeling and analysis of resource sites using a rate-of-return on investment method, analysis of state and federal institutional and regulatory processes, and development of a Regional Program Progress Monitor computer data base. The State Teams focused their activities upon the identification of geothermal resource sites and areas, the collection and analysis of secondary resource assessment data, the estimation of resource energy quantities, the postulation of area and/or site-specific geothermal development scenarios for both electric and direct thermal applications, and the analysis of state institutional procedures and constraints.

This document is a summary report of the information, data and results presented by NMEI and the five State Teams in their separate draft final reports for the first of the Southwest Program. The contents of this report are in part a direct representation of some findings of NMEI and the five State Teams and in part a composite analysis and interpretation of other results of the project. The latter process was necessary by the authors in order to provide the reader with a reasonably consistent set of geothermal resource data and development plans for the entire five state region. Since this summary report numbers only one-seventh the total number of pages in the NMEI and state reports, the reader may need to refer to those more detailed reports for specific information and data.

This summary report also attempts to reflect the change in the thrust of the program for the second year (1978-79). The first year activity centered on generating plans (scenarios) for the physical development of the geothermal resources. The second year project will focus on planning the utilization and western states have been incorporated into the ten state Rocky Mountain Basin and Range Regional Hydrothermal Commercialization Program, which is under the direction of the DOE Idaho Falls Operations Office and its prime contractor, EG&G Idaho, Inc.

The authors wish to acknowledge the valuable assistance of the following persons, in addition to the NMEI staff and the five State Teams, in the preparation of this summary report: Ms. Barbara Coe for drafting Chapter 2, Economic Analysis, and for the compilation of many of the Tables in Chapter 4; Dr. W.D. Gertsch and Mr. Robert N. Chappell for technical reviews of the document; and Ms. Pam Mueller for superb typing of the manuscript.

January 10, 1979

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CHAPTER 1

1.0 Overview

The subject of geothermal energy could be, and was, ignored by most Americans in the past simply because it was not worth bothering with in a nation richly endowed with convenient and inexpensive oil and natural gas. By prior standards of resource development it could be shunted aside today with the simple observation that, if and when this form of energy is economically competitive, private enterprise will find a way to bring it to the user, just as Colonel Drake dug the world's first petroleum well in Pennsylvania when whale oil became increasingly scarce and expensive as a growing world population sought more fuel for its lamps.

But today the energy crisis poses security and economic problems upon the nation which cannot be tolerated; development of alternative energy sources cannot await the maturing of conventional market demands. Therefore it is a national policy to investigate and, where possible, promote the use of alternate energy sources, including geothermal, at a faster than normal pace of development.

Certain assessments are needed. Is the geothermal resource really there, in quantities and qualities worthy of attention? Is the cost tolerable? If the answers to these two questions are tentatively positive, what then are the roadblocks standing in the way of development? And, finally, how may these roadblocks be removed?

The Southwest Regional Geothermal Operations Research Program seeks to begin to answer these questions. Partial findings and tentative answers found during the first year of the program are summarized in this document for the benefit of two principal audiences: (1) public offical at federal, state, and local levels, and (2) technologists who will probe deeper into the subject.

The Southwest Program finds that there are geothermal resources of significance in each of the five states. Further study, exploration and experience will determine how much--a little or great deal--they can contribute to national energy requirements. In some cases, development cost is now acceptable and given various changed circumstances this will be true in more cases.

There are worrisome institutional constraints which slow down development, as well as cost problems. Some of these constraints can be overcome rather easily, others with more difficulty.

1.1 Background: Geothermal Energy--Its Definition and Past Uses

Geothermal energy is "earth heat" emanating from the molten core of the planet and from subsurface radiological decay, as contrasted with "solar heat" which manifests itself in direct sunshine, wind and other weather phenomena, conversion into plant and animal matter (biomass), and further conversion of biomass into the fossil fuels of coal, petroleum and natural gas.

There are five forms of geothermal energy, only two of which will be defined here and only one of which will be discussed except in passing. The five are: (1) hydrothermal convective, (2) hot dry rock, (3) geopressured, (4) magma, and (5) normal or near-normal subsurface heat gradients.

Hydrothermal convective is the form in which hot vapors or fluids flow from the ground surface through springs or wells. It is the only form thus far put to practical use.

Hot dry rock is the form in which formations of dense, relatively impervious and very hot rock are found at an accessible distance beneath the surface, but which includes no fluids which can transport heat to the surface. Experiments are underway at Los Alamos Scientific Laboratory in a technique of injecting water into such formations, where it will be heated and then pumped (or allowed to flow) to the surface for practical use. This technology may or may not be found workable; if it is, the resource potential is huge because such formations are widely distributed in the western third of the country. Within the five state Southwest region, New Mexico and Arizona are believed to have viable hot dry rock resources. In this summary hot dry rock will be mentioned only in passing.

There is extensive experience in using hydrothermal convective geothermal energy in various countries around the workd. A few examples:

- For more than 50 years electricity has been generated from geothermal steam in Italy.

- Vast greenhouses heated by geothermal waters produce vegetables and flowers in Iceland.

- Hot dry steam from wells in the Geysers field north of San Francisco now powers more than 500 megawatts of electrical generation capacity and this capacity is expected to increase to 1,500-2,000 MWe. Steam there is so hot and so pure that it can be piped directly into turbines, as if from conventional boilers, at costs lower than for steam from oil or coal-fired boilers. There may not be another geothermal site of such high quality in the United States, but lower quality steam and/or hot water can be used.

- Numerous buildings, greenhouses, etc. have been heated with geothermal waters at various places in the West and around the world for many decades. Many of these have been simple, relatively primitive applications which have been abandoned during the era of cheap oil and gas.

These are only examples; many others could be cited. Further development is underway in various countries.

1.2 Potential Magnitude of Southwestern Geothermal Resources

All authorities agree that the Southwest is rich in geothermal energy resources of the hydrothermal convective and hot dry rock forms, but there are large uncertainties in the estimates.

In only a few cases have hydrothermal reservoirs been explored sufficiently to permit reasonably accurate measurement of the quantity of heat contained.

In other cases--at least 500 identified sites in the five states--the presence of reservoirs has been established but in most cases size and temperature quantities can only be extrapolated from limited data. (As an example of such extrapolation, chemical analysis of waters issuing from the land surface can reveal temperature of the water at subsurface depths because various minerals dissolve at specific temperatures.)

In still other cases, subsurface temperature anomalies are detected by geoscientific measurements; these pointing to possibilities of geothermal reservoirs.

As in the case of oil and gas exploration, fully definitive information can be obtained only by drilling wells into the potential geothermal reservoir zones. It is reasonable to expect that further research and exploration will reveal more geothermal sites than have been detected thus far.

Meanwhile, measurements are not only incomplete but also are uneven: more study and exploration have been carried on in some localities than in others which may have as great or greater potential. The United States Geological Survey estimates that further discoveries could be possibly five times the volume and heat content of the high temperature systems (above 150° C) already identified.

Table 1.1 provides a preliminary estimate of the quantity of geothermal energy available in the five southwestern states. It is a table to be read with reservations, for the reasons given above.

The resource is estimated on the basis of the quantity of proven, potential, and inferred heat. The proven category includes only those reservoirs for which the resource parameters have been reasonably well measured at depth by test drilling. The potential category includes those for which limited subsurface data are available to make reasonable resource estimates. The inferred category includes areas and sites where a good many surface manifestations point to the presence of usable geothermal energy but where data are insufficient to make confident estimates. (See Section 4.4.)

Table 1.1 separates the geothermal resources into quantities of energy which can be used for electric power generation and quantities which can be used only for direct thermal applications.

Only reservoirs containing steam or fluids of 150° C or higher are considered for the electrical estimation, since serious technical difficulties are encountered in use of lower temperature steam or fluid. Actually, current energy conversion technology requires 200° C fluids, but advanced technologies are expected to be applicable to 150° C fluids by year 1985.

Table 1.1

Estimated Geothermal Resource Applications in the Southwest Region (1)

State	Electric (MWe) (2)				Direct Thermal (Quads) (3)			
	Proven	Potential	Inferred	Total	Proven	Potential	Inferred	Total
Arizona	0	150	4300	4450	0	(0.2018)	(5.785)	(5.9869) (4)
Colorado	0	100	400	500	0.0121	0.3254	0.3929	0.7304
Nevada	110	1540	12590	14240	0.0840	0.0740	0.4600	0.6180
New Mexico	50	395	1677	2122	0	0.0830	2.0678	2.1508
Utah	100	440	880	1420	0.0027	0.1946	1.400	1.5973
Total	260	2625	19847	22732	0.0988	0.8788	10.1057	11.0833

(1) See Section 4.5 for an explanation of the compilations of this Table.

(2) Energy for electric applications is cited as the energy rate (MWe), assuming a 30-year reservoir capacity; electric energy is based upon reservoir temperatures in excess of 150° C, which is also useable for direct thermal applications if not converted to electric energy.

(3) Energy for direct thermal applications is cited as the total energy recoverable/useable over a 30-year period.

(4) Estimates of Arizona's direct thermal applications are a multiple (1.5x) of the estimated electric applications, not a summation of resource sites.

Lower temperature waters, ranging down to about 65° C, can be used for direct thermal applications such as space heating and agricultural process heating. Of course, the higher temperature resource also can be used for direct thermal applications whenever circumstances make this an appropriate use.

Table 1.1 does not refer to the quantities of heat contained in the reservoirs, but rather to the more meaningful quantity which can be used after the losses which occur in extraction and conversion to useable form. The electric potential is given in terms of the rate of generation of electricity which could be put on line continuously for the 30-year period upon which power plant economics are generally calculated. The direct thermal resource is expressed in quads (quadrillions (10^{15})) of Btus of heat) which could actually be extracted and used over the life of the reservoir (not the rate of usage).

Chapter 4 provides further, more detailed identification of the various sites in each of the five states where the geothermal resource has been found. Various measurements, or indications, are used in that chapter to indicate and specify resource locations. The principal contribution of Chapter 4 is to show where, geographically, the resources have been found.

1.3 Actual and Postulated Developments

Chapter 5 goes a step further by presenting actual and postulated scenarios for development and use of geothermal energy in the five states. Included are specific timetables for development projects which are underway and for postulated developments which quite likely will take place in the near future. This chapter then provides aggregated scenarios showing total energy postulated to be on-line at various future dates in each of four of the five states. (The resources in Arizona, though potentially very large, have not been sufficiently explored to permit such postulations.) Chapter 5 thus takes the subject of geothermal development a step beyond the level of estimations and shows current or near-at-hand actual applications and beneficial uses of geothermal energy.

1.4 Economic Aspects of Geothermal Applications

Except for a few experimental or demonstration efforts subsidized by the Federal government, geothermal energy will be put to use only if investors can make satisfactory rates-of-return on their investments from bringing it to the surface and converting it into electricity or piping it to direct thermal users. That there is a possible profit from such enterprise is indicated by the fact that a number of investors have spent money to acquire geothermal leases and to drill exploratory or test wells. The extent of this activity in the Southwest is indicated in part in Chapter 4.

These investments have been tiny, however, as compared with the investments made in exploration for the more conventional fuels of oil, gas and coal. A facet of the Southwest Program has been, therefore, to perform economic analyses to determine what combination of circumstances must prevail to make geothermal exploration and development attractive to investors.

New Mexico Energy Institute developed a computer model to measure potential return on investments in geothermal production. A number of factors influencing profitability were identified and given baseline values as to the influence of each on the rate-of-return on investment. Changes of various factors were measured in simulations to determine the influence of such changes on the rate-of-return. Some of the factors, such as the physical characteristics of a given reservoir, are immutable, but others are institutional in nature and can be changed to enhance profitability if it is decided as a matter of public policy to do so.

Chapter 2 also reports the result of these simulations on a site-by-site basis to indicate which sites promise an adequate rate-of-return for either electric or direct thermal applications, given the baseline set of factors; the number of profitable sites can be increased or decreased by public policy changes in the factors.

1.5 Institutional Barriers to Geothermal Development

Some students of geothermal development believe that economics will determine the course of the future use of this energy resource.

Others believe that institutionsl constraints, mostly posed by government, are the major deterrents and argue that if these were removed or at least substantially reduced development would proceed expeditiously. The process of overcoming institutional constraints adds substantially to costs, of course, and thus become economic in nature. Lack of public awareness of geothermal energy also constrains development.

Chapter 3 details federal and state governmental land management and regulatory roles and partially indicates local governments roles in geothermal activities. It is evident that investors considering exploration for and development of the geothermal resource face numerous, complex, sometimes duplicative, and always costly and time-consuming governmental regulations sufficient to dim the prospect of eventual adequate return on investment. The federal role appears to be the most overwhelming, particularly in view of the fact that the Federal government owns about half of the total land in the five states and holds mineral rights on still more land and the further fact that a disproportionately large share of the identified geothermal resource is under federal ownership. Crude but convincing figures have been gathered to indicate that geothermal development is proceeding more rapidly on non-federal than federal land.

The Federal government does provide incentives as well as constraints to geothermal development, these including research, resource assessment, contracts or grants for demonstration projects, loan guarantees, and cost sharing for exploratory drilling when data obtained from such is made public.

1.6 Recommended Actions to Promote/Accelerate Development

The constraints to geothermal development are technological, economic and institutional in nature. The technological constraints have not been examined other than superficially by the Southwest Program. It is generally accepted that much of the needed technology is in hand and that further improvements and refinements will occur almost automatically if and when investors are convinced that an adequate rate-of-return can be realized.

Some institutional constraints can be mitigated, and thereby economic constraints will be reduced, through changes in public policies and procedures. Participants in the Southwest Program recognize that governmental entities must consider geothermal energy within the context of other public needs. They also recognize that sweeping governmental changes cannot be expected and might indeed be counterproductive to geothermal development.

Nevertheless, there is a consensus among participants in the Southwest Program that certain federal and state actions should be taken to promote and accelerate the use of this alternative energy source. A set of such recommended actions is provided in Chapter 6 with the caveat that they are not formally presented by either NMEI or any State Team participating in the program. They do reflect in a consensual way many expressions made by participants in the program, geothermal industry spokesmen, state officials, and federal agency officials.

CHAPTER 2

- how have these models been tested / calibrated?

2.0 Economic Analysis

New Mexico Energy Institute conducted an economic analysis for the potential geothermal development sites which had been identified throughout the Southwest region. The first objective was to determine the opportunity for the financial return from an investment in geothermal development, given various economic conditions. The analysis assumed that the development of geothermal energy by private or non-federal developers would occur only if it could result in a sufficient rate-of-return to be attractive to investors. To be attractive, an investment in geothermal development must compete with both other energy sources and other kinds of investments.

The second objective was to identify the influence of public policy factors upon the rate and magnitude of development of geothermal energy. Some conditions that are controlled by public policy, such as leasing requirements, taxation laws, royalty rates and interest rates, have an important bearing upon the potential for financial return in an investment. But without understanding the extent of that relationship, the benefits that could be derived from a change in such policy cannot be predicted. Therefore, a sensitivity analysis of the economic factors was designed to aid in that understanding.

Finally, from these analyses, it was hoped that those conditions that could be influenced by the Department of Energy, Division of Geothermal Energy, to improve the profitability of geothermal development investment could be identified. Making the indicated changes, then, presumably would stimulate the development of geothermal energy.

The approach used was to identify those geothermal sites which would result in a specified minimum internal rate-of-return on the investment in present value terms. The greater the present value of net revenues on the one hand, or the lower the cost of investments throughout the project life on the other, the higher the rate-of-return. For the development of electrical power, profitability for the resource developer was examined. The analysis takes into account the investments that are made for leases, wells, and interest payments throughout the life of the project.

2.1 Economic Models and Factors

For both the electric and the direct use economic analysis, simulation models were used to estimate the internal rate-of-return or profitability of investment in the development of various geothermal resource sites. The models are identified as GIRORA-Electric and GIRORA-Nonelectric (GIRORA = Geothermal Internal Rate of Return Algorithm). Their basis is the calculation of discounted cash flows for investment versus income. Where net income is equal to total revenues less operating costs and taxes, it must be equal finally to the total investment plus a reasonable profit in present value terms. The basic equation is:

$$\sum_{t=1}^{T} (\text{investment}_t)\ (1 + R)^{-t} = \sum_{t=1}^{T} (\text{net income}_t)\ (1 + R)^{-t}$$

For each site, the internal rate-of-return was calculated, postulating various plausible circumstances. Sites were then ranked by the highest rate-of-return to create a time-phased growth plan. The specific kinds of data used in the model for the potential electrical power generated on sites differs from those used for the potential direct use sites because of variations in the development operations for the two types.

2.2 Electric Power Generation

2.2.1 Analytical Approach.

The economic analysis of potential geothermal electrical power generation sites analyzes the potential profitability for two sectors, the producer sector and the utility sector. It assumes that both the power plants and the energy will be developed by the private or non-federal sector, but only if that development is profitable. It assumes, too, that geothermal energy is only one of a variety of energy sources available to the utility and, therefore, that it must compete in the energy market place. However, even though a particular resource is economically competitive, it may not be developed unless there is a sufficient demand for electricity. So, in order to draw conclusions about the probability of development of geothermal energy for electrical power generation, the forecast electric power demand is explored.

For the utility, the cost of energy is limited by the competitive price of electricity and the utility's regulated profit. Revenue values for the utility sector, therefore, are derived from the quantity and price of electricity. The price is defined as the busbar price as determined by the market, with escalation over time.

For the utility sector, the costs of electricity production are first established for capital investment for a specified kilowatt capacity, for operating expenses, for income and property taxes, and for the energy. Capital costs consider the regulated return to equity, the bond rate, the debt-to-equity ratio and the depreciation. Operating costs are assumed to escalate over time. The output of the utility sector analysis is the price of geothermal energy. The price and quantity of energy become the total revenue for the geothermal energy producer.

For the producer sector, the model is somewhat different from that of the utility sector for two reasons. First, the time segment is somewhat longer because of the period required for exploration and development of the field prior to generation of power. Second, the output of the producer model is the rate-of-return on the investment, which is a share of the total investment for each year of activity.

Cost components for the producer model include leasing, interest, drilling and operating costs. Total drilling costs vary depending upon the number of wells required, the production well success ratio and the drilling cost per foot. Other production cost variables include cost per acre, acres per well, exploration costs, pipe costs and other field development costs. Operating costs include property and income taxes, taking into account depreciation, investment and depletion allowances. A temperature decline is estimated in order to estimate the resultant need for additional wells. From the model is obtained the internal rate-of-return on the producer's equity for any given site.

2.2.1.1 Sensitivity Analysis. Initially, baseline parameters were established for certain variables for both the utility and the producer sectors. Although they were not necessarily considered to be typical, they provided points of departure. Table 2.1 lists the more important of these parameters, which may be grouped into three categories: resource, economic and policy.

- Resource - These parameters relate to the physical characteristics of the geothermal energy site. As shown in the table, the only resource characteristics given are downhole temperatures and flow rates. This reliance upon so few resource characteristics tends to oversimplify the conditions. Furthermore, most of the temperatures are not measured but are estimated using geochemical analyses. Flow rates must be estimated, as well, because of the minimal geothermal resource exploration conducted so far. However, given the current state of knowledge about the resources, these data are considered to be the most consistent and most appropriate ones available for this kind of analysis.

- Economic - In this category are those parameters that are affected by market decisions. They include the price of electricity, the bond rate, the equity and debt proportions of capital and the royalty rates.

- Policy - These variables are those specific to geothermal resource development that are directly affected by government policy. They include land policy and enviromental factors which affect the length of the exploration and development periods and taxation factors such as the depletion allowance, investment tax credit and depreciation rates. The economic variables may also be affected either directly or indirectly by government policy.

After establishing baseline parameters for these variables, alternative values were chosen in order to test the sensitivity of the internal rate-of-return to changes in them. The three groups of values, described as baseline, pessimistic and optimistic, are shown in Tables 2.1 and 2.2.

Table 2.1

Base Case Values

Geothermal Energy Producer

	Variable	Value
BR:	Bond Rate	0.085
CRRT:	Investment Tax Credit Rate	0.12
FR:	Flow Rate – for 1 well? one field?	585,794 lb/hr – wow! to 6 sig. fig!
TEMP:	Initial Downhole Temperature	190° C
EPK:	Equity Proportion of Capital	0.70
DPK:	Debt Proportion of Capital	0.30
λ:	Royalty Rate	0.10
Z:	Depletion Allowance Rate	0.00
EXP:	Exploration Period	0 years
DVP:	Development Period	8 years
TXRT:	Income Tax Rate	0.50
IRR:	Internal Rate of Return	0.15

Electric Utility

	Variable	Value
CAP:	Capacity	50,000 Kilowatts (Net)
LF:	Plant Factor	0.80
UF:	Plant Use of Power (Proportion)	0.18
PB_e:	Base Price of Electricity (Busbar)	0.021 ($/kwh; current $)
$\dot{P}$:	Escalation Rate of Base Price	0.05
EK:	Equity Proportion of Capital	0.50
DK:	Debt Proportion of Capital	0.50
UR:	Regulated Return to Equity	0.12
BR:	Bond Rate	0.085
TXRT:	Income Tax Rate	0.50

Table 2.2

Values of Choice Variables and Parameters: Optimistic and Pessimistic Market Scenarios

	"Pessimistic"	"Optimistic"
LF: Plant Factor	0.60	0.75
PB: Base Price of Electricity (Busbar)	0.021 ($/kwh)	0.030 ($/kwh)
$\dot{P}$: Escalation Rate of Baseline	0.05	0.065
D/E Utility: Debt to Equity Ratio for Utility Capital	1	1
D/E Producer: Debt to Equity Ratio for Producer Capital	1.5	1.86
Utility's Rate-of-Return	0.15	0.12
TXRT: Income Tax Rate	0.48	0.48
BR: Bond Rate	0.085	0.075
CRRT: Investment Tax Credit Rate	0.12	0.12
FR: Flow Rate	250,000 lb/hr	400,000 lb/hr
Royalty Rate	0.10	0.05
Depletion Allowance Rate	0	0.22
Exploration Period	5 years	5 years
Development Period	8 years	5 years

The baseline parameters were selected to yield a 15 percent rate-of-return from the GIRORA-Electric model. The pessimistic and optimistic values were individually selected as extreme values, rather than as an interrelated and collective set of pessimistic and optimistic conditions; for temperature 230° C, the calculated rates-of-return turn out to be 3 percent and 300 percent, respectively. In a separate activity, NMEI tested the effect that changes in each parameter had on the rate-of-return.

2.2.1.2 Site by Site Profitability. After testing the parameters individually, geothermal sites were tested using the baseline, pessimistic and optimistic groups of parameters indicated above to indentify the estimated internal rate-of-return possible from each combination. Since all the parameters except the temperatures in each group are the same for all sites, it was necessary only to test each of the different temperatures. The temperatures are then the indicators for determining which of the sites would fall into each of the groups. Resource temperatures equal to or greater than 190° C are required to produce a baseline case profitability of 15 percent or greater. The pessimistic case parameters require site temperatures to exceed 230° C in order to produce even a 3 percent rate-of-return; whereas the optismistic case yields a greater than 20 percent rate of return for temperatures as low as 150° C.

2.2.2 Results.

2.2.2.1 Baseline Case Sensitivity Analysis. The implications of certain kinds of changes in government policy on the rate or magnitude of electrical production from geothermal resources were derived from the sensitivity analysis. The analysis showed that changes in several of the variables would have minimal effect. Among these were the royalty rate and the depletion allowance. Increases in the magnitude of these two parameters serve only either to increase the profitability of sites which would be developed in any case or to increase the probability that additional sites would be developed.

Other factors seemed more likely to affect significantly geothermal development. The sensitivity analysis indicated that the most significant variables were the investment tax credit rate, plant factor, the bond rate, the temperature and the plant capacity. Changes in these variables most significantly affect the internal rate-of-return on the investment equity.

2.2.2.2 Site by Site Profitability. The results of the analysis of the internal rate-of-return, using the baseline assumptions for potential electrical power generation sites in the region are shown in Table 2.3. It is important to note here that the estimated or measured resource temperature was the only site-dependent resource factor used in this evaluation, since it is the only parameter which is known or estimated for all of the resource sites in the five states. Only those sites which have temperatures which yield rates-of-return equal to or greater than 15 percent are considerable "profitable" in this analysis. Once again, the listed values of the estimated power (MWe) in Tables 2.3 and 2.4 are those provided by the State Teams (see Chapter 5) and are not a product of the economic model calculations.

As indicated in Table 2.3 about 13,000 MWe could be produced at 43 sites, given the baseline case assumptions. The specific sites which make up the profitable listing for each state are given in Table 2.3. Using the pessimistic parameters reduces the estimated power produced by the geothermal energy in all five states to 3880 MWe. Using the optimistic parameters, on the other hand, results in an estimated power-on-line potential of 20,000 MWe.

Table 2.3

Site by Site Profitability
(Rate-of-Return 15% or More)

State	Pessimistic		Optimistic		Baseline	
	No.of Sites	Est.Power (MWe*)	No.of Sites	Est.Power (MWe)	No.of Sites	Est.Power (MWe)
Arizona	0	0	10	2450	5	400
Colorado	0	0	3	500	1	100
Nevada	2	1610	101	13600	31	9478
New Mexico	2	1970	5	2250	1	2000
Utah	1	300	5	1200	5	1200
Totals	5	3880	124	20000	43	13178

*MWe is power estimated by State Teams, not a product of economic analysis sizes of individual power plants are generally 20, 50, or 100 MWe.

Table 2.4

Listing of "Baseline" Profitable Sites by States

State	Site	Temperature ($^{\circ}C$)	Estimated Power (MWe)
Arizona	White Mountains	210	100
	Yuma	150-180	50
	Hyder Valley	200	50
	Springerville*	210	100
	Safford	210	100
	(State Total)		400
Colorado	Mt. Princeton	170-200	100
New Mexico	Valles Caldera	260	2000
Utah	Roosevelt	230	500
	Cove Fort	200	200
	Thermo	185	100
	West Cove Fort	200	200
	North Cove Fort	200	200
	(State Total)		1200
Nevada	The Needles Rocks	200	245
	South Smoke Creek Desert	200	65
	Dyke Hot Spring	200	245
	Bill Creek Reservoir	200	65
	Howard Hot Springs	200	65
	Humboldt Wells	200	245
	San Emidio Desert	200	245
	Double Hot Spring/Black Rock Hot Spring	200	735
	Gerlach	200	370
	Kyle Hot Springs	200	245

Table 2.4 (continued)

Listing of "Baseline" Profitable Sites by States

State	Site	Temperature (°C)	Estimated Power (MWe)
Nevada	Hot Springs (Tipton) Ranch	200	245
	Leach Hot Springs	200	735
	Smith Creek Valley	200	245
	Beowawe Geysers	245	1220
	Sulphur Hot Springs	200	490
	Ruby Lake	200	245
	Steamboat Spring/Huffaker	215	400
	Desert Peak	215	665
	Brady's Hot Springs	215	265
	Huxley	200	65
	Hot Springs Mountains	215	265
	Hazen	200	65
	Carson Sink/Alkali Flat West Side	200	65
	Carson Sink/Alkali Flat East Side	200	65
	Soda Lake/Upsal Hogback	215	400
	Stillwater	215	530
	Dixie Hot Springs	200	245
	Hyder Hot Springs	200	145
	Jersey Valley	200	145
	Fish Lake Valley	260	390
	Silver Peak Hot Springs	200	63
	(State Total)		9478

2.2.3 Policy Implications. The implications of certain kinds of changes in government policy on the rate or magnitude of geothermal development can be derived from the sensitivity analysis. The analysis showed that to increase the number of megawatts of electrical power generated by geothermal energy would require the creation of conditions that would enhance the development of lower temperature resources. Testing of the variables attendant to such development indicated that if the cost of capital could be lowered by increasing the tax credit by 4 percent or decreasing the bond rate by 2 percent, then as much as 7,000 MWe could be added to the total shown in the baseline case. A combination of the two could add about another 2,000 MWe. Any action which reduces the cost of capital to both the geothermal producer and the electric utility to this extent would have a similar result.

2.2.4 Market for Electricity. Although a minimum profitability for any given geothermal site was considered to be a necessary condition for development of that site, it may not be a sufficient condition. A sufficient market demand for energy must also exist to induce utilities to add or substitute geothermal electric plants for required or planned coal-fired electric plants. To identify this market demand, two tasks were performed. First, the relationship between the quantity of electricity demanded and other factors was estimated in order to project future electricity needs. Second, this projected need was compared with the planned electrical power generation capacity in the five state region.

For this effort, the consumption of electricity is considered to be a function of its own price, the price of natural gas, per capita income, population and the supply of electricity-using consumer durables. The model was tested using historical data. Then regional population and real income growth were projected and an estimated range of price increases for electricity and natural gas was obtained. From these data projections of electricity consumption were produced.

To predict the future supply, the electrical generating capacity existing and planned in the region was surveyed. The survey showed that 20,708 MWe are now on-line, with another 16,083 MWe of capacity planned by 1986. Reducing that to allow for replacement and generation requirements and transmission losses, the planned effective capacity for 1986 would be 25,965 MWe versus an existing 15,282 MWe. Further reducing the projected capacity by a constant 26 percent for exported power results in about a 19,214 MWe capacity.

Comparison with the projected need shows sufficient planned capacity up to 1990-1995. But, by the year 2020, the region may require an additional 30,000 MWe (net) of electrical power generation capacity for domestic use plus another 10,000-15,000 MWe (net) for export. If this is the case, geothermal steam-driven power plants could supply about 15-30 percent of the total capacity if it becomes an economically viable alternative.

2.3 Economic Analysis for Direct Thermal (Space Heating) Use.

2.3.1 Analytical Approach. Because of the transportability of electricity, the focus of geothermal development activity has in the past been upon electrical power generation. The incongruence between geothermal resource sites and energy market locations can be a limiting factor for direct geothermal use. But, in recent years, greater emphasis has been given to non-electric or "direct" use. One reason for this shift is that many more sites have temperatures suitable for direct use than have sufficiently high temperatures for power generation. In fact, in the Southwest region, 504 sites with temperatures of 150^{o} C or less were identified while only 80 sites with temperatures over 150^{o} C were identified, a ratio of 6 to 1. Also, a large porportion of the energy demand (an estimated 18 percent in 1968) is for low temperature space heating, a demand for which geothermal energy is ideally suited. Interest is generated, too, by the need for alternatives to fossil fuels for low temperature energy needs.

The analysis of low temperature geothermal resources differs from that for high temperature resources for several reasons. First, because of the number of sites, the breadth of the analysis is greater. Second, the variety of possible applications of low temperature geothermal energy vastly increases the complexity of the analysis. Such uses include residential and commercial space heating and cooling, water heating and cooling, and numerous industrial and agricultural heat processes. For this analysis, however, only the residential space heating application is considered, differing from the electric site analysis in that the energy consuming sector is assumed to be a district heating system, with no separation between producer and utility. Finally, the portability of the geothermal energy for direct use is much more limited than is electricity. This analysis must, therefore, consider market factors different from those in the analysis of the electrical power generation potential.

The data base for the geothermal resources in the region shows an estimated supply potential of the geothermal energy of 38,945 MBtu/h from a total 504 sites, as indicated in Table 2.5. This is, however, an exaggerated estimate of the energy potential, because it fails to consider the technical feasibility or the economic feasibility of use of the energy.

The following analysis, consisting of two stages, was conducted in order to estimate a more realistic potential of the geothermal resources in the region: first, a preliminary screening for technological feasibility was carried out; then an analysis of economic profitability on the remaining sites, based on certain parameters, was performed. This analysis provided the means for a sensitivity analysis to identify those parameters which could be affected by public policy changes to stimulate geothermal development.

Table 2.5

Distribution of Low Temperature Geothermal Resources by State

State	Number of Resource Sites	Estimated Supply Potential in MBtu/h
Arizona	40	1892
Colorado	45	1460
Nevada	328	30423
New Mexico	46	2969
Utah	45	2201
Total	504	38945

MBtu/h = Millions of British Thermal Units per Hour

2.3.1.1 Screening Model. In order to derive a more realistic picture of the low temparature geothermal energy potential, the identified sites were first exposed to a preliminary technological screening. The intent of this screening was to (1) show those sites which are currently usable given some assumptions about the current state of production technology and (2) those which are not considered usable given those assumptions.

Three criteria are used for the initial screening. The first is temperature, since effective and efficient space heating requires a minimum temperature, for this analysis considered to be 65° C (160° F). The second criterion is the distance between the geothermal resource and the nearest market, 50 miles or less being considered to be the maximum feasible. Finally, a minimum market size of 1,000 persons is considered to be necessary for development feasibility.

Several limitations of this screening are apparent. The temperatures are only estimated temperatures and are only a part of the resource information needed to screen the areas realistically. In addition, establishing specific boundaries for each of the variables without regard for their relative weights may eliminate some cases that should be included. For example, because of the high cost of transporting the fluid, a geothermal system located under a community of 900 population would more likely be profitable to develop than would a site 49 miles from a town of 1,200 population. Yet, the former would be screened out, the latter not. The lack of sufficient information precludes a very detailed preliminary analysis, however. And in spite of these limitations, the results of this screening should provide a much more realistic estimate of the low temperature geothermal energy potential than do estimates of the energy in the ground. The criteria are objective, rather than subjective. The majority of the most technologically feasible space-heating sites under current conditions should be identified assuming the validity of the estimated temperatures. Furthermore, as technological innovations occur and more information becomes available, the process can easily be reiterated using different values for the criteria.

2.3.1.2 Site-by-Site Profitability. An economic simulation model, GIRORA-Non-Electric, was used to evaluate the financial feasibility of the resource areas that remained following the technological screening. It estimates the profitability for a developer of a low temperature geothermal site for space heating. The sites can then be ranked by their expected development profitability, assuming that they will be developed in order of their relative internal rate-of-return. The model also provides a means to measure the estimated economic impact of policy variables and site-specific geophysical variables on the rate and magnitude of development.

The total investment costs considered are drilling investment, leasing costs, plant investment and interest paid during construction. During the exploration and development years, the investment costs are the sum of all four. During operation, they are drilling, leasing and interest. The drilling costs are determined by the number of wells, the average depth, and the cost unit depth. To determine the number of wells, the amount of hot water required to meet the space heating system demand is estimated. This is assumed to be 75 percent of the amount necessary to supply the peak heat load, with 25 percent of the peak supplied by back-up units. The user mix, among single-family homes and apartments, is specified, as well. Fifty percent of the total residential demand is assumed for the non-residential demand.

For transporting the geothermal fluid, a temperature decline proportionate to the distance is included in the calculations. Other costs include leasing and the cost of transmission and distribution lines.

For the purpose of the analysis, gross revenues are related to the average heating demand on the system. Reduction of this to net revenues takes into account variable expenses and taxes.

Testing each of 82 technologically feasible sites (as defined in Section 2.3.2.1 below) with this model indicates which of them would be most profitable to develop, given the values assigned to the variables. These sites can then be ranked on the basis of the estimated profitability, assuming they will be developed in that order. A more important function of the model, however, is to test the sensitivity of the internal rate-of-return to the given variables. The results of such testing helps to indicate which of them would be most responsive to deliberate change and what would be the probable magnitude of the impact of such change.

2.3.1.3 Sensitivity Testing. The calculation of a site-specific internal rate-of-return is valuable for still another purpose. By altering the values of variables, the sensitivity of the internal rate-of-return to such changes can be explored. Accordingly, baseline, optimistic and pessimistic values were selected for certain variables, the values are listed in Tables 2.6 and 2.7.

Table 2.6

The Baseline Case Values

Parameter or Variable		Base Case Value
TEMP	Temperature	100°
DIST	Distance	5 miles
PRICE ($\$/10^6$ Btu)	Price of Natural Gas	$3.00
LF	Load Factor	0.6
CRRT	Investment Tax Credit Rate	0.12
λ	Royalty Rate	0.15
Z	Depletion Allowance	0.0
POP	Population	5,000
BR	Producer Bond Rate	0.085
USER MIX	Homes/Apartments	50/50
EK	Equity Capital	0.3
R	Internal Rate-of-Return	0.11 (11%)

Table 2.7

Optimistic and Pessimistic Scenarios

Parameter or Variable	Pessimistic	Optimistic
Load Factor	0.5	0.9
Price ($\$/10^6$ Btu)	\$3.00	\$6.00
Royalty Rate	0.20	0.10
Tax Credit	0	0.20
Bond Rate	0.085	0.065
Depletion	0	0.22

These were then tested to see which of them were most influential in determining the internal rate-of-return. A subsequent analysis explored the impact of altering all the economic and policy variables as well as the load factor simultaneously.

2.3.2 Results.

2.3.2.1 Screening. The low temperature geothermal resource sites which had been identified in the region were screened based on the parameters of distance to a population which could use the energy for space heating. The process reduced the number of potential low temperature sites to 82. Table 2.8 lists the remaining sites and their estimated energy supply potential. Figure 2.1, shows their geographic distribution. These 82 sites represent 16 percent of the total 504 low temperature sites in the region.

Table 2.8

Distribution by State of Low Temperature Geothermal Resources Which Pass Initial Technological Screening for District Heating

State	Site	Estimated Supply Potential, MBtu/h
Arizona	Gillard H.S.	70
	Cat Tank	35
	Eagle Creek H.S.	82
	Safford Area	22
	Coolidge H.S.	117
	Castle H.S.	110
	Coffers H.S.	30
	Yuma	156
	Littleton	160
	Wilcox	29
	Casa Grande (North)	120
	Casa Grande (South)	114
Colorado	Craig Warm Water	21
	Roub H.S.	20
	Steamboat Springs	54
	Hot Sulphur Springs	27
	Idaho H.S.	50
	Glenwood H.S.	16
	South Canyon H.S.	4
	Colonel Chinn H.S.	3
	Hartsell H.S.	17
	Brown Canyon Thermal	37
	Poncha H.S.	54
	Don K Ranch	30
	Mineral H.S.	41
	Shaws Warm Spring	4
	Dutch Crawley	8
	Pagosa Springs	15
	Wagon Wheel Gap	22
	Cebolla H.S.	37
	Orvis	3
	Duray	20
	Lemon	18
	Rico	60
	Pinkerston	7
	Tripp & Trimble	20
Nevada	Cherry Creek H.S.	78
	Hot Pot Bloosom	32
	Mineral H.S.	7
	Hot Springs Point	8
	Warm Springs	10

Continued--

Table 2.8 (Continued)

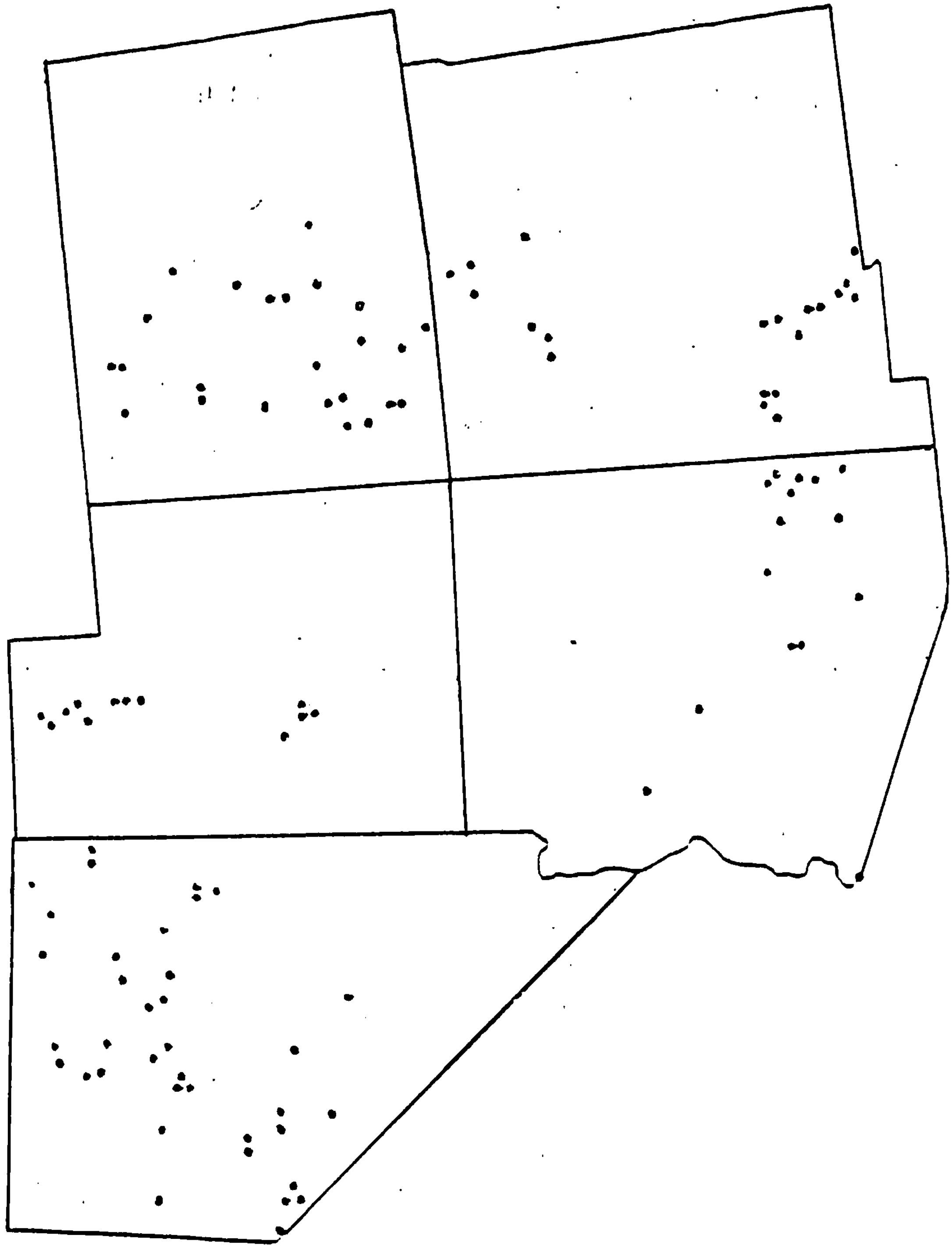
Distribution by State of Low Temperature Geothermal Resources

Which Pass Initial Technological Screening for District Heating

State	Site	Estimated Supply Potential, MBtu/h
Nevada (cont)	Sou H.S.	9
	Elko H.S.	44
	Sodaville Springs	40
	Walley H.S.	116
	Hind's H.S.	110
	Carson Lake	35
	Wilson H.S.	85
	Eightmile Flat	35
	Wellington	63
New Mexico	Radium Springs	141
	Ojo Caliente	141
	Gila H.S. (Below Bridge)	63
	Gila H.S. (Middle Fork)	14
	Montezuma H.S.	141
	Mamby's H.S.	90
	Turkey Creek	34
	Las Alturas	129
	Berino-Mesquite	129
	Ponce De Leon	40
	T or C	25
	W. Mesa-Black Mountain	98
	Derry Warm Spring	27
	Guadalupe Spring	128
	Hot Well	104
	San Ysidro	104
	Hueco-S. Tularosa	66
	Aleman	116
	Sandiego Mts.	134
Utah	Joseph H.S.	153
	Red Hill H.S.	147
	Crystal H.S.	147
	Abraham H.S.	136
	Wasatch H.S.	130
	Monroe H.S.	130
	Odgen H.S.	117
	Stinking Springs	117
	Meadows Springs	110
	Hooper H.S.	110
	Utah H.S.	99
	Becks H.S.	92
	Crystal H.S.	92

Figure 2.1

Technologically Feasible Low Temperature Sites in Southwestern Region for District Heating



2.3.2.2 Sensitivity Testing. The values of the geophysical economic and policy factors specified in Table 2.6 are variables in this model. Each of these factors exerts impacts upon the rate-of-return (R) which are, for the most part, clearly defined but quantitatively unspecified. For the sake of convenience, these factors have been grouped into three classes. The first class includes the geophysical factors, the second class includes the economic variables, and the third class includes the policy variables. The role of the geophysical factors in influencing R will be examined first.

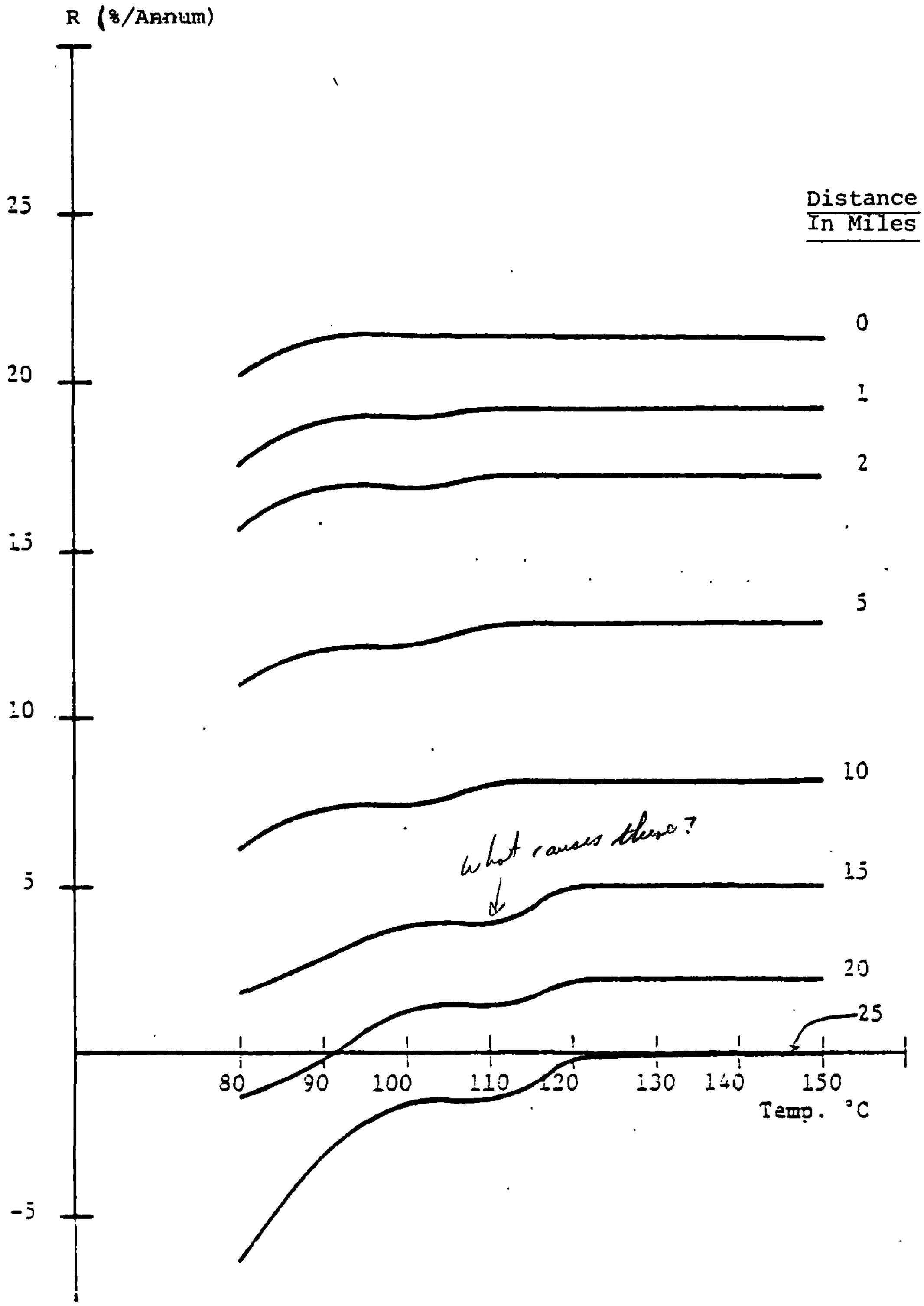
Consider the ramifications of variations in resource temperature upon the estimated rate-of-return. In this analysis, the temperature span considered ranges from 80° to 150° C. The changes in resource temperature clearly exert only minimal impacts upon the rate-of-return. If all other parameters and variables considered are maintained at their base case values, the rate of return is 11-percent at 80° C, and it rises to just over 12.5 percent at a temperature of 150° C. Such a finding, that lower temperature resources generate nearly as high a return as the hotter resources is encouraging given the abundance of relatively lower temperature anomalies in the Southwest.

Consider next the importance of the distance to the market as a determinant of the internal rate-of-return. Given the potentially large size of the transmission expense, changes in distance can be expected to exert substantial impacts upon the rate-of-return. Figure 2.2 depicts the effects of differences in distance between 0 and 25 miles when all other base case values are held constant. In order to maximize the information provided, the estimated rate-of-return is plotted against the resource temperature. In this manner, the interactive impacts of changes in distance and temperature become evident.

The distance over which geothermal fluid must be transported strongly influences R values for a given resource site. For example, at distances of 5, 15, and 25 miles, the rate-of-return falls from 12.75 to 10.0 to -0.25 percent at 120° C. In the case of a user who is located on site (distance = 0),

Figure 2.2

Sensitivity of R to Changes in Distance (in miles)



an estimated 21.5 percent would be earned. For space heating purposes, therefore, the distance between the resource and the user is of major importance in determining the financial return on investment in geothermal energy development.

The third geophysical parameter in which we are interested is the population of the district heating unit. Variations in population will alter both revenues earned and investment costs sustained. To clarify the net impacts upon R, populations sizes of 1000, 2000, 3000, 4000, 5000, 10,000, 15,000,20,000, and 25,000 have been proposed. Figure 2.3 summarizes the results for various temperatures between 80° and 150° C.

The results are highly informative. Changes in the rate-of-return are directly related to changes in population at all temperatures. For example, at 120° C, the return on investment rises significantly 1000 to 25,000 population. These findings indicate that sizeable financial incentives exist for investment in space heating for relatively larger versus smaller communities.

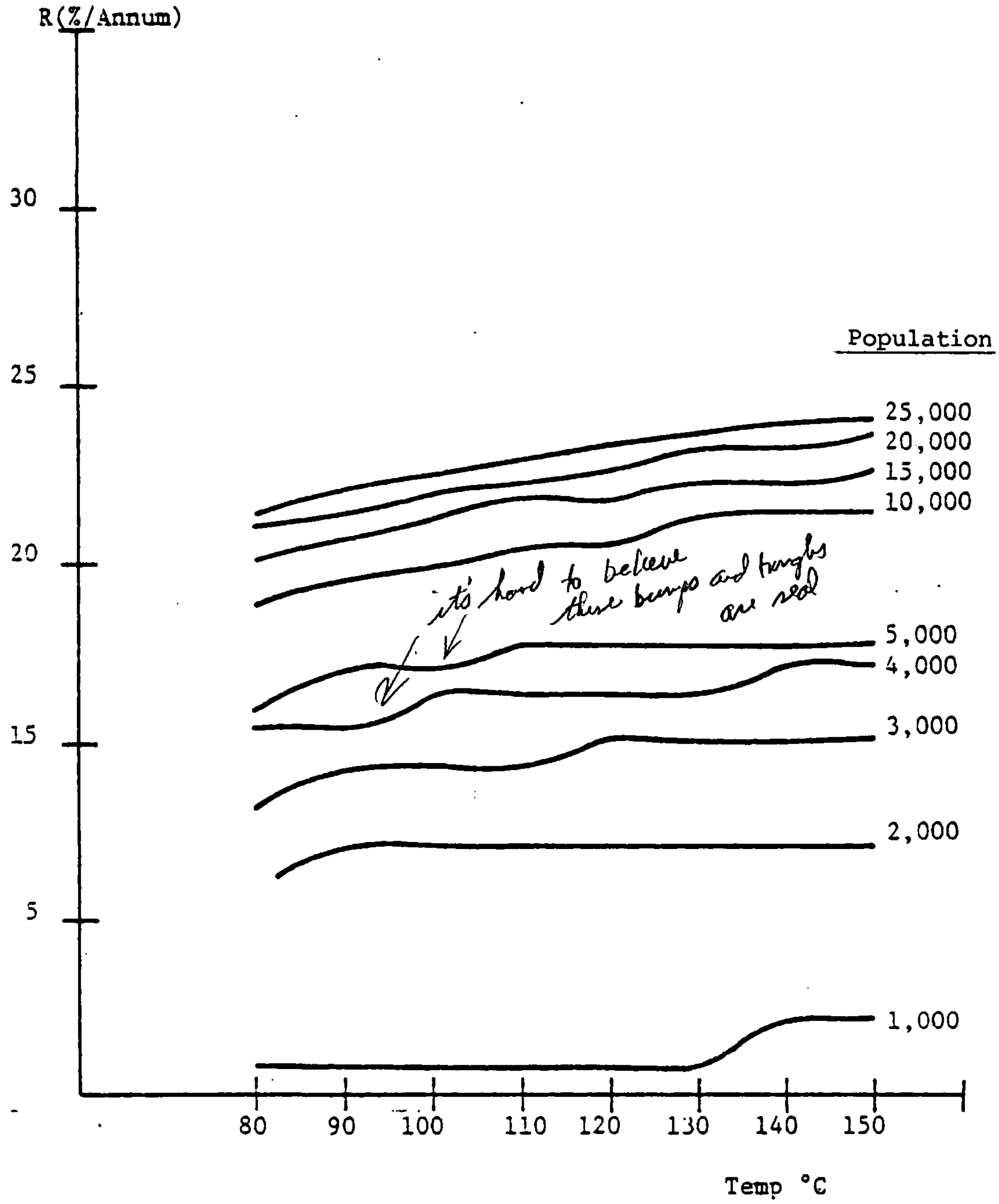
Two other characteristics of the user sites which may significantly affect the rate-of-return are the plant load factor and the user mix of single family homes versus apartments. The load factor may be considered to be a measure of efficiency of the physical plant. It is directly related to the revenues earned and is significant. The effect of the user mix, on the other hand, is not so obvious, since revenue earned and investment costs vary with changes in the user mix. The study showed that at temperatures below 130° C, the rate-of-return is directly related to a higher proportion of houses relative to apartments; but above 132° C, they are inversely related.

• Economic Variables - Changes in competitive fuel prices seem to offer the greatest potential for estimating the geothermal energy potential. The analysis showed that increasing the natural gas price from \$3.00 to \$6.00 per 10^6 Btu increased the rate-of-return for resources at 120° C from 13 percent to 24.5 percent. Although the bond rate and the royalty rate do affect the rate-of-return somewhat, they are less significant than other variables, particularly temperature, distance population and load factor.

• Policy Variables - The depletion allowance and investment tax

Figure 2.3

Sensitivity of R to Changes in Population



credit are two policy variables often mentioned as important to stimulate geothermal development. This analysis indicates they are relatively insignificant in their influence on the development of low temperature geothermal resources. The analysis shows that the rate-of-return would increase by 2.5 percent with a change in depletion allowance from 0 percent to 22 percent, at all temperatures. Similarly, raising the investment tax credit from 4 percent to 20 percent would only increase the rate-of-return by 1.5 percent. A combination of the two, however, could have a significant effect.

2.3.2.3 Profitability. The profitability of the geothermal resource sites in the region which survived the preliminary screening was examined. The findings of the analysis provide a rough estimate of the profitability of low temperature geothermal sites used for space heating, under certain conditions. To identify the rate-of-return possible from the low temperature sites, the set of baseline values shown in Table 2.6 were used. The internal rate-of-return resulting from the analysis was 11 percent, which should be sufficient to encourage the development of a geothermal site for profit. To assess the results of changes in the set of variables, two other scenarios were investigated. Specifying different values for a pessimistic and an optimistic scenario resulted in a dramatic difference between the rate-of-return for each. With the pessimistic values, the internal rate-of-return is 9.5 percent at 120° C, but with the optimistic values, it is 50 percent.

Subsequently, a minimum acceptable internal rate-of-return of 12 percent was chosen as a cut-off point to identify those sites which are likely to be developed if the parameters are accurate. This analysis showed that 30 of the 82 sites remaining after the technological screening could earn 12 percent or more, given the assumptions of the analysis. This amounts to 6 percent of the sites in the region and 6 percent of the total MBtu/h estimated to be available. Table 2.9 and Figure 2.4 show the final results of the technological and economic screening analyses. Figure 2.5 provides

Table 2.9

Summary Table of Technological and Economic Feasibility of Low Temperature Geothermal Resources in the Southwest for District Heating Applications

State	Total		Technological Feasibility		Economic Feasibility	
	No.of Sites	Available Heat MBtu/h*	No.of Sites	Heat MBtu/h	No.of Sites	Heat MBtu/h
Arizona	40	1892	12	1045	6	364
Colorado	45	1460	24	588	7	234
Nevada	328	30423	14	672	3	186
New Mexico	46	2969	19	1724	6	383
Utah	45	2201	13	1573	8	904
Total	504	38945	88	5602	30	2071

Technological Feasibility:

Temperature: 65 C $\leq$ T <150 °C

Population: 1000

Distance: 50 miles for single population center

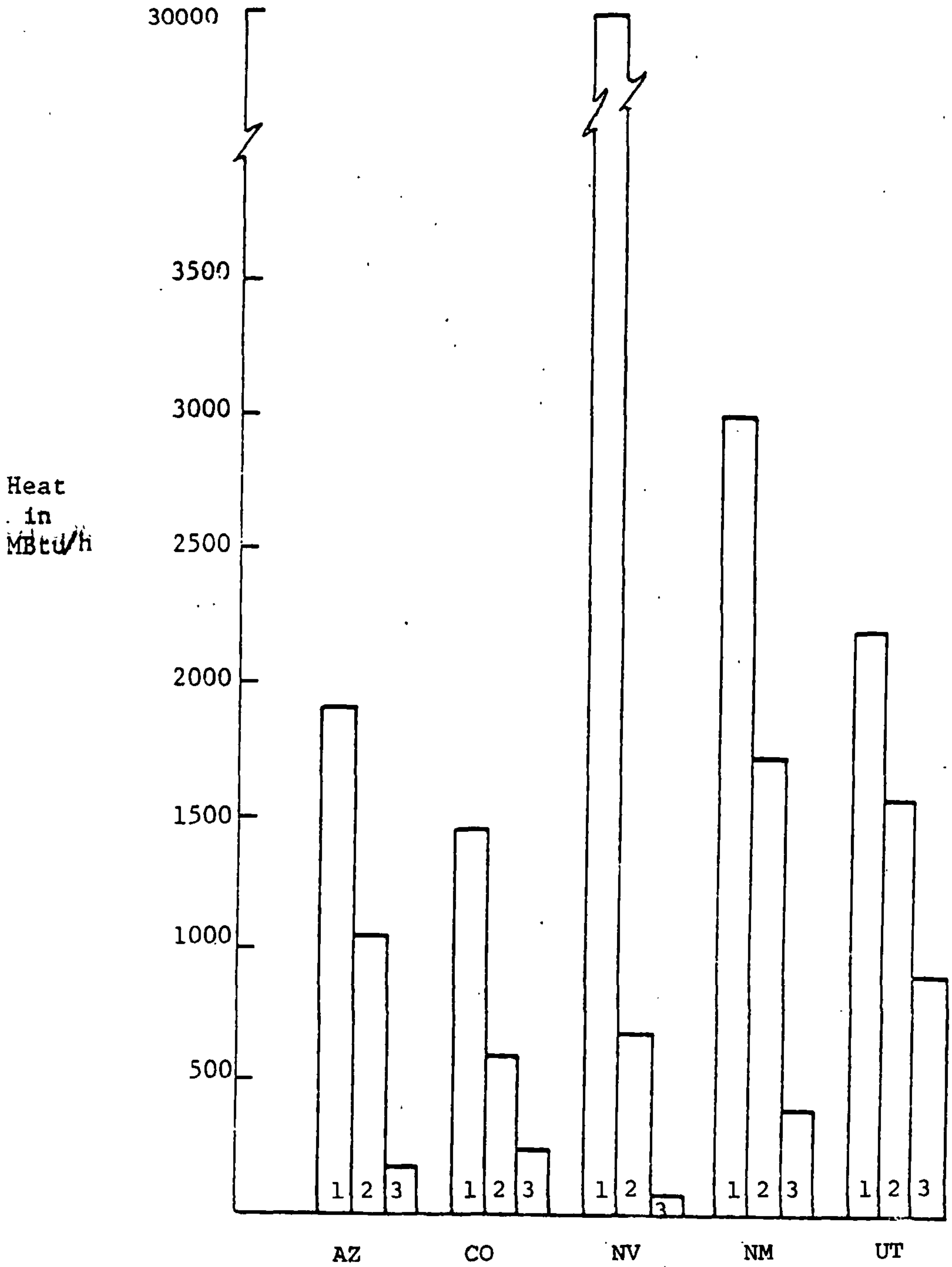
Economic Feasibility:

Rate-of-Return $\geq$ 12% from GIRORA - Nonelectric

*MBtu/h = Millions of British Thermal Units per Hour

Table 2.4

Estimated Energy Potential of Low Temperature Geothermal Energy Before and After Technological and Economic Screening for District Heating Applications



1) Total Energy

2) Technological Screen

3) Economic Screen

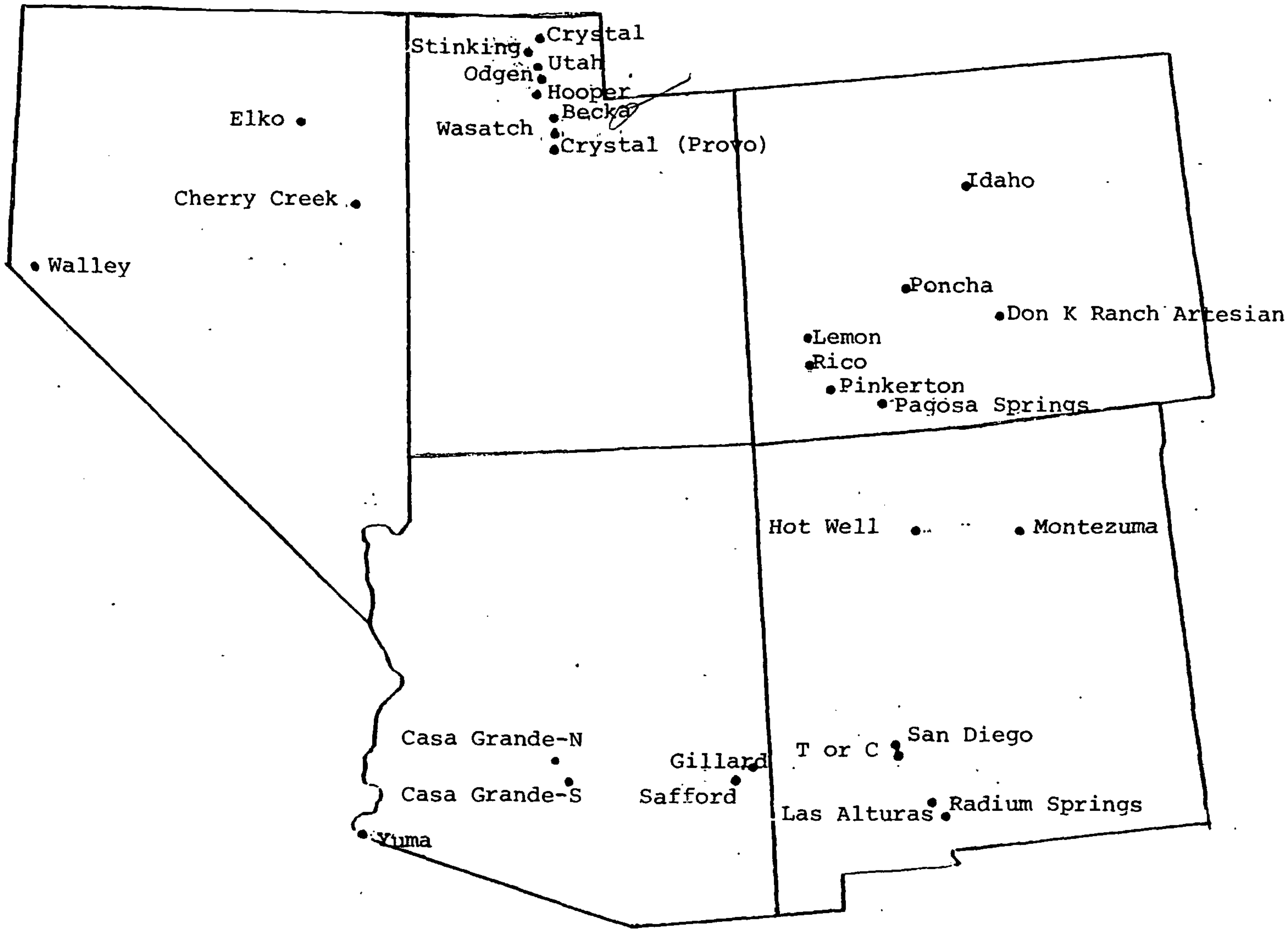


Figure 2.5

Economically Feasible District Heating Sites in the Southwestern Region a map of the five state region, which identifies the location and names the 30 remaining sites.

<u>2.3.3 Policy Implications.</u> Several conclusions may be drawn from the analysis of low temperature geothermal resource sites. According to the analysis, unless a relatively hot geothermal resource is located reasonably near a space heating district of good size, the ability of investors to obtain a reasonable profit from its development for space heating will be limited. Clearly, the larger the community the greater will be the profitability for investors. Furthermore, most of the policy options that were considered, including royalties, investment tax credit, depletion allowance, and the cost of capital, seem to be of limited effectiveness in raising the internal rate-of-return. The price of alternative fuels and the geothermal plant load factors are exceptions. Finally, effectively combined policy initiatives and efficient load factors may generate improvement in the internal rate-of-return. In short, a "carefully orchestrated mix of policy alternatives will evidently be required to encourage the orderly and timely development of geothermal energy for district space heating" (Source: NMEI Final Report, Chapter 5, August 1978.)

CHAPTER 3

3.0 Institutional Procedures, Constraints and Incentives

Industry is hesitant to commit the extensive capital--estimated at $75 billion over the next 20 years--to achieve the potential for development and use of geothermal resources. It is widely believed that this hesitance is caused by (a) restrictive laws, court decisions, and regulations, and (b) actions and interactions of a large number of individuals who singly and jointly made decisions that are unresponsive to the needs of the industry. Many if not most developers believe, or talk as if they believe, that institutional factors are the major cause for the long delays and high costs associated with geothermal development.

This is challenged by others who believe that the principal impediments to rapid geothermal development are uncertainties about the resource itself, the technology required for development, and the overall economic risk. Those holding the latter view recognize, however, that legal and institutional factors can accentuate the uncertainties and risks of investment, and increase costs. Whether major or secondary in their impacts, institutional factors are serious deterrents to use of the geothermal resource.

The Southwest Program has sought to identify the individuals and agencies whose single and interactive roles affect the rate of development. Four major classes of these are suggested: (a) federal agencies and regulations; (b) state agencies and regulations; (c) policies and decisions of resource developers and utility companies; and (d) attitudes and actions of local officials and residents. During its first year, the Southwest Program concentrated on identifying pertinent state laws and state agencies and reviewing federal laws and agencies. The activities and perceptions of the latter two categories of institutions, inadequately assessed thus far, are being studied during the second year.

These institutional studies serve to identify the factors constraining development, to assist in presenting accurately the time-phased scenarios for development presented in Chapter 5, and to arrive at policy recommendations.

for mitigating or overcoming institutional constraints, some of which are informally made in Chapter 6. All of these can increase public understanding of the issues at hand and provide information to lawmakers, administrators, and other decision-makers which will help them in resolving the issues.

3.1 The Federal Role

Federal laws and the administrative and regulatory activities of federal agencies play a major role in geothermal development because (a) a large percentage of identified and expected resources in the five Southwest states are on federal land, (b) national energy policies serve as a model for and actually stimulate formation of state policies, (c) federal tax relief, grants, and loans will provide significant economic incentive, and (d) the Federal government originates and enforces environmental protection and conservation regulations.

3.1.1 Relevant Laws and Regulations.

The first three laws listed below pertain directly to geothermal energy, the others pertain to environmental protection and conservation and substantially affect development.

(1) The Geothermal Steam Act of 1970 controls leasing of federal lands and post-lease operations on these lands.

(2) The Federal Nonnuclear Energy Research And Development Act of 1974 mandates the active encouragement through commercial demonstration.

(3) The Geothermal Energy Research, Development, and Demonstration Act of 1974 authorizes and defines more specifically federal responsibilities in geothermal development and demonstration and provides for grants, contracts, and loan guarantees for private developers.

(4) The National Environmental Policy Act of 1969 has profound effects in calling public attention to the environmental consequences of major new projects; it has led to enactment of similar state laws; it requires environmental impact statements describing adverse impacts of a development, discussing alternatives to the proposed development, and describing irretrievable resource commitments.

(5) The Clean Air Act of 1970 (as Amended) provides for establishment of air quality standards which must be maintained.

(6) The Federal Water Pollution Control Act of 1972 applies to geothermal development in several sections; it provides for establishment of effluent guidelines which have not yet been developed for the geothermal industry but which may be expected.

(7) The Noise Control Act of 1972 provides for noise control regulations, many of which will be applicable at geothermal facilities.

(8) The Safe Drinking Water Act of 1974, administered by the Environmental Protection Agency (EPA), provides for state implementation of its provisions. Included is control of underground injection. Reinjection of spent geothermal waters is an integral part of most existing and proposed developments.

(9) The Resource Conservation and Recovery Act of 1976 is concerned principally with solid wastes. Regulations under it will significantly pertain to the geothermal industry in cases where brine impoundments are used and waste sludges are created.

(10) The Toxic Substances Control Act of 1976 is aimed principally at toxic chemical manufacturers and distributors; geothermal producers may be involved if by-product minerals are extracted from waters.

(11) Land Policy and Management Act of 1976; (12) National Forest Management Act of 1976; (13) Fish and Wildlife Coordination Act; (14) Endangered Species Act; (15) Wilderness Act; and (16) Marine Protection, Research and Sanctuaries Act. These federal laws can come to bear frequently on geothermal developments in southwestern localities.

3.1.2 Activities During Development of a Federal Geothermal Resources. As shown in Table 3.1, almost half the land in the five-state region is federally owned and as shown in Table 3.2 mineral rights under an additional 47.34 million acres are reserved to federal ownership. Furthermore, although precise data has not been assembled, it is widely accepted that a disproprotionate share of the geothermal resource is found under this federal land as contrasted with state and private properties.

Table 3.1

Land Ownership (x1000 acres) in Southwest Region

State	Total Acreage	Federal		State		Private	
		Acres	%	Acres	%	Acres	%
AZ	72,688	32,433	44.6	9,222	12.7	31,033	42.7
CO	66,486	24,152	36.3	3,233	4.9	39,101	58.8
NV	70,264	50,725	86.4	86	0.1	9,453	13.5
NM	77,766	26,388	33.9	11,032	14.2	40,346	51.9
UT	52,697	35,060	66.5	4,923	9.3	12,714	24.2

Table 3.2

Mineral Acreage Reserved to the State and to the United States

State	Mineral Subsurface Estate	
	Reserved by State	Reserved by U. S.
Arizona	1,000,000	5,662,640
Colorado	1,000,000	12,929,974
Nevada	-------	738,593
New Mexico	2,000,000	24,275,069
Utah	919,000	3,765,561

Source: Adapted from Sacarto, D.M., State Policies for Geothermal Development, National Conference of State Legislatures, November, 1976

Thus the Federal government is the by far largest single actor in its landlord role of issuing geothermal leases and regulating activities under these leases.

Additional complications may appear when a geothermal reservoir lies under land of mixed federal and state or private ownership, as is often the case.

Six phases of the federal leasing and regulatory processes are defined below, with the first phase broken into two parts. Figure 3.1 depicts the first five of the phases.

(1) Pre-Lease Exploration.

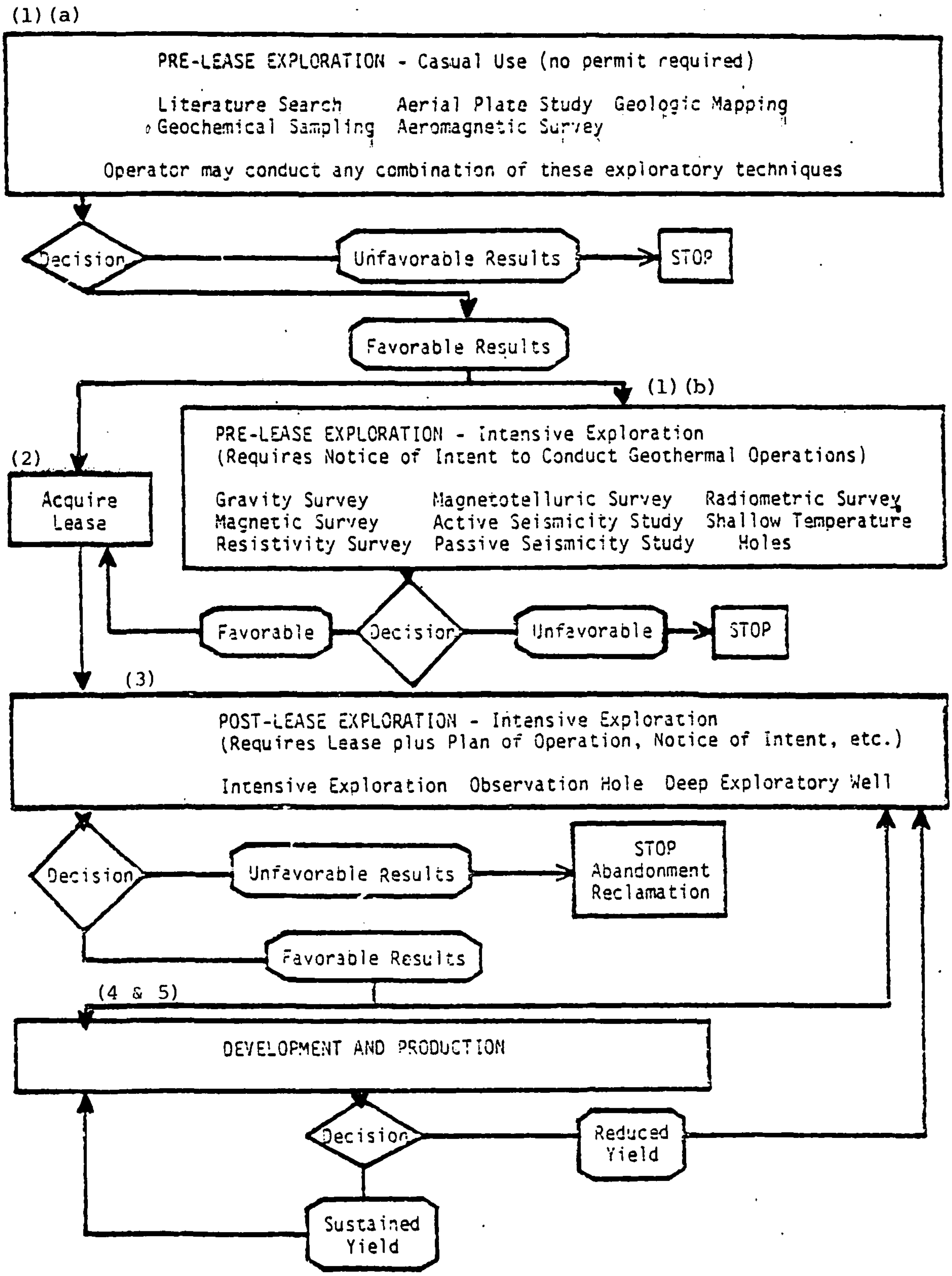
(a) Casual Use. At this stage the company or individual considering development of a geothermal resource makes only casual use of the land, defined in 43 CFR 3209 as meaning activities which do not ordinarily lead to any appreciable disturbance or damage to lands, resources or improvements. Use of heavy equipment or explosives is not involved, nor is vehicular movement except over established roads and trails. This use does not require a permit or an environmental assessment. The potential developer confines his activities to such things as literature review, geological reconnaissance, geochemical survey, and airborne surveys. On the basis of such limited review of the resource, the developer may elect to abandon the project or to enter into more intensive exploration.

(b) Exploration Operations (more intensive exploration) are defined in 43 CFR 3209 as "any activity which requires physical presence upon public land and which may result in damage to public lands, or resources." These operations may include, but are not limited to, geophysical operations, drilling of shallow holes of no more than 500 feet depth to calculate temperature gradients, construction of roads and trails, and movement of vehicles off roads and trails. Required for each activity of this sort is permission from the agency managing the land--either Bureau of Land Management (BLM) or Forest Service (FS). The explorer must file a notice of intent for each operation proposed, along with a $5,000 security bond or rider to a state-wide or nation-wide bond. Within 30 days the BLM and/or the FS prepares an

Figure 3.1

Typical Exploration and Development Sequence

Adapted from R. Raschen and W.S. Cook, Exploration and Development of Geothermal Resources; Geothermal Division, Office of the Area Geothermal Supervisor, U.S. Geological Survey, Merlo Park, CA.



Environmental Assessment Record (EAR) evaluating impacts of the proposed activity. Fish and Wildlife Service (FWS) and Geological Survey (GS) provide some input to this document in the form of special stipulations designed to reduce or eliminate adverse impacts. When this is done, BLM or FS approves the activity with all necessary environmental protection stipulations attached.

After the exploration project has been completed, the permit holder files a notice to that effect; the BLM or FS inspects the project location within 90 days and notifies the project holder if he has complied satisfactorily with all regulations and stipulations. The explorer decides, based on exploration findings, whether to abandon or continue pursuit of the project.

(2) Leasing. If the decision is to proceed, a lease of the federal land is then sought. Leases may be sought on either competitive or non-competitive basis.

(a) Competitive leasing is required on designated tracts of land within areas defined by GS as Known Geothermal Resources Areas (KGRAs). These tracts have been defined on the basis of previously accumulated information about surface and subsurface geology, drill log data, chemical analysis of water or by competitive interest in the area.

Procedures followed by BLM or FS in securing competitive bids and awarding leases are comparable to those used in other forms of mineral leasing, particularly oil and gas leasing. Winner of a lease must submit a "plan of exploration."

(b) Non-Competitive Leasing. Such leases are issued on any available federal lands outside of a KGRA, where geothermal resources supposedly have a lower potential. The applicant submits his application, bond or bonds, an application fee, and a proposed plan of exploration to the proper BLM or FS office. No bonus bids are required.

Provisions in both competitive and non-competitive lease contracts allow the government to provide protection for other natural resources in compliance with federal regulations affecting environment, antiquities, historic values, etc.

Figure 3.2 depicts the many stages and steps followed before issuance of a lease, separate charts being provided for competitive and non-competitive procedures, and identifies the agencies involved in each step. Figure 3.3 then traces the steps required and the agencies involved in the remaining stages leading to actual production.

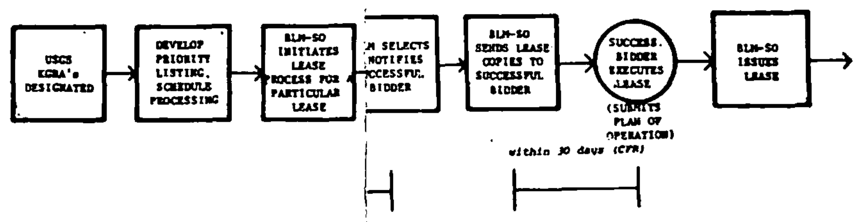
(3) Post-Lease Exploration. After a lease is issued, a "plan of operation" must be filed and approved by the land management agency (BLM or FS) and GS before any other activity than casual use is undertaken. Such a plan typically proposes the drilling of one or more exploratory wells. The plan, accompanied by maps, must describe all exploration activities. GS, as the lead agency at this stage, sends copies of the plan to all other interested agencies for comment. GS must prepare an Environmental Analysis (EA) covering the specific site of the plan. An on-site inspection with representatives of the lessee,GS, and the land management agency is conducted to assess potential impacts of the proposed operation. The plan and a draft EA are presented to the Geothermal Environmental Advisory Panel (GEAP), which advises GS on the environmental impacts of the plan and recommends mitigating measures. Following this input, the EA is completed and the plan is approved jointly by GS's area geothermal supervisor and the appropriate land management agency. Special conditions or stipulations deemed necessary to protect the environment may be attached.

The lessee applies for a permit(s) to drill one or more wells, and only upon approval by GS commences operations authorized under the plan. Also, the previously defined pre-lease exploration methods may be applied more intensively, as in drilling geological information holes, deeper exploratory wells (over 500 feet), and the like. Clearing and leveling of one to two-acre drilling pads, construction of service roads, etc., may be required. The lessee's operations are continuously monitored by GS's area geothermal supervisor to ensure that applicable regulations and stipulations are complied with.

(4) Development. If, on the basis of encouraging findings in the exploratory well or wells, the lessee elects to develop a geothermal field, he must file a "Plan of Development." GS then prepares another EA, and the

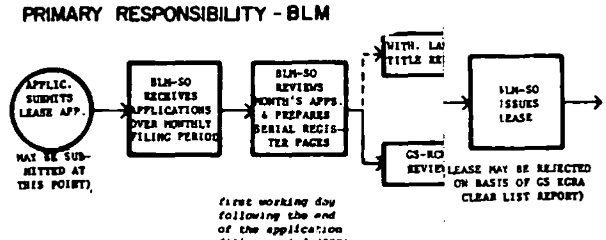
COMPETITIVE LEASING

PRIMARY RESPONSIBILITY - BLM



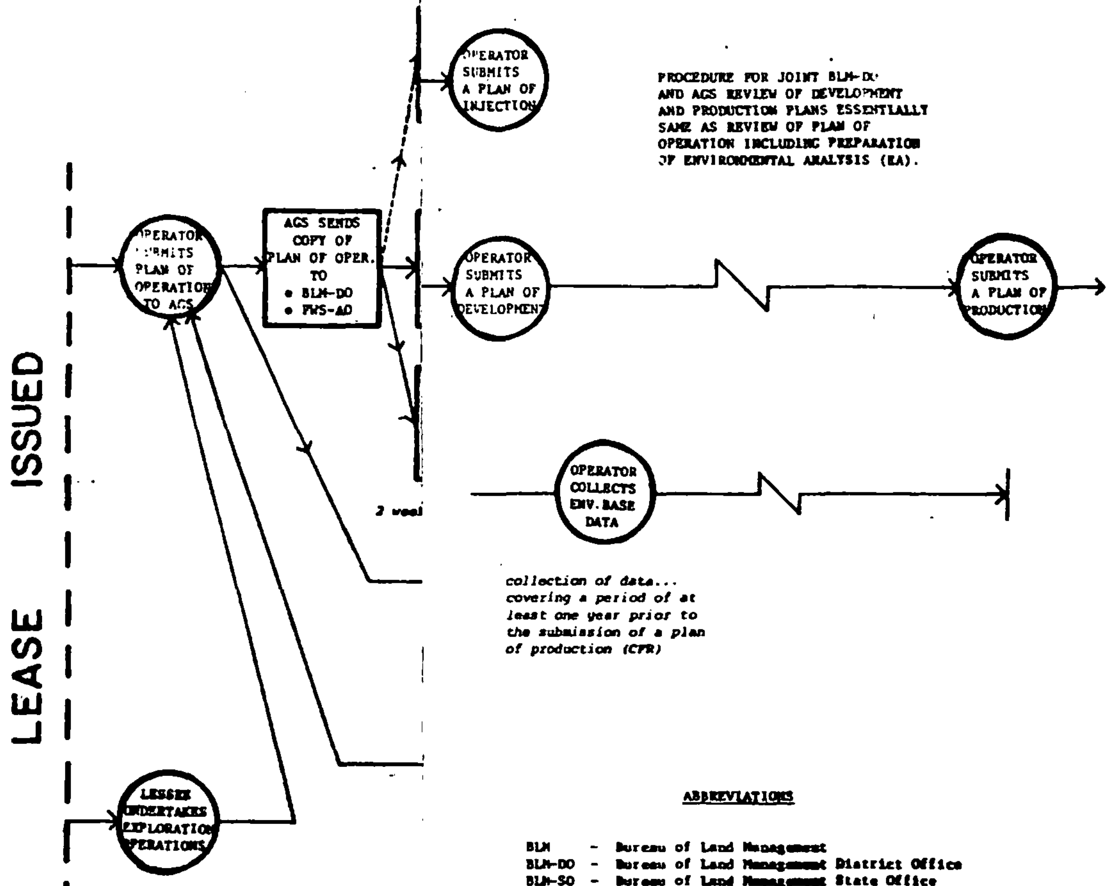
NONCOMPETITIVE LEASING

PRIMARY RESPONSIBILITY - BLM



ABBREVIATIONS

BLM - Bureau of Land Management
BLM-DO - Bureau of Land Management District Office
BLM-SO - Bureau of Land Management State Office
GS - U.S. Geological Survey
GS-RCM - U.S. Geological Survey, Regional Conservation Manager
AGS - Area Geothermal Supervisor
GS-AG - U.S. Geological Survey Area Geologist
GS-DG - U.S. Geological Survey District Geologist
FWS - Fish and Wildlife Service
FWS-RO - Fish and Wildlife Service Regional Office
FWS-AO - Fish and Wildlife Service Area Office
EAR - Environmental Analysis Record (prepared by BLM)
EA - Environmental Analysis (prepared by GS)
GEAP - Geothermal Environmental Advisory Panel
R/C - Agency Review and Comment
DOE - Department of Energy



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ABBREVIATIONS

BLM	-	Bureau of Land Management
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BLM-SO	-	Bureau of Land Management State Office
GS	-	U. S. Geological Survey
GS-RCM	-	U. S. Geological Survey, Regional Conservation Manager
AGS	-	Area Geothermal Supervisor
GS-AG	-	U. S. Geological Survey Area Geologist
GS-DG	-	U. S. Geological Survey District Geologist
FWS	-	Fish and Wildlife Service
FWS-RO	-	Fish and Wildlife Service Regional Office
FWS-AO	-	Fish and Wildlife Service Area Office
EAR	-	Environmental Analysis Record (prepared by BLM)
EA	-	Environmental Analysis (prepared by GS)
GEAP	-	Geothermal Environmental Advisory Panel
R/C	-	Agency Review and Comment

GEAP again recommends mitigating measures for protection of the environment, which may include additional stipulations. GS and the land management agency may then authorize commencement of the development operations. Normally a number of wells must be drilled, each in the same manner as those in the post-lease exploratory stage and under similar considerations, conditions and restrictions.

(5) Production. The lessee must collect data concerning existing air and water quality, noise, seismic and land subsidence impacts expected, and the ecosystem of the leased lands for at least one year prior to submission of a "Plan of Production". This may involve revising the plan of development. At this point additional uses of federal lands for such purposes as erection of power generation facilities, pipelines, transmission lines, or other facilities. An additional EAR is required before issuance of a permit to make such use of the land. (This permit does not constitute a license for construction of power generation facilities, which may be obtained only by securing a certificate of public convenience and necessity from the state public utilities commission.)

(6) Close-Out. A sizeable geothermal field will be abandoned gradually as the resource is depleted, a smaller one perhaps more abruptly. Plugging and abandonment of wells, involving appropriate subsurface filling-in, removal of surface installations, and rehabilitation of the service, must be done in accordance with Geothermal Resource Operation Order No. 3.

3.1.3 Summary of Federal Participants and Activities. The foregoing section describes only the regulatory interactions of federal agencies with the entrepreneur seeking to place geothermal energy on line. From the entrepreneur's point of view, all these complex and tedious activities are essentially negative, in that they are costly and time-consuming. Not included are the potentially positive impacts of federal research and development contributions, loans, and grants. These positive impacts involve a number of other institutional interactions not addressed here.

Several separate classes of activities are cited above, carried out by agencies and individuals with different objectives and responsibilities who work in a context of potentially conflicting and restrictive rules and regulations.

Investors seek to minimize the time and money involved in developing geothermal resources in order to maximize profits, or the opportunity for profits. They may decide to continue or to abandon their efforts at any point in the process described above whenever they find the resource to be of unacceptable quality or volume to warrant further investment and risk. In making their calculations, investors must consider the money and effort involved in meeting each of the institutional constraints. Costs include the expenses of preparing applications and environmental studies and reports, bonds and fees and technology for mitigating environmental damage.

The objectives of government agencies differ. While they generally are not opposed to and may indeed be supportive of geothermal development, they are obliged by law and regulation to assure that development and associated activities are compatible with air, water, wildlife, noise and other standards established by laws cited above. They must hold public hearings before granting permits. They have a general responsibility for controlling the pace of development and there are pressures on them to achieve politically acceptable resolution of issues between pro- and anti-growth forces. Public interest groups and citizens influencing these resolutions may differ among themselves in their attitudes toward geothermal development, but in general they have rather little knowledge about the details of this unfamiliar technology and many of them are concerned with minimizing adverse environmental and socio-economic impacts. More extensive public information is desirable, as will be noted in Chapter 6 below, in which recommended actions will be discussed.

<u>3.1.4 Federal Response to Legal and Institutional Barriers.</u> The federal geothermal program is intended to stimulate commercial development of geothermal resources by private industry and local public power authorities. The program

goal is to increase commercial use from the present rate of 0.04 quads per year to about 6.0 quads by the year 2000 and to over 16 quads by 2020. One step toward this end has been establishment of the Interagency Geothermal Coordinating Council depicted in Figure 3.4. As shown in the top box of this chart, six major departments and agencies of government are involved. While the figure does not delineate the fact, more than one agency of some of the departments is involved, as for example BLM, GS and FWS in Interior.

Three panels are provided for under the council, one of these being the Institutional Barriers Panel (IBP). It has identified several problems and has made recommendations to the council; actions to implement some of the recommendations are underway in various agencies.

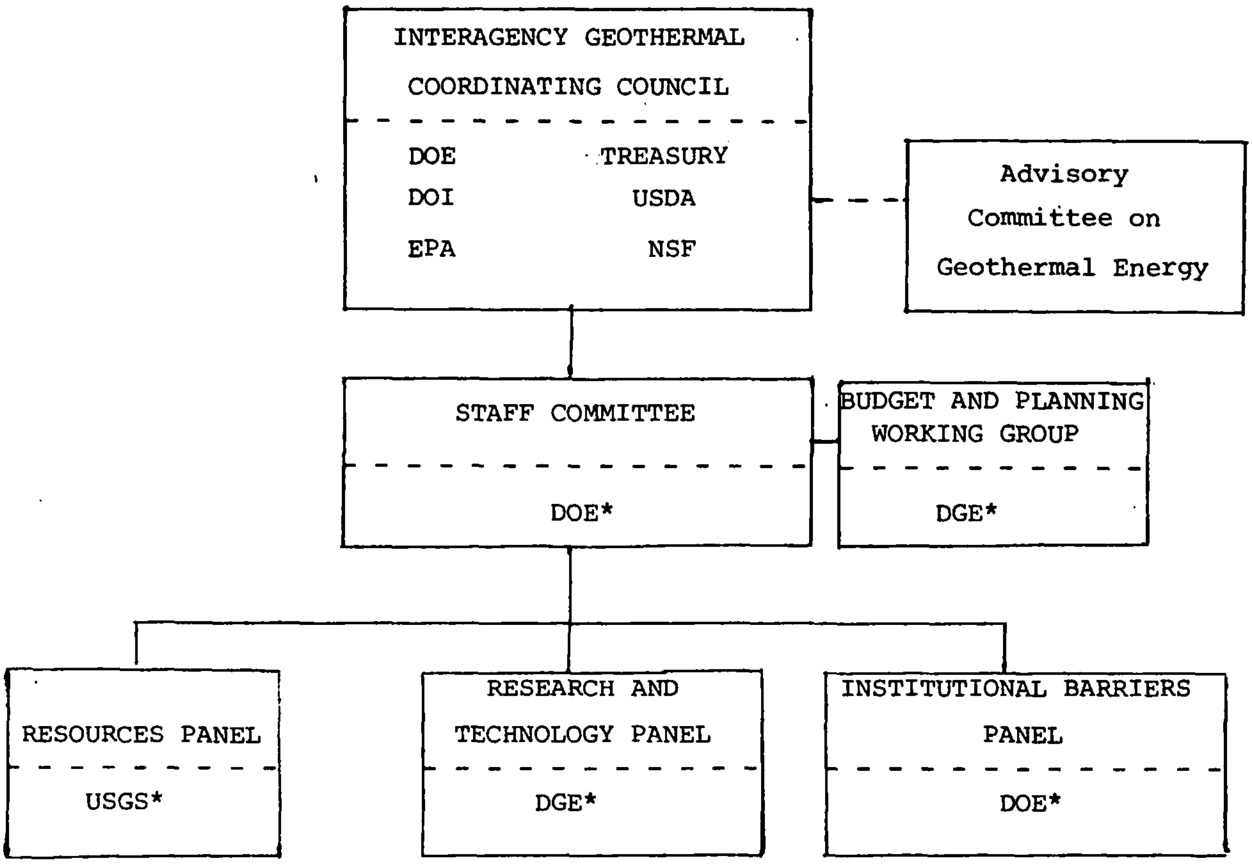
IBP has identified problems associated with delays in obtaining leases, environmental reviews and various permits. Due at least in part to activities of the council, the directors of BLM, GS and FWS have entered into a memorandum of understanding to cooperate on a set of procedures for federal land management practices designed to expedite activities and reduce uncertainties.

This memorandum applies only to land under control of the Department of Interior, while in the Southwest many large tracts of land with geothermal potential are managed by the Forest Service of the Department of Agriculture. By Presidential mandate, an Interagency Geothermal Streamlining Task Force has been formed to coordinate activities of the Departments of Energy, Interior and Agriculture. It is studying options for speeding up federal performance in issuance of leases and regulations of activities on leased federal geothermal lands. Table 3.3 portrays some of the time delays which have occurred in federal leasing, provoking considerable criticism from investors.

3.1.5 Concluding Comment on Federal Barriers. The Southwest Team studied much of the extensive literature now existent on federal institutional barriers to geothermal development. Various mitigating measures are recommended in such literature; others are suggested by the Southwest Team. These will be summarized in the recommendations section of this summary, Chapter 6.

Figure 3.4

Interagency Geothermal Coordinating Council



*CHAIRMANSHIP FUNCTION

3.2 State and Local Laws and Regulations

The federal role in geothermal development, presenting time and cost barriers to rapid geothermal development, was summarized in Section 3.1, preceding. While pervasive, complex, and tedious, it is at least more subject to summarization and description than the more heterogenous state and local legal and institutional roles. While there are many generic similarities in the activities of all states and local governmental units, the variations

Table 3.3

Age of Noncompetitive Lease Application Still Pending for Federal Land (as of April, 1978)

State	Less than 12 mos.		12-23 mo.		24.35 mo.		More than 35 mo.		Total	
	BLM	FS	BLM	FS	BLM	FS	BLM	FS	BLM	FS
AZ	5	27	11	0	2	26	7	1	25	54
CO	0	0	0	0	0	0	9	27	9	27
NV	53	1	7	0	17	1	197	8	274	10
NM	34	11	24	0	8	3	144	28	210	42
UT	38	2	34	15	9	3	135	41	216	61
Totals	130	41	76	15	36	33	492	105	734	194

BLM -- Bureau of Land Management

FS -- Forest Service

Source: Streamlining Task Force of Interagency Geothermal Council, June, 1978.

from state to state and community to community are sufficient to make generalization unsafe. The investor considering a geothermal venture is obliged to study with care applicable state and local laws and regulations. The state policy maker, such as a state legislator, also must examine specifically his own state's laws and regulatory practices and procedures. In so doing, however, he may find it helpful to study and make comparisons with neighboring states.

The Southwest Program sought in its first year to identify state and local institutional participants and roles. This activity was delegated to the State Teams in the various states and each state team approached the task from its own point of view and followed its own methodology. A certain unevenness in the five State Team reports resulted.

This summary presents a condensation of each state report. These, while not comprehensive, provide valuable information to policy makers who wish to consider making improvements and to those researchers who wish to study the matter further. Following the five state condensations, a generalized but limited summary is provided. Some recommendations for mitigation of these barriers are provided in Chapter 6 of this summary.

3.2.1 Arizona Laws and Regulations. The State Land Department awards leases on state-owned lands, the Oil and Gas Conservation Commission supervises drilling, operation, maintenance and abandonment of geothermal wells, and the Solar Energy Research Commission collects and provides information relating to solar and other non-polluting renewable energy sources, including geothermal.

Leasing. Prior to enactment of a legislative act (HB 2257) in 1977, the Arizona Land Department had maintained a moratorium on geothermal leasing of state-owned lands. Following passage of this legislation, the Department began preparing regulations, due to be available within a few months (perhaps by the time of the completion of this summary). It is anticipated that the procedures will allow for initiation of geothermal leases either by designation of likely resource areas by the Department or by an individual or company applying for a lease on a given tract of state land. In either case, competitive bids will be required. The Department will review each lease proposal, and, if it is found satisfactory, will publish a notice of availability of the lease for ten weeks in statewide publications. After a stipulated time, all bids will be opened and the lease awarded to the "highest and best bonus bid by a qualified application," with the Land Commissioner reserving the right to reject any or all bids. The bonus bid is the excess bid above the standard of $1 per acre for the first year; subsequent annual rental is $1 per acre. Legislation limits the size of a single lease tract to 2,560 acres.

Permitting and Regulation. The Oil and Gas Conservation Commission, as provided by law, "shall so supervise the drilling, operation, maintenance and abandonment of geothermal resource wells as to encourage the greatest ultimate recovery of geothermal resources, to prevent damage to and waste from underground geothermal reservoirs, to prevent damage to or contamination of any waters of the state or any formation productive or potentially productive of fossil fuels or helium gas, and to prevent the discharge of any fumes or gases or disposition of any substances harmful to the environment. . . ."

Legislative Changes Which May Be Considered. The Arizona Constitution requires competitive bids when state lands are leased, but in 1950 the constitution was amended to exempt oil and gas exploration leases from this provision, the rationale being to stimulate exploration and discovery. There is some support in the state for a similar exemption for geothermal leases.

The legislature may in the future attempt to define geothermal water resources as distinguished from other water.

The legislature may consider granting of tax breaks to industries or residences which either develop or use geothermal energy. (Tax credits and exemptions have been extended to users of solar energy.)

The legislature may consider legislation to retain state ownership of geothermal rights when state land is sold to private parties.

3.2.2 Colorado Laws and Regulations. Direct Colorado involvement in geothermal development includes leasing state lands and issuance of permits for various activities. While, as noted in Section 3.1, a large percentage of Southwestern geothermal resources are on federal lands, there are in Colorado identified resources under state-owned and private lands. In some cases, an appropriate development tract may be checkerboarded by federal, state and private ownership. Leasing of private land is simply by private contract with the owner. Leasing of state-owned land and minerals is under the jurisdiction of the Board of Land Commissioners, which is mandated to secure maximized income.

An applicant for a state minerals lease files an application with the Minerals Section of the Board; it is publicly posted and a questionnaire about the proposed lease is circulated among state and federal agencies, and local agencies such as county commissioners and county planners in the affected county or counties. Comments elicited by these questionnaires are considered as the Board evaluates the feasibility and impacts of the proposal. The Board may accept or reject the proposal. It may choose to auction leases, although it has not done so thus far due to limited interest. The entire process usually requires about six months.

Prior to any exploration or development, the Board must be notified and bond must be posted to guarantee compliance with Board requirements for restoration of the surface and settlement of damages to surface property. Lessees must agree to operate in a manner satisfactory to federal and state agencies relative to air and water pollution. Reports must be filed following drilling. A minimum royalty, an annual rental, and, where there is production, a production royalty is required, in amounts established by the Board. Leases for mineral resources have been issued throughout the history of the state, but geothermal leases have been issued only since passage of a state Geothermal Resources Act in 1973.

Prior to drilling any geothermal well, a permit must be obtained from the Colorado Oil and Gas Conservation Commission. Some counties and municipalities also require permits. An applicant for a permit to drill an exploratory well must provide the Oil and Gas Commission "a written statement based on competent geological opinion or data derived from similarly situated geothermal resource areas containing whatever information the Commission requires" to carry out its statutory purposes. An application for a permit to drill a development well must be accompanied by information from the drilling of the discovery well and competent geological opinion or data from a "similarly situated geothermal resource area." Required is information on location and depth of proposed wells, description of the resource base, amount and extent of anticipated surface development, mitigation measures for land subsidence, water and air pollution and noise pollution, proposed methods of by-product disposal and recovery, mineral and chemical composition of brine and gases of the resource, the proposed well casing program, and other information required by the Commission.

Permission must be obtained to recomplete or abandon a well or to change the manner in which any operation is carried out. Drilling and completion rules limit or specify the manner of some operations. Following any operation, a detailed report must be filed with the Commission. Daily production and other pertinent information must be reported, with logs so marked being kept confidential for six months.

The applicant for a drilling permit must submit evidence of public liability insurance and, except where a bond has been required for federal or Indian leases, a bond of at least $10,000 is required to assure plugging in accordance with rules of an abandoned well.

Whenever geothermal fluid is to be discharged into a stream or an injection well, a permit must be obtained from the Water Quality Control Division of the Department of Health, which will determine if heat or dissolved solids in the discharged fluid could pollute water in excess of quality standards. Application to discharge must be filed at least 180 days in advance of intended beginning of discharge. A public hearing and 30-day public review period may be required.

The Air Pollution Control Commission of the Department of Health, responsible for air quality protection, does not require advance notice of geothermal exploration and production, but developers are advised to contact the agency even when no releases of pollutants into the air are expected.

As in most states, a power generation facility may be erected only if a permit is issued by the Public Utility Commission (except in the case of municipal systems). The utility commission also regulates all pipelines for public use, an authority which would come to bear in case of sale of geothermal heat to members of the public for non-electric use.

Colorado counties and municipalities are permitted to regulate numerous activities, including geothermal development, within their boundaries. This local authority has not been widely exercised; in those cases in which it has, local regulations have been made a part of subdivision regulations.

3.2.3 Nevada Rules and Regulations. Most regulation of geothermal activity in Nevada is carried out by the Department of Conservation and Natural Resources through these divisions of the department: Water Resources, State Lands, Environmental Protection, Water Planning, and Minerals.

The Division of Water Resources licenses geothermal drillers, issues drilling permits, and issues permits authorizing appropriation of geothermal resources.

The Division of State Lands issues leases; however, very little Nevada land is state-owned.

The Division of Environmental Protection enforces air and water quality standards affecting geothermal activities.

The Division of Water Planning has general planning functions which may affect geothermal development.

The Division of Minerals probably will be involved in the regulation of certain geothermal exploration activities.

Some other state departments have less direct roles in geothermal exploration and development. The Nevada Department of Energy has the duty of reviewing policies related to research and development of the resource and of making recommendations to appropriate state and federal agencies.

The Nevada Bureau of Mines and Geology has various research responsibilities relating to geothermal and other resources.

The Department of Taxation has general responsibility for supervising taxation of geothermal resources, when such taxes are required by law. The Department has recommended a legislative review of taxes applicable to geothermal resources and such review is underway.

Finally, the Public Service Commission has authority to regulate the various uses of energy produced from the geothermal resource.

3.2.4 New Mexico Laws and Regulations. The State of New Mexico, like other states, has enacted laws and regulations covering mineral leasing of state lands and covering the drilling, development and production of geothermal resources. These, like all regulations, may be construed as constraining geothermal development. On the other hand, New Mexico has adopted public policies and has appropriated money to encourage geothermal development. Thus, institutional encouragements are found alongside rather routine institutional constraints.

The state recognized the geothermal era relatively early; in 1967 the legislature enacted the Geothermal Resources Act requiring all state lands to be leased through competitive bidding only. Lease terms are for an initial period of five years; thus many state leases are expiring and cannot be renewed. The Act restricts lease sites to between 640 and 2,560 acres and prohibits any lessee from leasing more than 25,000 acres in New Mexico. Both of these restrictions--time of lease and size of leases--have posed severe problems.

State leases may be issued through competitive bidding only. Royalties of 10 percent of gross revenue from the sale of steam and eight percent of net revenue from the operation of an energy plant, as well as a nominal lease rental of $1 per acre per year are exacted. However, the commissioner of public lands may suspend or reduce royalties and rentals if he finds it necessary to prove development. The commissioner has broad powers to improve various requirements and terms by lease negotiation or by regulation.

In 1973, the legislature directed the Oil Conservation Commission to regulate the drilling, development and production of geothermal resources and to conserve and prevent waste of the resource in the same way as it regulates natural gas production. This Act was followed, in 1975, by passage of the Geothermal Resources Conservation Act to prohibit waste and to give the Oil Conservation Commission board powers to prevent waste and protect correlative rights.

The state Energy and Minerals Department has broad powers concerning all aspects of energy development. It has the power to review decisions of the Oil Conservation Commission. The State Engineer also has regulatory powers; he must issue a permit to drill a well or appropriate the geothermal resource within a declared underground basin from which water as a gas or liquid will be withdrawn.

Further regulatory power is exercised by the Environmental Improvement Division over air quality, radiation control, noise control, and occupational health and safety. The Division also provides staff for the Water Quality Control Commission, which regulates aspects of water quality.

There has been no court litigation on geothermal development in the state, but there are many potential problems which ultimately will have to be resolved either through legislation or litigation. One issue is whether geothermal resources are to be defined as minerals in cases where the mineral estate has been severed from surface ownership.

In a special session in 1978, the legislature appropriated $200,000 to establish geothermal space heating demonstration projects, use of such money being contingent on 100 percent matching funds from federal, local or private sources. Further evidence of state interest was shown in a 1977 legislative memorial calling for a study of heating state buildings with geothermal energy. The resulting study indicated little evidence that geothermal energy could be found in the capital city, Santa Fe, but noted that money might be saved by conversion of state buildings to geothermal heating in areas where there is a potential resource.

New Mexico taxes the production of various forms of energy. None of these taxes specifically apply to the geothermal resource, but there may be future debate on whether or not this resource may be considered a mineral within the meaning of the tax laws. One tax, the oil and gas conversation tax of 19/100ths of one percent on sale value less transportation costs and royalties, would apply to geothermal production. It is not a revenue tax, but is used to insure proper abandonment of oil and gas wells and to help pay expenses of the Energy and Minerals Department.

3.2.5 Utah Laws and Regulations. The Utah state report includes two tables which permit a quick-scan overview of state and local agency involvement in geothermal development. Table 3.4 presents a preliminary assessment of the agencies involved, the type of permits they must issue, the estimated time for permit issuance, and comments. Table 3.5 is a simple listing of state and local agencies and groups involved in geothermal development. Similar tables and listings for other states, if drawn up, likely would reveal interesting parallels but some variance in details.

As shown in Table 3.4, state lands are leased by the Division of State Lands.

Utah law assigns primary geological regulation to the Division of Water Rights in brief and general terms. The Division has drawn up working rules and regulations which are being used as drafted although not formally promulgated.

The Utah team has found that developers of the resource for electrical application have done considerable research into potential institutional impediments, but that smaller developers aiming at non-electric uses tend to meet these problems on an ad hoc basis. Many unforeseen problems are expected, especially in the non-electric area.

The major, foreseeable state level impediments to geothermal development for electrical use appear to be associated with water rights. Legal problems concerned with priorities of water rights may arise as development progresses, particularly where the ground water reservoir is connected to the geothermal reservoir.

Priority problems also may arise where several developers are drawing from the same geothermal reservoir. Unitization of operations by the several operators drawing from a single reservoir may be indicated,

Table 3.4

Preliminary Assessment of Agencies and Permits Involved in Geothermal Development in Utah

	Permit	Required Prior To:	Estimated Time For Issuance	Notes
County Agencies				
County Planning Commission (1,2)	Zoning	Depends on county zoning ordinances	Variable	Already accomplished in some counties
County Clerk (1)	Business License	Sale of electricity		
County Commission or Health Department (1,2,3)	Health Code Enforcement Building Inspection	Use of buildings	Varies	
State Agencies				
Division of State Lands (4,5)	Lease State Lands	Exploration or use of lands	Few Days to 2-3 weeks	May be competitive bidding in some cases but that does not significantly increase issue time
	Special Use Permit	Surface disturbance (Construction of plant)	Not known--possibly about 2 months	Has not yet been applied for in Utah
Department of Transportation (6)	Encroachment Permits	Use of state highway lands for utility lines	Few days	Would be necessary for use of or crossing of State Highway Rights of Way with utility lines such as power lines, water mains, sewage pipes etc.
	Oversized Vehicles Permit	Use of highway for oversized vehicles	About a day	
Division of Water Rights (7,8)	Permits for Thermal Gradient Wells	Drilling of thermal gradient wells	Few days to few weeks	Letter of approval
	Permit for Exploratory "Test" Wells	Drilling of exploratory wells	Few days to few weeks	Letter of approval

Continued--

Table 3.4 (Continued)

	Permit	Required Prior To:	Estimated Time For Issuance	Notes
Continued from:				
Division of Water Rights (7,8)	Notification of Reservoir Test	Reservoir tests		
	Appropriation of Water	Use of water	6 months or longer	May depend on how fast the developer wants approval
	Production and Injection Wells			Covered by Appropriation of water if included in the Plan of Operations
Environmental Health Services				
Bureau of Water Quality (3)	Construction Plan Review and Permit	Construction	About 2 months	Pre-planning workshop
	Public Water Supply Approval	Use of building	1 to 2 months	
	Draft and Certification of Discharge Permit (Sanitary)	Use of building	1 to 2 months	In conjunction with EPA which issues the permit
	Liquid Waste Disposal System Approval	Use of building	1 to 2 months	
Bureau of Air Quality (9)	Construction Plan Review and Approval	Construction	About 3 months	In conjunction with EPA
	Discharge Permit	Use of plant	About 3 months	Plant discharges
Bureau of Solid Waste Management (3)	Solid Waste Disposal			
Department of Business Regulation (10)	Certificate of Convenience and Necessity or Approval of Contract Between Utility and Electricity Producer	Sale of Electricty	3 to 4 months	Certificate of convenience and necessity if utility owns plant; if utility buys power, approval of contract is required

Table 3.5

Utah State and Local Agencies and Groups Involved in Geothermal Development

"Direct" Involvement

Utah State Legislature
Division of State Lands
Division of Water Rights
Bureau of Water Quality
Bureau of Air Quality
Bureau of Solid Waste Management
Department of Transportation
Department of Business Regulation
Utah Tax Commission
County Commissions
County Clerks
County Health Officers
County Tax Commission

"Advisory" or Consulting

Utah Geological and Mineral Survey
University of Utah Research Institute (UURI)
EG&G (Idaho Falls)
Utah Division of Water Rights
Various Consulting Firms

"Indirect" Involvement

Utah Energy Office
Utah Farm Bureau
State Building Board
Department of Development Services
Industrial Development Division
Office of Legislative Research
Foresters Office
Division of Oil, Gas, and Mining
Division of Health
Utah Department of Agriculture
Water User's Association
State Court System
Environmental Groups
Municipalities and Communities
Division of Wildlife Resources
State Planning Office

as in the case of oil and gas fields. This, however, is as much of an industry problem as a state problem because unitization is based at least in part on administrative decisions by the involved developers. Federal regulations require unitization on federal lands. Utah Geothermal Rules and Regulations provide that on the request of any interested party or on his own initiative, the State Engineer may establish a unit plan or agreement for a geothermal area. Proper notice and a hearing is required. This state authority may be tested in the courts, but on the other hand litigation could take place between the various developers of a reservoir in the absence of unitization.

Water right controversies of a somewhat different nature are predictable in non-electric applications. It appears that many of these low temperature resources are connected to ground water basins or surface features such as springs where the water already is appropriated. In some cases, geothermal water may be used for heat and then reinjected; but water required for related uses may not be open to appropriation, although it might be available by purchase. Unfortunately, potential conflicts are most likely to occur in heavily populated areas, i.e., the Wasatch Front, where both population and resources are located but where most of the ground water already has been appropriated.

3.3 Comments on Laws and Regulations as Constraints

Doing business in any industry involves regulatory constraints at federal, state and local levels of government. Some regulations apply to business and industry in general, some to each particular line of business. There appears to be almost unanimous agreement that, while the major constraint to geothermal development may be economic, regulations greatly increase the difficulties of producing energy from this source. Costs, and costly time delays, caused by regulations increase the economic burdens of an infant industry attempting to compete with established industries.

The state teams working on the Southwest Program voiced or implied particular concerns with federal laws and regulations as constraints to geothermal development. Such state-oriented people might be expected to be more critical of federal institutions than of state and local institutions, but even so their comments are worth examination.

The Utah team states, "It is generally agreed that federal regulations, procedures and requirements impose significant encumbrances on geothermal development. Much of this impedance takes the form of delay in leasing and permitting; other impedence takes the form of restrictive stipulations or deliberate inaction on applications."

The Utah criticism is accompanied by some statistical support. Of the public lands in that state, 90.8 percent are administered by the federal government and 9.2 percent by the state. Yet of all the acreage leased for geothermal exploration in the state, 67 percent is federal and 33 percent state. "This is a crude comparison, but it demonstrates that a higher proportion of state lands have been leased compared with federal lands," the Utah report notes.

It also says, "The federal leasing procedure is complex and restrictive. Obtaining a (federal lease) takes at least six months and many applications have been pending since 1974 without action."

Beyond the leasing delays, the Utah report notes, "In the course of a geothermal development, six plans of operation must be submitted to the USGS and approved by them."

The Nevada team says that "the foremost barrier to geothermal development in Nevada is the fact that 86 percent of the lands are under federal jurisdiction" and "geothermal energy is in direct competition for investment dollars with the established energy industries yet the Federal government has not seen fit to create a fair and equitable environment for it to grow."

The Nevada report reveals that all of the exploratory geothermal tests have been made on private lands (12 percent of the state) and that no deep tests have been made on federal lands "due to institutional barriers."

The Colorado team notes that "the existing leasing laws and procedures make obtaining federal leases in advance of major exploration necessary; those same laws and procedures make it virtually impossible to obtain geothermal leases, at least on forest lands."

A subject noted but not extensively explored in the Southwest Program is the fact that vast acreages which may have geothermal resources are on Indian reservations. This land is under federal control, but as a practical matter leasing of it usually is accomplished by negotiation between the developer and the particular Indian tribe involved. To some extent, the action is comparable to leasing of private lands, although a federal role, exercised by the Bureau of Indian Affairs, is always in the background.

CHAPTER 4

4.0 Location of Geothermal Resources in the Southwest

Previous evaluations by the U.S. Geological Survey and others have indicated that the Southwestern states contain many of the nation's more promising sites for geothermal energy development, particularly in the hydrothermal form being considered here, and in the hot dry rock form.

Building on past information and carrying out additional research, the State Teams have further identified the areas and specific sites of geothermal resources. These identifications have been used as the basis for evaluation of the commercial potential of the resource and the drawing up of timely scenarios for its development.

Potential resources sites may be manifested in several ways:

- The geology of an area may be favorable.
- Hot springs and wells often provide surface manifestations of more precise locations.
- Leasing activity by private investors indicates that their research has pointed toward commercially profitable development.
- Drilling activity to test areas indicates that either private or public parties believe an area promising.
- And, of course, actual commercial development or beginning of development provides confirmation.

This section identifies resource areas on a state by state basis. The identifications are a bit uneven because each State Team took a different approach and had different materials to work with, as will be set forth in Section 4.1 below.

Section 4.2 then provides information on geothermal leases in each state.

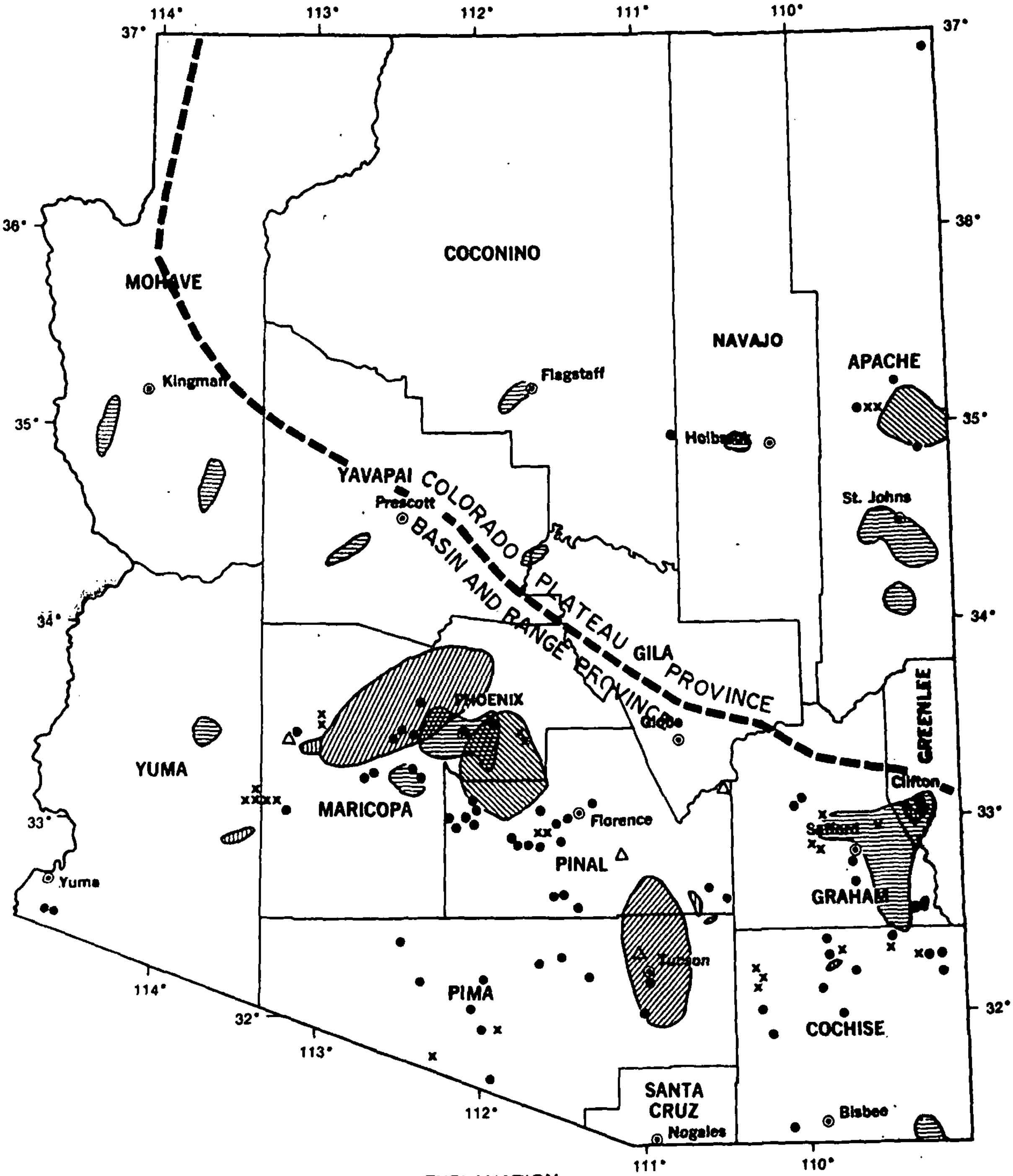
Section 4.3 summarizes drilling activities by states.

Section 4.4 lists in table form the identified geothermal resource sites and areas in each state.

Maps are provided (Figures 4.1 - 4.5) to show the geographical distribution of the resource in each state.

Figure 4.1

Geothermal Anomalies in Arizona



EXPLANATION

NEW MEXICO ENERGY INSTITUTE REPORT NO. 006	ARIZONA OIL AND GAS CONSERVATION COMMISSION
ANOMALOUS GEOTHERMAL REGIONS	GEOTHERMAL ANOMALIES – GRADIENTS > 60° C/Km
High chemical geothermometers	× Multi-well control within a minimum radius of 2½ miles
High heat flow (> 2.5 HFU)	• Single well control
High geothermal gradients (> 150° C/Km)	
Moderate geothermal gradients (> 38° C/Km)	
△ Single point anomalies	

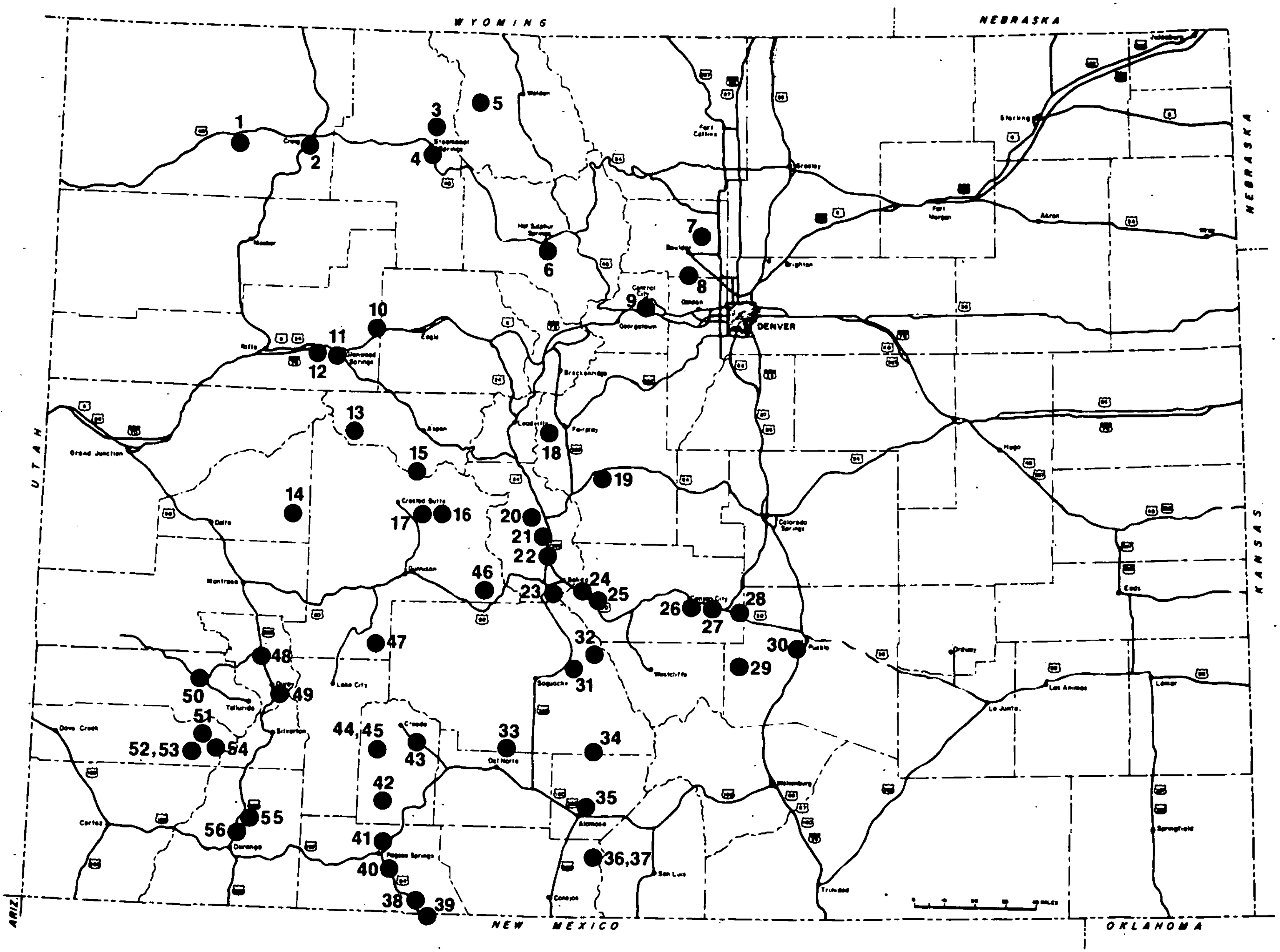


Figure 4.2

Geothermal Resource Locations in Colorado

Figure 4.3

Known Geothermal Resource Areas in Nevada

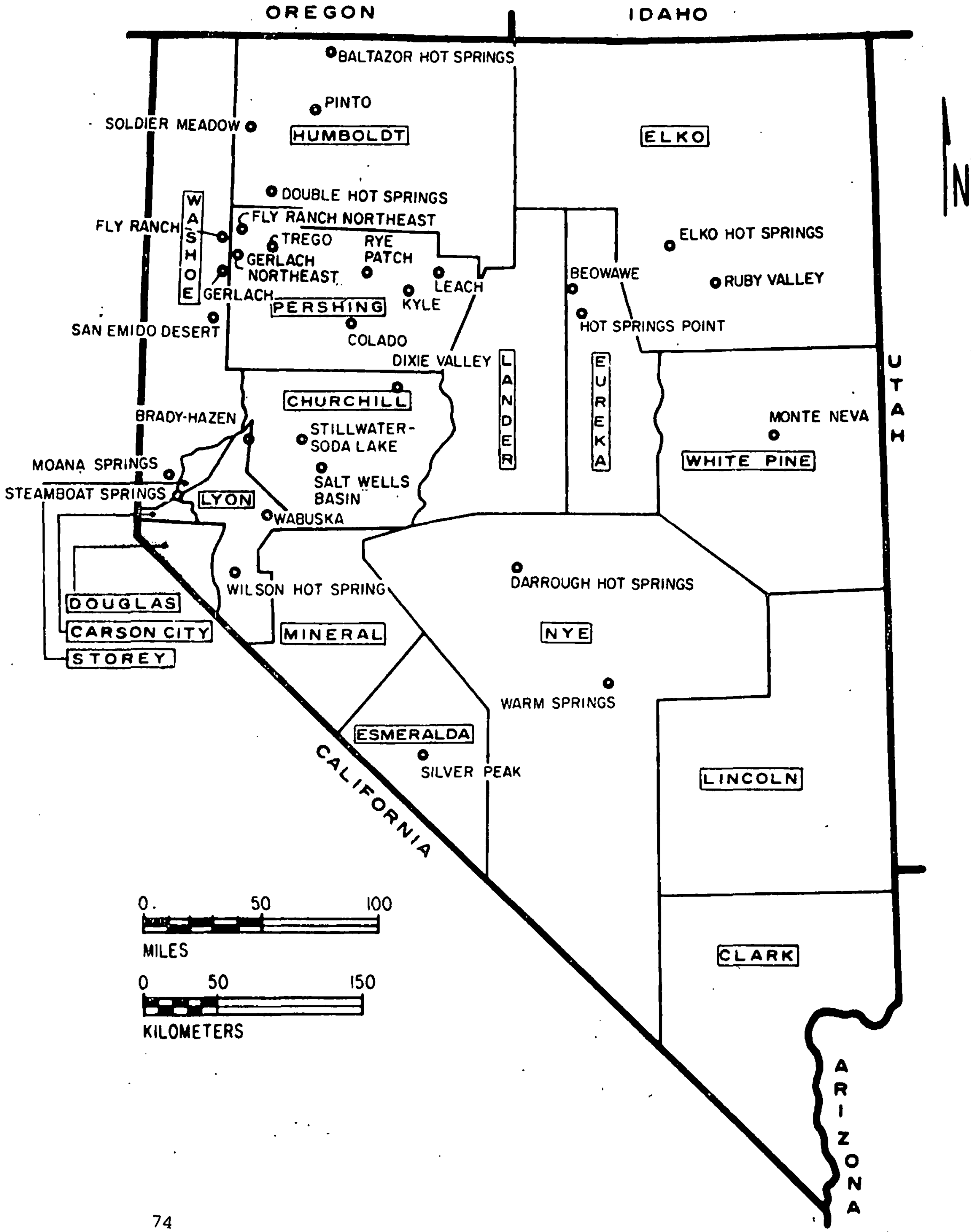


Figure 4.4

Geothermal Data Base Map, New Mexico

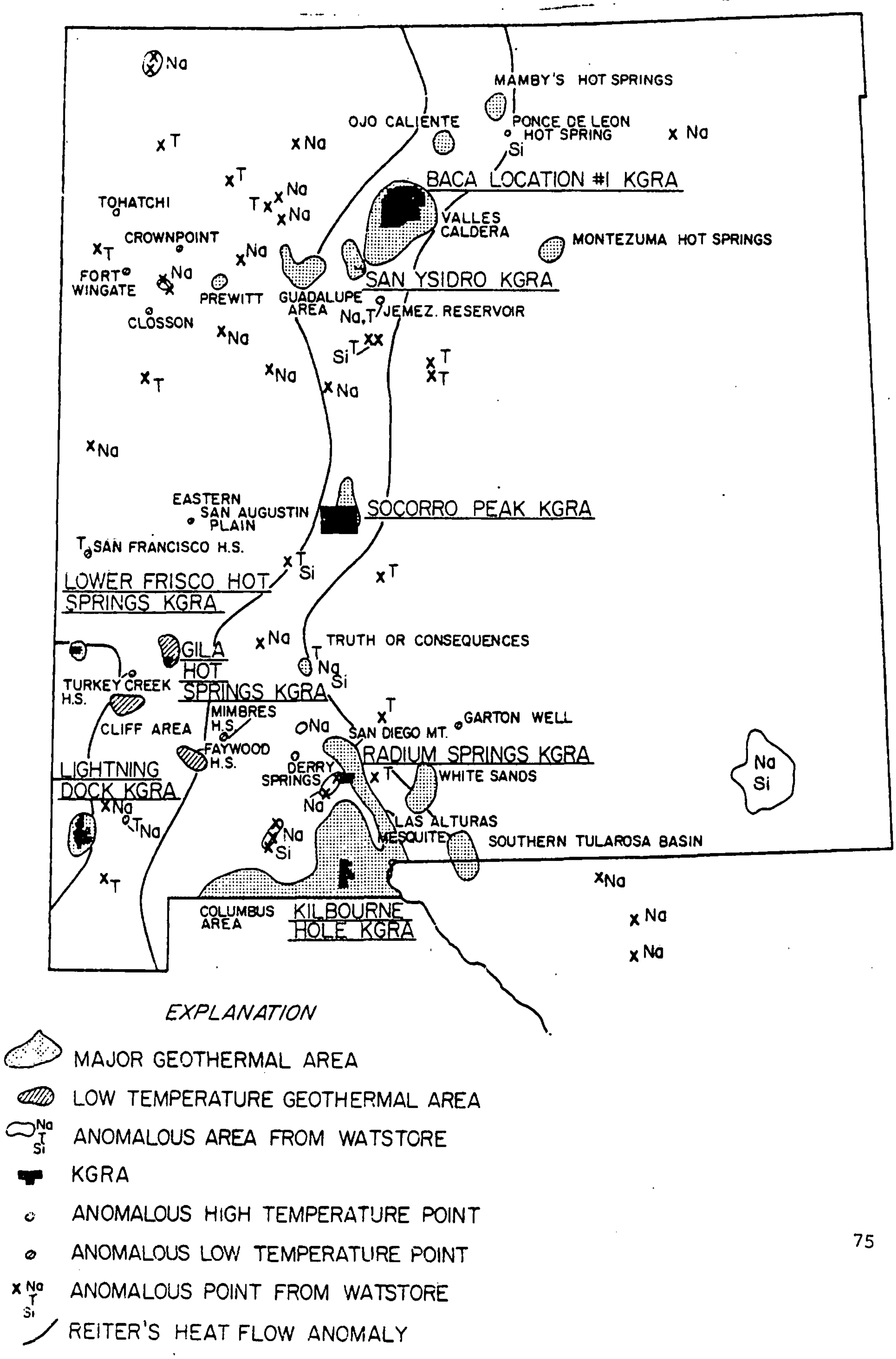
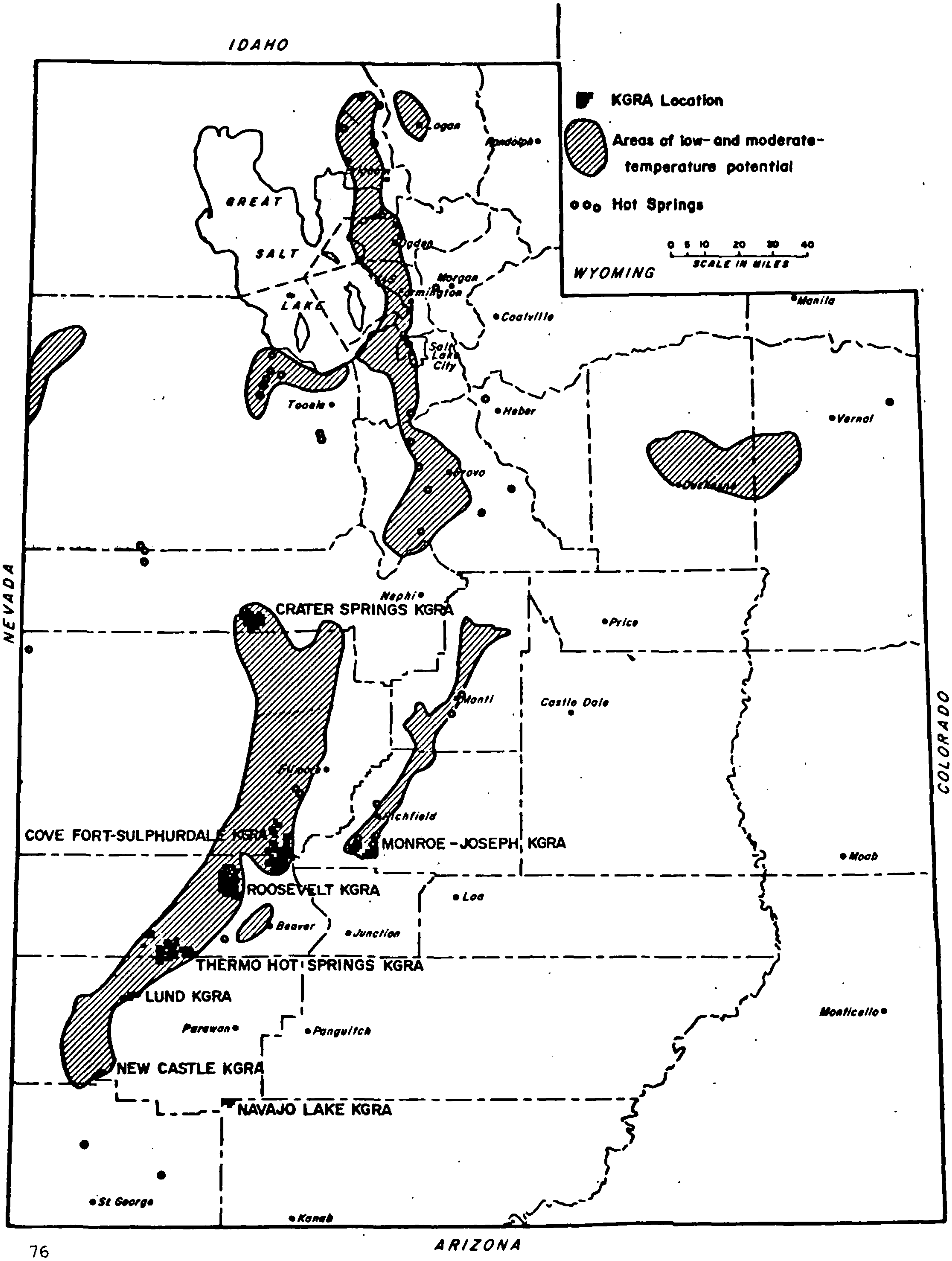


Figure 4.5

Geothermal Resource Areas in Utah



Facts about actual or immediate future actual commercialization of geothermal energy use are provided in Chapter 5 and are omitted from this chapter to avoid duplication.

4.1 State Team Approaches; General Comments

As noted above, each state team worked with somewhat different basic data and approached resource identification somewhat differently.

Arizona's team emphasized studies of the general geology of the state, and also identified more than 40 springs yielding anomalously warm water. The Arizona dependence on geological measurements was necessitated by the fact that there has been far less leasing and test drilling in the state than elsewhere in the region. Surface springs are not believed to reflect adequately the potential, because the desert environment and a low water table mask surface manifestations of hydrothermal waters which may lay beneath the surface, especially in the Basin and Range Province of the southern and western part of the state.

The geology of Arizona does indicate much promise; test drilling, which is now accelerating, will provide more definitive information.

There are very favorable indications that Arizona may be well endowed with the hot dry rock form of geothermal energy.

Colorado's team, by contrast, emphasized specific, site-by-site identifications and engaged relatively little in broader geologic evaluations. There are several hot springs in the state and there has been considerable land leasing and some test drilling by companies whose own evaluations encourage them to invest money.

Nevada's team followed an approach similar to that of Colorado's, but Nevada identifications are more extensive because there has been a much greater volume of leasing and test drilling. Almost half (47 percent) of federal and state land leases in the five state area is in Nevada (Table 4.1) and 71 percent of the wells drilled in the region have been in that state (Table 4.2).

New Mexico's team also emphasized a tabulation of leases issued and wells drilled, supplementing this with general geological information.

Substantial private industry activity in the state has made possible the accumulation of leasing and drilling information.

Utah's team emphasized a compilation of information on leasing and drilling, both of which have been extensive in the state, and coupled the information gained thereby with generally known surface manifestations and geological information.

4.2. Leasing Activity, by States

Table 4.1 shows the number of acres leased by private investors in each state as of the rendering of each state report in mid-1978, with number of leases in each category indicated in parentheses after the acreage figures. It must be noted that these figures do not include leases of private lands, this information generally being unavailable.

4.3 Drilling Activity, by States

In most oil and gas searches, the explorer drills to the geologically-indicated potential production zone. The well may reveal commercially profitable volumes of oil and/or gas, and, if so, the well is "completed," i.e., permanent casing pipe is set in place and, in the case of petroleum, tubing and pumping equipment to bring the oil to the surface is installed. If commercially profitable volumes of oil or gas are not found, the well yields geological information which encourages or discourages further exploration in the same geological structure in the vicinity.

In geothermal exploration, drilling of wells to the indicated potential production zone often is preceded by the drilling of narrow diameter holes for the sole purpose of calculating temperature-depth relationships (thermal gradients) and these wells are not useful for actual future production. Such wells may be deep, reaching to or near the potential production zone depth, or they may be only a few hundred feet deep. In the latter case, temperatures at increasing depths are determined and from this information the likely temperature at the potential production depth is extrapolated.

In the Southwestern region, a number of wells ranging from quite shallow temperature gradient measurement wells to deeper wells, potentially producers,

Table 4.1

Acreage of State and Federal Geothermal Leases

State	Federal Leases		State Leases	Private Leases	Total, Federal & State
	KGRA	Non-KGRA			
Arizona	NA	NA	NA	NA	NA
Colorado	5,035 (3)	28,488 (25)	83,192 (27)	NA	116,715
Nevada	152,662 (79)	729,309 (NA)	NA	NA*	881,971
New Mexico	70,880 (40)	88,490 (45)	63,694 (146)	NA	223,064
Utah	86,447 (50)	340,011 (199)	210,570 (221)	NA	637,028
Totals	315,024 (172)	1,186,298 (269)	357,456 (394)	NA	1,858,778

Source: Final state team reports, August, 1978

KGRA - Known Geothermal Resource Area

NA - Not Available

Numbers in parenthesis reflect number of leases

*Nevada reports that "a large portion of private land is leased or being evaluated." However, only 12 to 13 percent of land in the state is privately owned.

have been drilled and applications are pending for the drilling of others. This drilling is summarized below on a state-by-state basis.

Table 4.2 shows the extent of exploratory drilling in the five states as of mid-1978.

4.3.1 Arizona. Two deep test wells were drilled in 1973 near Chandler, by Geothermal Kinetics Systems, Inc. Another was drilled near Eloy in 1974 by AMAX Explorations, Inc. A fourth has been partially drilled by Nix Drilling Co. in T5S R24E S16. In March, 1978, the Geological Survey (USGS) began drilling five shallow (400 foot) heat gradient holes in the Kingman area; USGS has indicated intention to drill 50 shallow heat flow holes throughout southern Arizona in 1978. The Bureau of Reclamation has indicated that it will finance a drilling program of 500-foot holes in the Springerville area, along with additional and possibly deeper holes in the Clifton area.

4.3.2 Colorado. Gradient holes are known to have been drilled in two areas. AMAX Exploration drilled a 2,000-foot hole in 1978 in the Mt. Princeton Hot Springs area. Colorado Geological Survey drilled 5 holes at Pagosa Springs in 1977. Chevron has a permit from USGS to drill five shallow gradient holes in the Cebolla area.*

In 1974, Mapco drilled a 9,480-foot exploratory well on the eastern side of the San Luis Valley near Great Sand Dunes National Monument to determine temperature gradient and hydrologic properties of the acquifer as well as oil and gas potential. The test was inconclusive.

Colorado Geological Survey was drilling a 2,000-foot exploratory well at Pagosa Springs at the time the state team report was completed.

4.3.3 Nevada. Exploratory drilling in the past has included 64 tests by private companies seeking hydrothermal resources for electric application. All these tests have been made on private lands, which comprise only about 12 percent of the state's territory. No deep tests have been made on federal lands due to institutional barriers posed by federal regulations.

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*A number of the wells for which permits have been issued or applied for may have been drilled by the time of the writing of this summary, a time lag having occurred between collection of initial information and preparation of the summary.

Table 4.2

Geothermal Drilling Activity in the Southwest Region

Drilling Activity	AZ	CO	NV	NM	UT
Thermal Gradient Holes[1]	5	6	1000+	165+	NA
Shallow (500 Ft. or Less)	5	5	NA	NA	NA
Deep (500 Ft.)	--	1	NA	NA	NA
Test Wells Drilled	4	2[2]	64	17	20
Thermal Gradient Holes Planned[1]	50	5	67	21	225
Test Wells Planned[3]	NA	NA	6	3	NA

1. Known thermal gradient holes. Because permits are not required in all cases, information is not readily available.

2. Only includes those drilled since adoption of the state regulations requiring a drilling permit.

3. Incomplete information.

NA -- Not Available

Phillips Petroleum Co. has submitted a plan to drill six test wells to a depth of 2,438 meters (8,000 feet) on federal leases in the Rye Patch Reservoir area.

There are no wells now in production, but there are numerous existing wells which have the capability of providing sustained energy for electric power production, commercial processing, and other lower temperature uses.

As with the 64 exploratory tests referred to above, most slim-hole temperature gradient wells in Nevada have been drilled on private lands and have not been recorded with federal or state agencies. Such holes are estimated to be in the thousands. BLM has recorded 67 separate notices of intent to carry out temperature gradient surveys, many of these involving a number of holes.

4.3.4 New Mexico. Union Oil Co. has drilled 17 test wells ranging from 6,000 to 9,000 feet in depth in the Valles Caldera, with six of these reported to have produced water and/or wet steam with temperatures of at least 200 degrees C. Public Service Co. of New Mexico has joined with Union Oil in submitting a proposal to DOE for a 50MW electric generation facility; funding has been approved and production of electricity is expected by 1982. (See Section 5.2.1)

Other drilling activity is underway by Sunoco Development, AMAX Exploration, Chevron, Sandia Laboratories and the State of New Mexico.

Direct thermal use is being made in four locations for space heating and in two locations for greenhouses.

4.3.5 Utah. A total of 225 temperature gradient well applications have been filed with the state's Division of Water Rights. Often a series of wells is included in a single application, and no notification is required if a well is not drilled, so records do not show how many gradient wells actually have been drilled.

Eighteen deep exploration wells had been drilled and two were underway at the time the State Team delivered its report (July 1978). Of these 20, eleven are in the Roosevelt Hot Springs area, three in Cove Fort/Sulphurdale area, one in North Cove Fort area; one in Thermo area; three in Beryl area; and one in North Wasatch Front/Brigham City area.

4.4 Geothermal Prospect Areas and Sites, by States

Tables 4.3 through 4.7 list areas and sites of geothermal prospects in each of the five states as these have been identified by various criteria, for both electric and direct thermal uses. The prospective sites and areas are broken down in these lists to those which are (1) proven, (2) potential, and (3) inferred.

Definitions:

Proven sites are those (1) which are in an advanced stage of development or commercialization by a private company or by government for specific applications, or demonstrations, or those (2) on which is available favorable quantitative data on the measured subsurface temperatures, volume, and water flows.

Potential sites are those on which (1) there is exploration/development activity, or (2) some favorable quantitative subsurface data have been estimated or measured.

Inferred sites or areas are those identified by (1) surface manifestations such as wells or springs, (2) chemical thermometry, or (3) proximity to potential or proven sites.

Tables 4.8 through 4.16 provide further information on proven and potential sites, both for electric and direct thermal applications, in each of the states.

Table 4.3

Geothermal Prospect Areas/Sites--Arizona

ELECTRIC

Proven	Potential	Inferred
None	Phoenix/Chandler Phoenix/Eloy Clifton - Morenci - Safford Palo Verde Kingman	San Bernardino Valley Springerville - St. Johns Flagstaff Verde H.S. Yuma Hyder Valley Tucson Phoenix Wilcox Pinacote Field + 73 Prospects with temperature gradients in excess of 150° C/km

DIRECT THERMAL

Proven	Potential	Inferred
None	San Simon Castle H.S. Yuma Gillard H.S. Eagle Creek H.S. Coolidge H.S. Coffers H.S. Cat Tank Javelina Peak Safford Area Indian H.S.	Littleton Casa Grande (North) Casa Grande (South) Wilcox Whitewater Coolidge Area Radium Sp. Hooker's H.S. Buckhorn Area Hyder Valley Agua Caliente Artesia H.W. Mt. Graham Lucats Spa Palomas Mts. Branon Mtn.

Continued--

Table 4.3 (Continued)

DIRECT THERMAL (Continued)

Proven	Potential	Inferred
		Theba Bowie Mobil Area Artesia Area Warm Sp. Hoover Dam Sp. Cottonwood Sp. Lava Sp. Colorado Pool Prescott Sp. Soda Sp. Chalk Mtn. Sp. Roosevelt Dam Sp. Bronco Gulch Sp. Mescal Sp. Pioneer Sp. Arsenic Cave Sp. Little Boiling Sp. Graperine Sp. Agua Caliente Agua Caliente +~100 Prospects with temperature gradients between 36° and 150° C/km + Basin and Range Province

Table 4.4

Geothermal Prospect Areas/Sites--Colorado

ELECTRIC

Proven	Potential	Inferred
None	Mt. Princeton/Hortense Cottonwood Creek Poncha Springs/Browns Canyon Cebolla	

DIRECT THERMAL

Proven	Potential	Inferred
None	Glenwood Hot Springs Hartsel Waunita San Luis Valley Shaws Sand Dunes Splashland Mineral/Valley View	Routt/Steamboat Springs Hot Sulphur Springs Ouray Dunton/Geyser/Paradise Haystack Butte Eldorado Springs Idaho Springs Juniper/Craig Brands Ranch South Canyon Penny Cement Creek/Ranger Wellsville/Swissvale Canon City/Fremont Don K Ranch/Florence Clark Wagon WheelGap Orvis Rico Pinkerton/Mound Tripp/Trimble +8 other sites

Table 4.5

Geothermal Prospect Areas/Sites--Nevada

ELECTRIC

Proven	Potential	Inferred
	Substate Areas:	Specific Sites:
Rye Patch	The Needles Rock	Surprise Valley
Desert Peak	Dyke Hot Springs	South Smoke Creek Desert
	Cordero Mercury Mine	Anaho Island
	Hot Sulphur Springs	Baltazor H.S.
	Humboldt Wells	Bilk Creek Reservoir
	San Emidro Desert	Pinto Hot Springs
	MacFairlane's	Cordero Mercury Mine
	Rye Patch	Hot Sulphur Springs
	Leach Hot Springs	The Hot Springs
	Beowawe Geysers	San Emidro Desert
	Darrough's Hot Springs	Gerlach
	Sulphur Hot Springs	Cholona
	Steamboat Spring--Huffaker	Fly Ranch NE
	Desert Peak	MacFairlane's
	Carson Sink--Alkali Flat, West Side	Sulphur
	Soda Lake--Upsol Hogback	Colado
	Dixie Hot Springs	South Eugene Mountains
	Wabuska Hot Springs	Horsehoe Ranch Springs
	Dead Horse Wells	Duff Creek
	Wedell Springs	Bruffey's Hot Springs
	Fish Lake Valley	Monte Neva Hot Springs
	Warm Springs	Ruby Lake
		Cherry Creek Hot Springs
	Specific Sites:	Hot Springs Mountains
	The Needles Rocks	Huxley
	Dyke Hot Springs	Carson Sink-Alkali Flat, West Side
	Bog Hot Springs	Carson Sink-Alkali Flat, East Side
	Howard Hot Springs	Lone Rock
	Humbolt Wells	Carson Lake
	Mineral Hot Springs	Eight Mile Flat
	Double H.S.--Black Rock H.S.	Hyder Hot Springs
	Fly Ranch	McCoy Hot Springs
	Trego	Dixie Comstock Mine-Humboldt Marsh
	Soldier Meadows H.S.	Wilson Hot Springs
	Rye Patch	
	Hot Springs Ranch	
	Hot Pot	
	Leach Hot Springs	

Continued--

Table 4.5 Continued

ELECTRIC (Continued)

Proven	Potential	Inferred
	Kyle Hot Springs Smith Creek Valley Beowawe Geysers Hot Springs Point Darrough's Hot Springs Walti Hot Springs Kolbe Hot Springs Spenser Hot Springs Desert Peak Brady's Hot Springs Hazen Soda Lake-Upsal Hogback Stillwater Lee Hot Springs Dixie Hot Springs Sou Hot Springs Buffalo Valley Hot Springs Jersey Valley Wabuska Hot Springs Fish Lake Valley Warm Springs	Dead Horse Wells-Wedell Springs West Gabbs Valley Silver Plat Hot Springs Southern Clayton Valley Railroad Valley-Pancake Range Hot Creek Valley Hot Creek Canyon Lunar Crater

DIRECT THERMAL

Proven	Potential	Inferred
Brady Hot Springs Elko Hot Springs Moana Spring-Lawton	<u>Substate Areas:</u> Golconda Battle Mountain Steamboat Spring-Huffaker Soda Lake-Upsal Hogback Wabuska Hot Spring Sodaville Springs Caliente Hot Springs Sarcobatus Flat-Beatty <u>Specific Sites:</u> Golconda Carlin Hind's Hot Springs	<u>Specific Sites:</u> Gerlach, N.E. Sand Dunes Winnemucca Mountain Battle Mountain Steamboat Spring-Huffaker Washoe Valley Eagle Salt Works Brady's Hot Springs Stillwater Soda Lake-Upsal Hogback Senator IXL Wabuska Hot Springs Silver Peak Hot Springs Sodaville Springs Caliente Hot Springs Sarcobatus Flat-Beatty

Table 4.6

Geothermal Prospect Areas/Sites--New Mexico

ELECTRIC

Proven	Potential	Inferred
Valles Caldera	Animas Kilbourne Hole Radium Springs	Guadalupe Area Columbus Area Lower Frisco H.S. Mamby's H.S. San Diego Mtn. Mesquite-Berino Derry Spring Southern Tularosa Basin White Sands (Town) North of Socorro Prawitt Area Jemez Reservoir Lordsburg

DIRECT THERMAL

Proven	Potential	Inferred
None	Albuquerque Animas Faywood Jemez Springs Los Alturas Ojo Caliente Radium Springs San Ysidro Socorro	Truth or Consequences Montezuma H.S. Ponce de Leon Turkey Creek H.S. Gila H.S. Closson Fort Wingate Mimbres H.S. Faywood H.S. Tohatchi San Francisco H.S. Crown Point E. San Augustin Plain Garton Well Cliff

Table 4.7

Geothermal Prospect Areas/Sites--Utah

ELECTRIC

Proven	Potential	Inferred
Roosevelt Hot Springs	Cove Fort/Sulphurdale Thermo	North Cove Fort West Cove Fort/Black Rock Desert

DIRECT THERMAL

Proven	Potential	Inferred
Monroe Hot Springs Crystal Hot Springs (State Prison) Sandy City	Red Hill H.S./Johnson H.S. Wasatch H.S./Beck's H.S./ Hobo H.S. Midway Ogden H.S./Hooper H.S./ Utah H.S./Hill AFB Meadow H.S./Hatton H.S. Joseph H.S. New Castle Cove Fort/Sulphurdale Thermo Tintic Beryl Abraham H.S. West Cove Fort Black Rock Desert Veyo H.S. La Verkin H.S.	Blue Warm Springs Bothwell Warm Springs Castilla Hot Springs Como Warm Springs Cultler Warm Springs Diamond Fork Warm Springs Fish Springs/Big Springs/ Wilson Hot Springs Gandy Warm Springs Goshen Warm Springs Grantsville Warm Springs Lincoln Point Warm Springs/ South Utah Lake Little Mountain Warm Springs Livingston Warm Springs Morgans Warm Springs/Russells Warm Springs Radium Warm Springs Richfield Warm Springs Saratoga Hot Springs/Crater Hot Springs Split Mountain Warm Springs

Continued--

Table 4.7 Continued

DIRECT THERMAL (Continued)

Proven	Potential	Inferred
		Stansbury Mountains--Big Warm Springs, Burnt Springs, Horseshoe Springs, Iosepa Springs, Muskrat Spring Sterling Warm Springs Stinking Hot Springs Uddy Hot Springs Warm Spring Cache Valley Uintah Basin Wendover/West Toole County

Table 4 .8

State of Arizona

Proven and Potential Electric Applications

Site	Latitude / Longitude	Temperature (°C) Surface	Subsurface * HDTF/HDR	Estimated Volume (km^3)	Estimated Energy (MWe) Proven	Potential	Total
Phoenix/Chandler	33° 17.1' / 111° 41.2'	-----	184/----			50	200
Safford	32° 50' / 109° 45'	-----	110/205			50	200
Palo Verde	34° 21.5' / 111° 42.5'	-----	54/205			25	100
Kingman		-----	50/200			25	100
					0	150	600

* HDTF = Hydrothermal fluid temperature; HDR = Hot dry rock temperature

Table 4 . 9

State of Colorado

Proven and Potential Electric Applications

Site	Latitude / Longitude	Temperature ($^{\circ}C$)* Surface	Temperature ($^{\circ}C$)* Subsurface	Estimated Volume (km^3)	Estimated Energy (MWe) Proven	Estimated Energy (MWe) Potential	Estimated Energy (MWe) Total
Mt. Princeton/ Hortense	38° 44' / 106° 10'		200	2.368		100	100
Cottonwood Creek	38° 49' / 106° 13'		170	1.100			
Poncha Springs/ Browns Canyon	38° 30' / 106° 5'		100-145	4.260			200
Cebolla	38° 16' / 107° 6'		60	0.750			200
					0	100	500

*Mid Point Estimate

Table 4.10

State of Colorado

Proven and Potential Direct Thermal Applications

Site	Latitude / Longitude	Temperature (°C) Surface	Temperature (°C) Subsurface	Estimated Volume (km^3)	Estimated Energy (Quad) Proven	Estimated Energy (Quad) Potential	Estimated Energy (Quad) Total
Pagosa Springs	37° 16' / 107° 01'	54	75-125	0.34	0.0121		0.0121
Glenwood	39° 33' / 107° 19'	15-51	55-88	0.39		0.0070	0.0070
Hartsel	39° 01' / 105° 48'	45-52	55-85	0.34		0.0102	0.0102
Splashland	37° 29' / 105° 51'	40	40-100	0.59		0.0194	0.0194
Sand Dunes	37° 47' / 105° 51'	44	45-100	0.59		0.0194	0.0194
Shaws	37° 45' / 106° 19'	30	30-60	0.25		0.0039	0.0039
Mineral	38° 10' / 105° 55'	60	70-90	7.89		0.2351	0.2351
Valley View	38° 12' / 105° 49'	--	40-50	0.83			
Waunita	38° 31' / 106° 30'	62-80	110-160	0.22		0.0148	0.0148
					0.0121	0.3254	0.3375

Table 4.11

State of Nevada

Proven and Potential Electric Applications

Site	Latitude / Longitude	Temperature (°C) Surface	Subsurface	Estimated Volume (km^3)	Estimated Energy (MWe) Proven	Potential	Total
The Needles Rock	40° 9' / 119° 40'	98	145-200	20			245
Dyke Hot Springs	41° 34' / 118° 34'	70	140-200	20		120	245
Bog Hot Springs	41° 56' / 118° 48'	88	115-170	10			180
Howard Hot Spring	41° 43' / 118° 30'	73	130-200	10			125
Humboldt Wells		90	140-200	20		70	245
Mineral Hot Springs		60	130-185	10			180
Double H.S. -- Black Rock H.S.	41° 3' / 119° 3'	94	150-200	60			735
Fly Ranch	40° 52' / 119° 21'	94	130-185	10			90
Trego		86	130-185	10			90
Rye Patch		--	182-185	60	40	150	540
Hot Springs (Tipton) Ranch		85	180-200	20			245
Hot Pot		58	125-185	10			90
Leach Hot Springs	40° 36' / 117° 39'	96	170-200	60		235	735
Kyle Hot Springs	40° 24' / 117° 53'	96	180-200	20			245

Continued--

Table 4.11

State of Nevada (Continued)

Site	Latitude / Longitude	Temperature (°C) Surface	Temperature (°C) Subsurface	Estimated Volume (km³)	Estimated Energy (MWe) Proven	Estimated Energy (MWe) Potential	Estimated Energy (MWe) Total
Smith Creek Valley	39° 21' / 117° 33'	86	160-200	20			245
Beowawe Geysers	40° 34' / 116° 35'	98	240-245	80		170	1220
Hot Springs Point	40° 24' / 116° 31'	59	125-185	20			180
Darrough's Hot Springs	38° 49' / 117° 11'	97	140-185	10		20	90
Walti Hot Springs	39° 54' / 116° 35'	73	120-185	10			90
Kolbe Hot Springs		70	130-185	10			90
Spenser Hot Spring	39° 19' / 116° 51'	96	125-185	10			90
Steamboat Spring-Huffaker	39° 23' / 119° 45'	96	210-215	30		50	400
Comstock Mining District		ND*	77-155	10			75
Desert Peak		ND	212-215	50	70	250	665
Brady's Hot Springs	39° 47' / 119° 0'	98	214-215	20			265
Hazen		ND	132-200	10			125
Soda Lake-Upsol Hogback	39° 34' / 118° 49'	90	165-215	30		250	400
Stillwater	39° 31' / 118° 33'	96	160-215	40			530
Lee Hot Springs	39° 13' / 118° 43'	91	175-185	10			125
Dixie Hot Springs	39° 48' / 118° 4'	72	150-200	20		70	245

Continued--

Table 4.11

State of Nevada (Continued)

Site	Latitude / Longitude	Temperature (°C) Surface	Temperature (°C) Subsurface	Estimated Volume (km^3)	Estimated Energy (MWe) Proven	Estimated Energy (MWe) Potential	Estimated Energy (MWe) Total
Sou Hot Springs	40° 5' 117° 44'	93	115-185	15		35	135
Buffalo Valley Hot Springs	40° 22' 117° 20'	79	130-185	15			135
Jersey Valley	40° 11' 117° 29'	57	185-200	15			145
Wabuska Hot Springs	39° 10' 190° 11'	97	155-170	10		80	80
Fish Lake Valley		ND	253-260	20			390
Warm Springs		63	125-170	10		40	90
					110	1540	9700

* ND = Not Determined

Table 4.12

State of Nevada

Proven and Potential Direct Thermal Applications

Site	Latitude Longitude	Temperature (°C) Surface	 Subsurface	Estimated Volume (km^3)	Estimated Energy (Quad) Proven	 Potential	 Total
Soldier Meadows H.S.	41° 22' 119° 13'	54	115	12			0.7
Galconda		74	125-185	20		0.070	2.0
Elko Hot Springs	40° 49' 115° 47'	89	115-185	10	0.007		0.2
Carlin		100	120-185	10		0.004	0.1
Moana Spring-Lawton		48	98-60	40	0.037		1.1
Brady H.S.		98	215	10	0.040		1.2
Hind's Hot Springs		67	105-155	10			0.8
					0.084	0.074	6.1

Table 4.13

State of New Mexico

Proven and Potential Electric Applications

Site	Latitude / Longitude	Temperature (°C) Surface	Temperature (°C) Subsurface	Estimated Volume (km^3)	Estimated Energy (MWe) Proven	Estimated Energy (MWe) Potential	Estimated Energy (MWe) Total
Animas (lightning Dock)	32° 85' 108° 50'	99	170	2.25		20	100
Kilbourne Hole	31° 57' 106° 58'	45-83	155	3.50		20	50
Radium Springs	32° 30' 107° 58'	30-85	130-198	2.25		5	30
Valles Caldera	35° 53' 106° 35'		260-315	130.00	50	350	1942
					50	395	2122

Table 4.14

State of New Mexico

Proven and Potential Direct Thermal Applications

Site	Latitude / Longitude	Temperature (°C) Surface	Temperature (°C) Subsurface	Estimated Volume (km^3)	Estimated Energy (Quad) Proven	Estimated Energy (Quad) Potential	Estimated Energy (Quad) Total
Albuquerque	35° 05' / 106° 45'	30	NA*				0.0449
Faywood	32° 33' / 108° 00'	54	--				
Jemez Springs	35° 47' / 106° 4'	73	135	2.25		0.0206	0.6150
Los Alturas	32° 16' / 106° 42'	46	120	2.25			0.5635
Ojo Caliente	36° 18' / 106° 3'	45	122-161	2.25			
Radium Springs	32° 30' / 107° 58'	30-85	130-198	2.25			0.0368
San Ysidro	35° 30' / 106° 40'	50	80	2.25			0.0206
Socorro	34° 2' / 106° 56'	34	72				0.0135
Truth or Consequences	33° 9' / 107° 15'	36-46	100	2.25		0.0269	0.4563
Animas						0.0359	0.4102
					0	0.0834	2.1508

* NA = Not Available

Table 4 .15

State of Utah

Proven and Potential Electric Applications

Site	Latitude / Longitude	Temperature (^{o}C) Surface	Subsurface	Estimated Volume (km^3)	Estimated Energy (MWe) Proven	Potential	Total
Roosevelt Hot Springs	38^{o} 30' / 112^{o} 49'	88	213	8.0	100	200	500
Cove Fort/ Sulphurdale	38^{o} 36' / 112^{o} 33'			2.25		220	220
Thermo	38^{o} 11' / 113^{o} 12'			2.25		20	80
					100	440	800

Table 4 .16

State of Utah

Proven and Potential Direct Thermal Applications

Site	Latitude / Longitude	Temperature (°C) Surface	Subsurface	Estimated Volume (km³)	Estimated Energy (Quad) Proven	Potential	Total
Monroe Hot Springs	38° 31' / 112° 12'	76	120	2.25	0.0009		0.0341
Red Hill Hot Springs	38° 38' / 112° 6'	77	135	2.25		0.0117	0.0386
Johnson Hot Springs	38° 36' / 112° 15'	25		2.25			0.0036
Crystal Hot Springs	40° 30' / 111° 55'	58	80	2.25	0.0009	0.0126	0.0386
Wasatch H.S.	40° 45' / 111° 55'	42	120	2.25			0.0341
Beck's H.S.	40° 47' / 111° 56'	56	90	2.25		0.0350	0.0242
Midway H.S.	40° 31' / 111° 28'	45	43	2.25		0.0054	0.0099
Ogden H.S./Hooper H.S./Utah H.S./ Hill AFB	41° 14' / 111° 58'	58-60	95-110	2.25		0.0359	0.0852
Meadow H.S./Hatton H.S.	38° 50' / 112° 31'	38-41	105	2.25		0.0063	0.0404
Joseph H.S.	38° 38' / 112° 11'	64	162	2.25		0.0063	0.0404
New Castle			100-110			0.0072	0.0404
Cove Fort/ Sulphurdale	38° 36' / 112° 33'			2.25		0.0054	0.3589
Thermo	38° 11' / 113° 12'			2.25		----	0.1794
Tintic						0.0090	0.0897
Beryl						0.0278	0.0897

Continued--

Table 4 .16

State of Utah (Continued)

Site	Latitude / Longitude	Temperature (°C) Surface	Temperature (°C) Subsurface	Estimated Volume (km^3)	Estimated Energy (Quad) Proven	Estimated Energy (Quad) Potential	Estimated Energy (Quad) Total
Abraham H.S.		82	125	2.25		0.0036	.0897
West Cove Fort						0.0018	.0897
Black Rock Desert						0.0018	.0897
Veyo H.S.		42		2.25		0.0072	.0090
La Verkin H.S.		42		2.25		0.0063	.0090
Crystal (Madsen's) H.S.		56	90	2.25		0.0072	.0242
Sandy City					0.0009		.0009
Other Areas						0.0063	0.1800
					0.0027	0.1950	0.4922

4.5 Estimated Geothermal Resource Applications in the Southwest Region

As already pointed out in Section 4.1, the five State Teams used a variety of approaches in compiling information on the geothermal resources in their states. Similarly, it will be seen in Chapter 5 that the State Teams applied different methods for estimating the development of those resources for specific applications over future time. Therefore, a consistent summary of the geothermal resource applications for the Southwest Region was most difficult and required considerable reinterpretation of the state-by-state data by the authors of this summary report.

Table 4.17 provides estimates of the electric and direct thermal applications of the geothermal resources for the five states. The resources are distributed among the three quality categories of definitive information: proven, potential and inferred, as described in Section 4.4. In addition, the electric applications are quantified in terms of the rate of energy supply (MWe), assuming a 30-year reservoir capacity for the geothermal resource; only reservoirs with measured or estimated subsurface temperatures in excess of 150^{o} C are evaluated for electric applications. For the direct thermal applications, the resource quantity is expressed as the total energy (Quads) recoverable or useable above ground from the estimated reservoir size. The reasons for using energy delivery rate for electric and total energy above ground for direct thermal are (1) this represents current convention and (2) the efficiency for geothermal energy conversion to electric energy is reasonably well known whereas the efficiency for direct thermal varies with the specific application.

In the following sections, brief descriptions of the origin and basis of the numbers quoted in Table 4.17 for each state are enumerated.

4.5.1 Arizona.

4.5.1.1 Electric Applications.
The Arizona team found no advanced development activity with electric applications, so the proven electric resources are zero. However, potential applications totaling 150 MWe are based upon the four sites listed in Table 4.8 and the "probable" energy rate assignments for those sites provided by the Arizona team. The inferred applications

Table 4.17

Estimated Geothermal Resource Applications in the Southwest Region [1]

State	Electric (MWe) [2]				Direct Thermal (Quads) [3]			
	Proven	Potential	Inferred	Total	Proven	Potential	Inferred	Total
Arizona	0	150	4300	4450	0	(0.2018)	(5.785)	(5.9869) [4]
Colorado	0	100	400	500	0.0121	0.3254	0.3929	0.7304
Nevada	110	1540	12590	14240	0.0840	0.0740	0.4600	0.6180
New Mexico	50	395	1677	2122	0	0.0830	2.0678	2.1508
Utah	100	440	880	1420	0.0027	0.1946	1.400	1.5973
Total	260	2625	19847	22732	0.0988	0.8788	10.1057	11.0833

(1) See Section 4.5 for an explanation of the compilations of this Table.

(2) Energy for electric applications is cited as the energy rate (MWe), assuming a 30-year reservoir capacity; electric energy is based upon reservoir temperatures in excess of 150° C, which is also useable for direct thermal applications if not converted to electric energy.

(3) Energy for direct thermal applications is cited as the total energy recoverable/useable over a 30-year period.

(4) Estimates of Arizona's direct thermal applications are a multiple (1.5x) of electric energy, not a summation of resource sites.

of 4300 MWe are for those same four sites plus eight others listed by the Arizona team (San Bernardino Valley, Springerville, Flagstaff, Yuma, Hyder Valley, Tucson, Wilcox and Pinacati Field).

4.5.1.2 Direct Thermal Applications. The Arizona team did not in its first year estimate the resource size of each low temperature site, because of a lack of sufficient resource assessment data. The team geologists, therefore, multiplied their estimates of the electric resources by a factor of 1.5 to derive estimates of the direct thermal resources. This same factor was applied to the numbers cited in Section 4.5.1.1 to obtain the direct thermal values quoted in Table 4.17; the results are 0.02018 Quad of potential and 5.785 Quads of inferred resources.

4.5.2 Colorado

4.5.2.1 Electric Applications. The Colorado team reported zero proven electric resource applications but estimated 100 MWe of potential resource for the Mt. Princeton site through the year 1985. The 400 MWe of inferred resource is for the sites of Poncha Springs and Cebolla after 1985.

4.5.2.2 Direct Thermal Applications. The district heating development at Pagosa Springs, recently awarded a geothermal demonstration contract by DOE, constitutes the only proven direct thermal resource in Colorado, other than existing single unit spas, swimming pools, etc; the total estimated recoverable energy value of 0.0121 Quad is quoted in Table 4.10. The potential recoverable energy of 0.3254 Quad is based upon the Colorado team's data on eight leading sites (see Section 5.1.2, Table 5.1); Colorado's "Estimated Usable Energy" (same Table) was converted back to total recoverable energy above ground to obtain the value of 0.3254 Quad. The same procedure was used to obtain the inferred value of 0.3929 Quad, being calculated from Colorado's "Areas of No Known Activity But High Potential" and "Areas of Moderate Potential."

4.5.3 Nevada

4.5.3.1 Electric Applications. The proven resource applications totaling 110 MWe are based upon (1) the advanced drilling activity at Desert Peak

(70 MWe) and at Rye Patch (40 MWe) by Phillips Petroleum Co. and Sierra Pacific Power Co.; (2) the Nevada State Team "Postulated Development Schedule," (see Section 5.3); and (3) the judgment of the State Team Leader, G. Martin Booth, III.

The potential electric applications are estimated at 1540 MWe and are derived from the resource sites listed in Table 4.11 and the Nevada Area Scenarios for those same sites for any postulated development through year 1990 (the end year listed by the Nevada team for "indicated" resources). The inferred resources total 12,590 MWe and represents the difference between the total electrical applications postulated by Nevada (14,240 MWe) and the sum of the proven and potential (1650 MWe).

4.5.3.2 Direct Thermal Applications. The proven applications of 0.084 Quad consist of the existing food processing plant at Brady Hot Springs and the forthcoming development activities at Elko Hot Springs and Moana Hot Springs. The potential resource applications (0.074 Quad) are based upon the resource sites listed in Table 4.12 and the Nevada Area Scenarios for those same sites for any postulated development through year 1995 (the end year listed by the Nevada team for its "indicated" direct thermal applications). It is desirable to point out here that the Nevada team placed all sites having estimated subsurface temperatures in excess of 150°C in potential electric applications, while recognizing that the same sites would be liable for direct thermal applications. Hence, the inferred resource is only 0.460 Quad.

4.5.4 New Mexico

4.5.4.1 Electric Applications. Only the first electric generation unit (50 MWe) of the Union Oil Company/Public Service Company of New Mexico operation at the Redondo Field of Valles Caldera is listed here in the proven category, with an additional estimated 350 MWe placed in the potential category. The other 45 MWe of potential electric resource is derived from 20 MWe at Animas, 20 MWe at Kilbourne Hole, and 5 MWe at Radium Springs through the year 1985. The inferred total of 1677 MWe is derived largely from Valles Caldera but includes additions for the other three sites for the years after 1985.

4.5.4.2 Direct Thermal Applications. New Mexico has no proven direct thermal resources, as of this writing, except for the small private spas, swimming pools, etc. The potential resource of 0.0834 Quad is based upon the New Mexico Composite Scenario (Table 5.3) for the development of three sites (Jemez Springs, T or C, and Animas) through the year 1984. The inferred resource of 2.0674 Quads is attributed to those three sites plus five others for development through the year 2020. It should be noted here that the New Mexico team considered the Animas site for both electric and direct thermal applications.

4.5.5 Utah

4.5.5.1 Electric Applications. Utah's proven electric resource (100 MWe) is assigned by the State Team to the Roosevelt Hot Springs area, where extensive development activity is underway. The potential resource is assigned to Roosevelt (200 MWe), Cove Fort/Sulphurdale (220 MWe), and Thermo (20 MWe). An additional 880 MWe of inferred resource includes further expansion and the addition of North Cove Fort, West Cove Fort/Black Rock, and other unnamed areas.

4.5.5.2 Direct Thermal Applications. The DOE sponsored development activity at Monroe Hot Springs, Crystal Hot Springs, and Sandy City is the basis for the proven resource of 0.0027 Quad, estimated at 0.0009 Quad per site. The potential resource of 0.1946 Quad is derived from the Utah's Aggregate Scenario for postulated development through year 1985. The inferred resource of 1.400 Quads is the balance of the estimated total energy from all sites listed in the Utah Direct Use Development Profile (Figure 5.4).

CHAPTER 5

5.0 Geothermal Development Postulations, State by State

The Southwest Program called for the development of scenarios by each state showing planned or postulated geothermal development by sites. State Teams took different approaches to this task, largely because of wide variances from state to state in data available and in degree of development already underway or in an advanced planning stage. The state by state summaries below, therefore, are not parallel in form or content but are intended to project useful information on developments which may be reasonably predicted and the timetables of such development.

5.1 Colorado

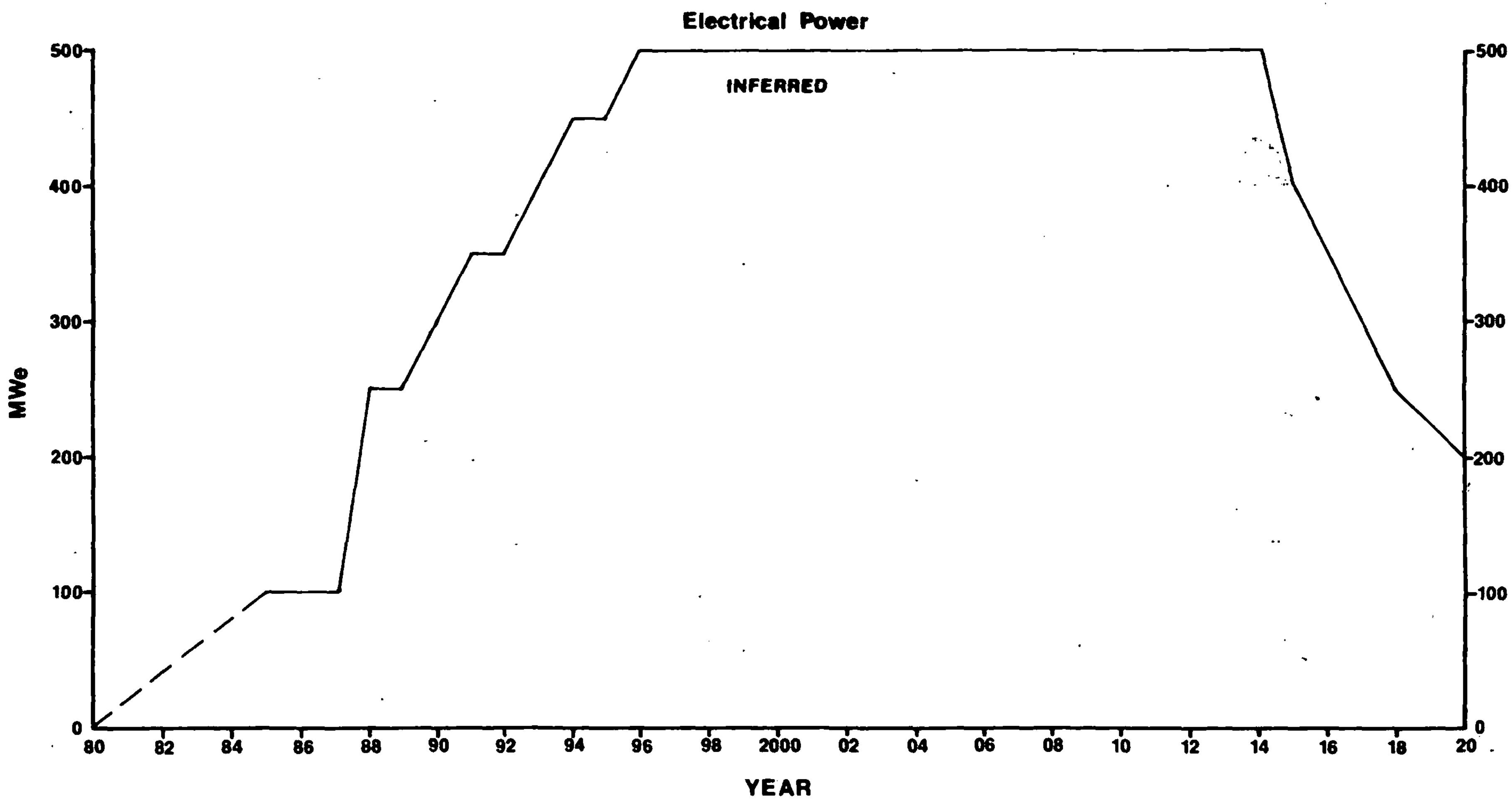
5.1.1 Electric Applications. At least three areas in Colorado appear at this time to have high enough temperatures for economical production of electricity. These indications are sufficient to have led private companies to obtain leases and begin investing money. The estimated potential of the three sites totals 500 MWe electric production and the timetable by which this production could come on line is shown in Figure 5.1. A brief discussion of each site follows.

Mt. Princeton. Discussions with industry officials result in an estimated potential of 100 MWe of electric production for 30 years at this site, where AMAX Exploration, Inc., drilled a 2,000 foot thermal gradient hole in 1977. With surface fluid temperatures of 44^{o}-56^{o} C, this field is estimated to have subsurface temperatures of 205^{o} -236^{o} C. Land ownership is private, state and federal. Leases have been issued covering 1,286 federal and 7,617 state acres. There appear to be no technological constraints, but institutional constraints have held development nearly to a standstill.

Two companies, AMAX and Petro-Lewis Corp., holding state and private leases are awaiting issuance of federal leases to round out and appropriate blocks of land before investing in further drilling. Delay has been caused

Figure 5.1

Possible Geothermal Energy Development Schedule For Colorado



by a legal debate about the ownership of geothermal resources in some cases where surface ownership is private and mineral rights are reserved to the Federal government. Some other lease applications involve Forest Service land, where both surface and subsurface ownership is federal and the Forest Service has prolonged review of the applications.

Contingent upon lease issuance, there could be 50 MWe of power on line by 1985 and a total of 100 MWe by 1988.

Poncha Hot Springs. Industry estimates point to a potential of 200 MWe at this site, which includes a known geothermal resource area (KGRA) where Occidental Oil holds federal leases and had scheduled drilling of shallow gradient holes in 1978. Occidental and Petro-Lewis applied in 1974 for leases on adjacent Bureau of Land Management and Forest Lands. These leases have not been issued or denied. The companies have asked that the leases be issued with a non-occupancy clause or put into escrow until a court resolution of some title disputes.

An institutional constraint here, presumably similar in other areas, is the extreme delay in obtaining return on investment. Geothermal development, estimated to take 13 years for payout, must compete for risk capital with other types of project which have payout periods of as little as three years.

Surface fluid temperatures are 40°-71° C, with subsurface temperatures of 110°-145° C estimated from geochemistry. The site includes 916 federal acres in the KGRA, 5,023 other federal acres, 5,147 acres of state lands, and about 20,000 acres of private land.

If leases are issued in the near future, at least 200 MWe of power could be expected ultimately with some estimates of a much higher potential.

Cebolla Hot Springs. Industry estimates indicate that 200 MWe can be produced from this site. Surface temperatures are 38°-40° C, with estimated subsurface temperatures running 175°-200° C from a reservoir 500 feet thick and 0.86 square mile in area. Chevron Oil Co. holds federal leases in the area, but has not obtained necessary private leases.

The only apparent physical constraint is the rugged topography of the area. Apparently more serious is leasing difficulty, in this case involving private land. Some private landowners have denied access to federal leases.

Chevron has scheduled drilling of five thermal gradient holes. If results are satisfactory Chevron may be expected to drill 1,500-2,000 foot holes along fault zones attempting to hit the anomaly and obtain water samples. If these results are satisfactory, the company likely will drill up to three slim-hole wells to 3,000 to 5,000 foot depths. If success occurs along the line, a 50 MWe plant could be on line by 1988 with three more units of this size added by 1997 for a total of 200 MWe.

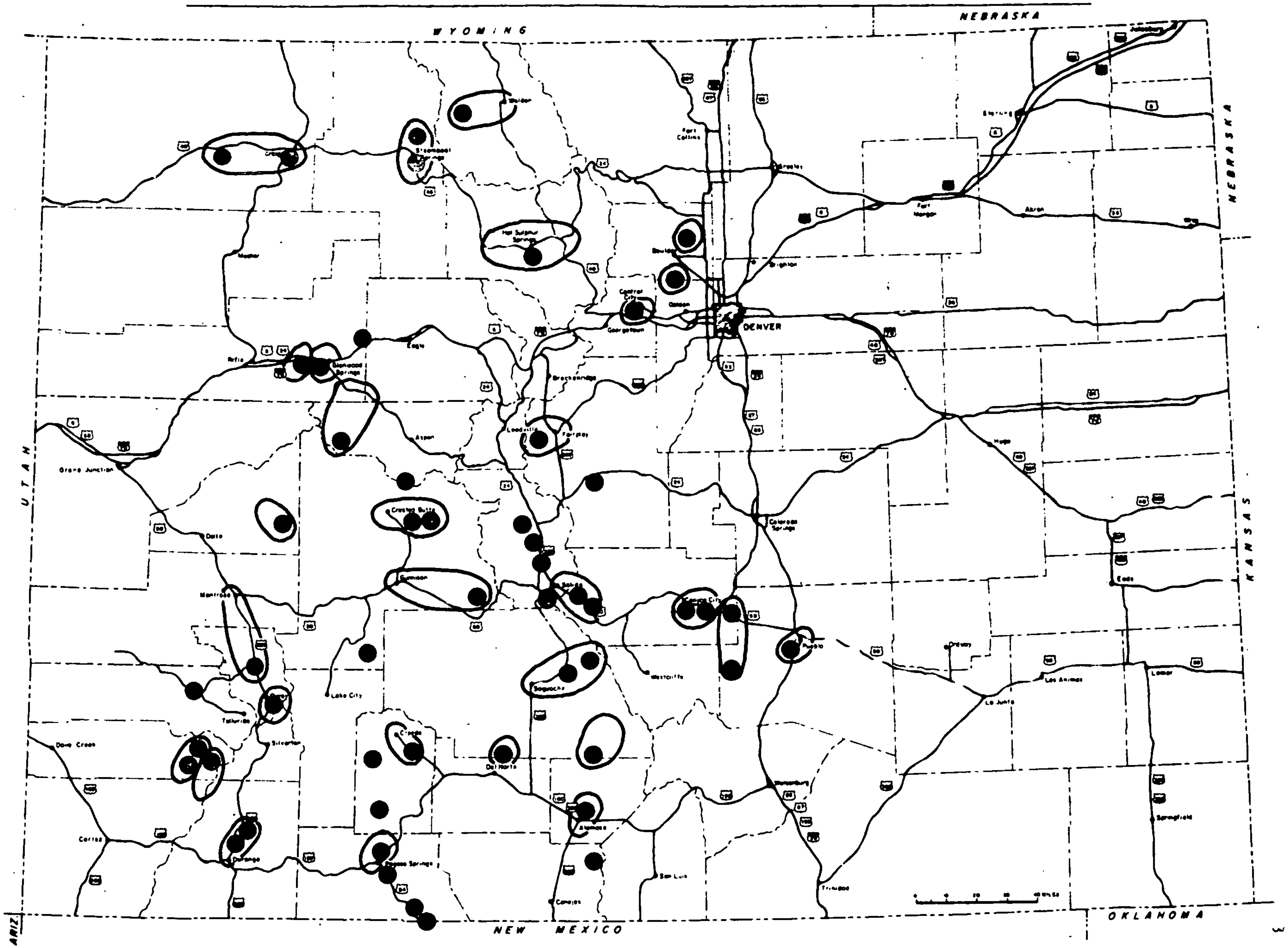
5.1.2 Non-Electric Applications. In drawing up scenarios for non-electric, or direct thermal, use of geothermal heat, the Colorado State Team matched resource areas with existing communities which might use the resource, based on proximity and the amount of energy estimated to be available. Data was collected for use in subsequent feasibility testing of the direct use of the resource for space and water heating, the predominant existing demand. Relatively little attention was given to other direct thermal uses because of a lack of information on the other applications.

It was found that ample energy seemed to be available to supply a substantial part of the space and water heating for 27 incorporated municipalities, plus several subdivisions and developments. Twenty-three of these communities are within 10 miles of the resource and of these 16 are virtually on site. In 14 areas, federal leases appear to be required, if not at the outset, then later to expand systems. Ten of these involve Forest Service land. Thirteen areas appear to require only fee land leases. The map in Figure 5.2 relates the location of resource sites with communities which might be served.

In the 27 communities identified, geothermal energy appears to be available to heat more than 16,000 homes plus an equivalent amount for existing industrial, commercial and public buildings, and also plus some assorted use for two timber kilns, one feed lot, one hog pen, three greenhouses, one barley malting plant and one food dehydrating plant. The composite of these scenarios shows a total of 0.003 Quads developed for

Figure 5.2

Potential Geothermal Resource Use Areas In Colorado For Scenarios, June, 1978



actual use by 1991, as shown in Figure 5.3.

A constraint to use of the resource in the cases is the cost of converting heating systems from natural gas to geothermal use, this cost generally making conversion non-competitive with use of gas. However, in areas where new structures of sufficient size and number are being built, and especially where gas is not available but higher-priced electricity, propane, or solar heating must be used, the economies of geothermal use are greatly enhanced. Moreover, on the long term, retrofitting may be economically justified. If geothermal systems were developed now, this energy would be available for new buildings as they are erected and over a period of time economies of scale could be effected.

The Colorado state scenarios relate location of the resource to communities, number of dwelling units, estimated 1975 natural gas demand, estimated number of dwelling units in 2020, and other factors for each of the resource areas. Reproduced here, as Table 5.1, is the Colorado table showing these elements in only the leading eight resource areas.

5.1.2.1 An Advanced Scenario: Pagosa Springs, Colorado. The most advanced development in Colorado is a space heating project in Pagosa Springs, a town of 524 dwelling units and rather depressed economic conditions in the southwestern part of the state. DOE has approved a contract for a cost-shared demonstration project for space heating of several public buildings and some businesses and homes.

A space heating district will be managed by the town, Archuleta County, and School District 50, which already has budgeted funds for conversion of heating facilities within school buildings. Coury and Associates of Denver is preparing architectural/engineering plans.

This is not an entirely new application of geothermal energy, since several small buildings already are heated from 12 existing wells and the Colorado Geological Survey drilled an additional well in 1978. (Use of geothermal waters for space heating dates back to the early 1900s in the community and 27 wells are known to have been used at one time or another.)

The major technical problem is the high level of dissolved solids in

Figure 5.3

Possible Geothermal Energy Development Schedule For Colorado

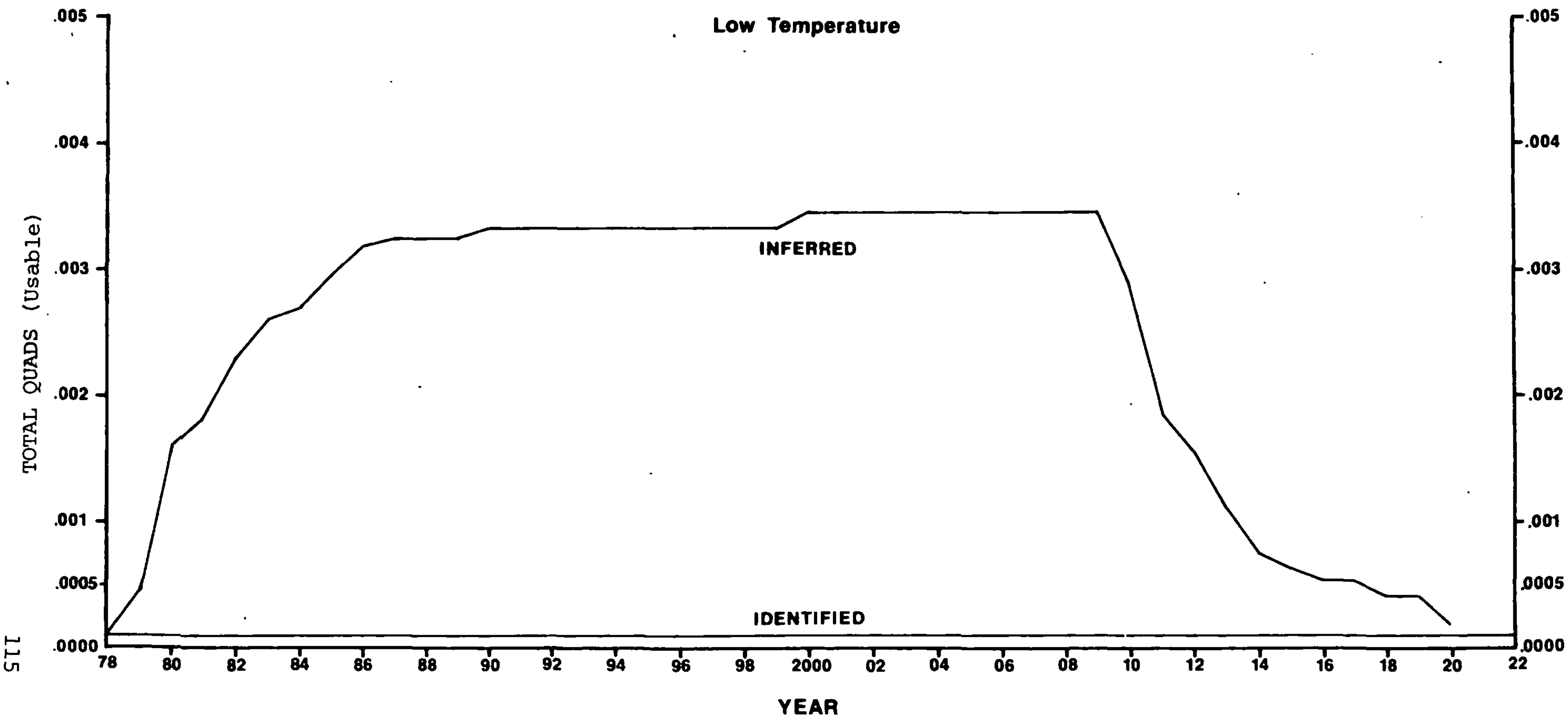


Table 5.1

Postulated Direct Thermal Use at Eight Leading Colorado Sites

Area Name	Number	Use	Distance	1975 Estimated Dwelling Units	1975 Estimated Natural Gas Demand (10^{12} Btu's)	2020 Estimated Dwelling Units	2020 Estimated Natural Gas Demand (10^{12} Btu's)	Estimated Usable Energy Available (10^{12} Btu's)	Estimated Usable Energy Available Per Year for 30 Years (10^{12} Btu's)
Glenwood	11	space heat Glenwood Springs	0	1,784	.32	3,796	.68	1.7	.06
Hartsel	19	space heat Fairplay	16	215	.04	271	.04	2.5	.08
Splashland	35	Alamosa	2	2,807	.50	8,083	1.44	4.7	.16
Sand Dunes	34	Baca Grande	14	225	.02	10,000	1.78	4.7	.16
Shaws	33	greenhouse	0	NA*	.02	NA	NA	.9	.03
Mineral/Valley View	31/32	space heat Saguache	12	226	.04	380	.06	60.0	2.00
		timber kiln			.04				
		barley melting			.22				
		potato flakes			.86				
Pagosa Springs	41	space heat Pagosa Springs	0	524	.09	1,481	.26	2.9	.10
Waunita	46	space heat Gunnison timber drying	22	1,880	.33	4,326	.77	3.6	.12

*Not applicable

the water--3,040 to 3,320 mg/l,--which presents corrosion problems. Such corrosion caused the replacement of some earlier geothermal systems with natural gas systems (during the era of low gas prices), although several small buildings currently use geothermal space heating.

Not only are natural gas prices now higher but also the supply is inadequate; therefore community interest in geothermal space heating is high.

The Pagosa Springs water has a surface temperature of 54^{o} C, an estimated subsurface temperature of 55^{o}-125^{o} C, and a reservoir area estimated to be 200 feet thick in a 2.13 square-mile area. The usable energy potential is estimated at 2.9×10^{12} Btus, this being the net available after allowing for conversion inefficiencies. (Estimated 1975 natural gas demand in the town in 1975 was 0.09×10^{12} Btus.)

Aside from the benefits of reducing dependence on natural gas, an incentive for geothermal development in Pagosa Springs is the potential economic stimulation which might occur. Suggested uses, particularly if the reservoir is found to be adequate after further evaluation, include kiln drying of lumber, greenhouse heating, fish farming and feed lot warming, all of which could aid the economy of the depressed area.

At best the Pagosa Springs project, and even a combination of many like it, can contribute only infinitesmally to the national energy requirement. However such geothermal applications assume much greater significance when viewed from the standpoint of the needs of local people who have their own particular problems in small, isolated communities. Evaluation of projects such as this should not be so much in terms of "how much" as in terms of where and when a specific need is fulfilled.

No timetable for the Pagosa Springs scenario has been suggested, but due to the advanced stage of planning, the existence of productive wells, and the relative simplicity of the work to be performed, energy should be on line quite soon.

5.2 New Mexico

5.2.1 Electric Applications. The State Team identified five sites as promising substantial electric generation. One of these, Valles Caldera, is expected to begin putting power on line in 1982 and is postulated to produce 1900 MWe in 2020. Others are Animas, coming on line in 1986 and reaching 100 MWe in 1990; Kilbourne Hole, on line in 1986 and rising to 50 MWe in 1990; Lower San Francisco, coming on line in 1990 and rising to 20 MWe in 1992; and Radium Springs, coming on line in 1988 and rising to 30 MWe in 1990.

The development of each of these sites is postulated on a timetable given in Table 5.2. Their combined output is estimated at 2100 MWe in 2020.

5.2.1.1 An Advanced Scenario: Valles Caldera, New Mexico. The most advanced development in New Mexico is in the Valles Caldera, west of Los Alamos, where an initial 50 MWe power plant is expected to begin feeding power into the lines of Public Service Company of New Mexico in 1982.

Over a period of several years, Union Oil Company has carried out development activities and has proven out steam and hot water resources to power a 50 MWe electric generation plant. It has formed a partnership with Public Service Co. to build the plant and late in 1978 received approval of a DOE contract to share costs of the plant.

The developmental scenario is: environmental impact statements approved by early 1979; Public Utility Commission of New Mexico issues permit in 1979 to build plant; Forest Service grants right-of-way for transmission lines in late 1979 or early 1980; drilling of development wells, already under way, completed in 1980; construction of plants and transmission lines begins early in 1980 with completion by mid-1982.

The present development program is confined to private lands which encompass the thus far proven resource. This private land is ringed by federal lands on which several other companies have obtained leases. As the reservoir is further explored, potential yield is estimated to range from a pessimistic 400 MWe for 30 years to a more optimistic estimate of 1,900 MWe for 30 years.

5.2.2 Direct Thermal Applications. The New Mexico State Team postulated

Table 5.2, Page 1 of 2

Composite Scenarios for Geothermal Power Generation in New Mexico

Site	Total MWe	1980	82	84	86	88	90	92	94	96	98	2000
Animas	100				20	20	100	100	100	100	100	100
Kilbourne	50				10	25	50	50	50	50	50	50
Lower San Francisco	20						15	20	20	20	20	20
Radium Springs	30					5	30	30	30	30	30	30
Valles Caldera	2000		50	100	200	300	400	500	600	700	800	900
Cumulative Total			50	100	230	350	595	700	800	900	1000	1100

Continued--

Table 5.2, Page 2 of 2

Composite Scenarios for Geothermal Power Generation in New Mexico

Site	2002	04	06	08	10	12	14	16	18	2020
Animas	100	100	100	100	100	100	100	100	100	100
Kilbourne	50	50	50	50	50	50	50	50	50	50
Lower San Francisco	20	20	20	20	20	20	20	20	20	20
Radium Spring	30	30	30	30	30	30	30	30	30	30
Valles Caldera	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
Cumulative Total	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100

direct thermal utilization eight of state's most promising sites, beginning with modest present use and beginning to expand substantially by 1986. Table 5.3 sketches this development by sites and in the aggregate through 2010, after which a gradual decline in yield is postulated. While the State Team has prepared assessments of the potential yield and most likely uses at each of these sites, none lend themselves to presentation here as an advanced scenario.

5.3 Nevada

5.3.1 State Approach to Scenarios. By the end of the first year of the Southwest Program, the Nevada State Team had identified more than 300 geothermal sites. To make analysis and scenario projection less unwieldy, the team divided the state into 26 geothermal areas based on topographic, geological and/or geothermal features, each of these areas containing 6 to 12 sites. Scenarios were then developed for each area.

Each area scenario includes a site development scenario for the first electrical generating plant and/or the first direct thermal use to come on line. Within the 26 area scenarios, a total of 31 postulated site development scenarios have been constructed. These are sites which appear to have a reasonable chance for commercial development by the year 2020.

Although numerical energy capacities are assigned to sites with specific names, the Nevada team cautions that technical criteria for competent estimation is almost entirely lacking. It is fully expected that many electric sites will be incapable of producing a single megawatt, while some others, not yet recognized, will provide substantial power. The site-by-site estimates are largely subjective judgments which are more credible in the aggregate than for each particular site.

It is not improbable that fully one-third of the 300 sites eventually will prove to contain high (over 150^{o}C) to intermediate (90^{o}-150^{o} C) temperature resources. Low temperature sites also are prominent, not only in number but also due to the fact that they are widely distributed, each of the state's 17 counties having several.

Table 5.3

Composite Scenarios for Direct Utilization of Geothermal Resources in New Mexico

Site and Activity	Total MWth	1978	80	82	84	86	88	90	92	94	96	98	2000	02	04	06	08	10
Socorro Spg. (Campus Heating)	30					10	20	30	30	30	30	30	30	30	30	30	30	30
Kilbourne Hole, Las Alturas & Anthony; (Space Heating, Crop Drying, etc.)	50					20	40	50	50	50	50	50	50	50	50	50	50	50
Radium Spg. (Greenhouses, Crop Dehydration)	50					20	40	50	50	50	50	50	50	50	50	50	50	50
Jemez Spg. (Space Heating, Agriculture)	60	3	3	3	23	43	60	60	60	60	60	60	60	60	60	60	60	60
T or C (Space Heating, Recreation)	30	2	2	2	30	30	30	30	30	30	30	30	30	30	30	30	30	30
San Ysidro (Space Heating)	20						20	20	20	20	20	20	20	20	20	20	20	20
Animas (Space Heating, Greenhouses)	40	2	2	22	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Albuquerque	50					20	40	50	50	50	50	50	50	50	50	50	50	50
Cumulative Total		7	7	27	93	193	290	330	330	330	330	330	330	330	330	330	330	330*

*Declining use is indicated after 2010

T or C -- Truth or Consequences

To provide an example of the Nevada scenarios, this summary provides in slightly condensed form the scenario for Area 16 in Section 5.3.2 and in Tables 5.4, 5.5, 5.6 and 5.7 below. Section 5.3.3 and Tables 5.8 and 5.9 then present aggregations of postulated geothermal energy production in the state through the year 2020.

5.3.2 The Nevada Area 16 Scenario. This area includes two sites in which the earliest developments in the state are anticipated, one electric and one direct thermal. In fact, the first application of direct thermal usage already has been made in this area, so that the site specific schedule provided for it is past tense rather than postulated.

Area 16 includes seven sites, as shown in Table 5.4. Nearly 95 percent of the total area is a checkerboard pattern of alternating federal and private lands, including Indian reservation and Bureau of Reclamation withdrawn lands. Only two of the seven sites are on federal land, the remaining five being in a checkerboard ownership pattern. There are two KGRAs in the area, Brady's Hot Springs and Hazen, both with significant leasing interest. Only one site is without leasing activity and the heaviest activity is in one non-KGRA area, Biddleman Spring.

Table 5.4 lists the seven sites in the area and provides temperatures, reservoir assumptions and energy potential estimates for each. (Brady's Hot Springs is listed twice, once to show electric potential and once to show direct thermal values.)

Table 5.5 shows postulated production in each site over a time span of 1978-1998.

Table 5.6 then shows the development schedule for one direct thermal application at one site: a food dehydration facility at Brady's Hot Springs. Since this facility began operations late in 1978, the schedule is past tense.

Table 5.7 shows the postulated development schedule for the first 20 MW electric power plant expected in the state, which potentially will be on line at the Desert Peak site in Area 16 in 1982.

Table 5.4

Hot-Water Convection Systems in Area 16, Nevada

Location	Temperatures (°C)				Reservoir Assumptions		Energy Potential		
	Surface (1)	Geochemical SiO_2 (2)	Geochemical Na-K-Ca (2)	Subsurface (3)	Volume km^3 (4)	Heat content 10^{18} cal (5)	Recovery Factor e_r (6)	Electrical Potential MWe 30 yrs.	Thermal Energy for Direct Use Quads (7)
Desert Peak	ND			212 (215)	50	6.0	0.025	665	
Brady's Hot Springs	98	179		214 (215	20	2.4	0.025	265	
Huxley	ND			(200)	10	1.1	0.025	125	
Eagle Salt Works	Hot			(215)	10	1.2			1.2
Hot Springs Mountains	ND			(215)	20	2.4	0.025	265	
Hazen	ND			132-(200)	10	1.1	0.025	125	
Biddlemen Spring	24								
Brady's Hot Springs	98			(215)	10	1.2			1.2

Footnotes

(1) Maximum surface temperature reported from a spring or fumarole.

(2) Predicted using chemical geothermometers, assuming last equilibration in the reservoir; assumes saturation of SiO_2 with respect to quartz, and no loss of Ca from calcite deposition.

(3) Assumed average reservoir temperature based on data presently available. Temperatures from Circular 726 and other sources. Temperatures in parentheses are highly subjective.

(4) From surface manifestations, geophysical data, well records, geologic inference and leasing activity. Assumes 1.5 km^2 if no data pertinent to size is available. Top assumed at depth of 1.5 km if no data available. Bottom assumed at 3 km depth for all convection systems. Calculated from assumed area and thickness.

(5) Calculated as product of assumed volume, volumetric specific heat of 0.6 $cal/cm^3 {}^\circ C$, and temperature in degrees C above 15°C.

(6) 0.02 for 150°-200°C 0.025 for 200°-250°C

(7) 25 percent Heat Content Recoverable as thermal energy at the surface; 1 Quad = 0.25×10^{18} cal.

Table 5.5

Postulated Production in Nevada Area 16, By Site

SITE NAME	1978	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
Desert Peak					20	20	70	70	120	120	220	220	320	320	420	420	520	520	620	620	665
Brady's Hot Springs	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
Huxley																					
Eagle Salt Works									.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
Hot Springs Mountains																					
Hazen																					
Biddleman Spring																					
Brady's Hot Springs																		15	15	65	65

Continued →	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Desert Peak	665	665	665	665	665	665	665	665	665	665	665	665	665	645	645	595	595	495	495	395	395	295
Brady's Hot Springs	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04												
Huxley		25	25	75	75	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125
Eagle Salt Works	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04					
Hot Springs Mountains							15	15	65	65	165	165	215	215	265	265	265	265	265	265	265	265
Hazen												25	25	75	75	125	125	125	125	125	125	125
Biddleman Spring																						
Brady's Hot Springs	165	165	215	215	265	265	265	265	265	265	265	265	265	265	265	265	265	265	265	265	265	265

Fractional numbers (i.e., .04) refer to quads (quadrillions of Btus) and are used where direct thermal applications are expected.

Full numbers (i.e. 20, 70, et al) refer to megawatts electric and are used where electrical applications are expected.

The Brady's Hot Springs site is listed twice, the first listing covering direct thermal applications beginning in 1978 and the second covering potential electric application beginning in 1995.

Table 5.6

Development Schedule for Food Dehydration Plant at Brady's Hot Springs, Nevada

OPERATING ENTITIES	ACTIVITY	RECIPIENTS	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
BLM	Approve Notice of Intent	Developer							—	—								
USGS	Approve NOI & Drill Permit	Developer																
BLM/Owner	Lease Land	Developer					—	—	—									
BLM	Process EIA/EIS	CEQ						—										
County	Issue Land Use Permits	Developer	}															
Developer	Exploratory Drilling & Reservoir Evaluation		}															
Developer	Develop User Interest		}															
Developer & User	Feasibility Study		}	completed														
Producer (Developer) & User	Financial Negotiations		}															
Producer	Site Selection									—								
Producer & User	Commitment to Development									▽								
Producer & User	Design									—	—							
Producer & User	Prepare Master Development Plan	BLM, USGS								—								
User	Prepare Environmental Statement	BLM, STATE, County								—								
BLM, STATE, USGS	Issue Permits on Site	Producer & User								—	—							
USGS	Process EIA/EIS (Drilling)	CEQ								—								
Producer	Development Drilling										—							
User	Plant Construction										—							
	On Line											▼	—	—	—	—	—	→

Table 5.7

Postulated Site Development Schedule for First 20 MWe Electric Generation Plant
Desert Peak, Nevada

GENERATING ENTITIES	ACTIVITY	RECIPIENTS	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
BLM	Approve Notice of Intent-	Developer																
USGS	Approve NOI & Drill Permit	Developer																
BLM/Owner	Lease Land	Developer																
BLM	Process EIA/EIS	CEQ																
County	Issue Land Use Permits	Developer																
Developer	Exploratory Drilling & Reservoir Evaluation																	
Developer	Develop Utility Interest																	
Developer & Utility	Feasibility Study																	
Producer (Developer) & Utility	Financial Negotiations																	
Producer	Site Selection																	
Producer & Utility	Design																	
Prod. & Util.	Commitment to Develop																	
Prod. & Util.	Prepare Master Development Plan	BLM, USGS																
Utility	Prepare Environmental Data Statement	BLM,FPC STATE, County																
BLM, FPC STATE, USGS	Certify Plant & Site Issue Permits	Producer & Utility																
USGS	Process EIA/EIS (Drilling)	CEQ																

Continued--

Table 5.7 (Continue.

GENERATING ENTITIES	ACTIVITY	RECIPIENTS	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
FPC	Process EIA/EIS (Plant)	CEQ										—						
FPC	Process EIA/EIS (Transmission Line)	CEQ										—						
Producer	Development Drilling												—					
Utility	Plant Construction												—					
Utility	Install Transmission Line (40 km)													—				
	Power on line														▼—	—	—	—→

(It is postulated that additional units will be added between 1985 and 1998 bringing total generation capacity to 665 MWe.)

5.3.3 Nevada Aggregated Production Scenario. By combining the estimates of the resources and the postulated development scenarios in all 26 areas, the Nevada team arrived at postulated schedules of potential geothermal production for the state as a whole through each year to 2020. Table 5.8 provides these estimates by sites and for the state as a whole, in electric power generation; Table 5.9 provides the same information relative to direct thermal applications. The ultimate totals postulated are impressively high, showing geothermal electric generation as peaking at 14,095 MWe in 2015 and direct thermal use peaking at 0.618 Quad in 2005-6.

As noted in Section 5.3.1 above, these figures are based on inadequate criteria, although the Nevada team thinks they may be reasonably credible in the aggregate, and full use of the potential is hardly to be expected. Also, it must be emphasized that these totals include use of inferred and indicated as well as identified resources. Tables 5.8 and 5.9 roughly indicate the distinctions between these three categories.

5.3.3 Advanced Projects in Nevada. Three examples of advanced activity in direct thermal uses may be cited in Nevada.

5.3.3.1 Brady's Hot Springs. Use was scheduled to begin late in 1978 of hot waters from Brady's Hot Springs for food dehydration. Builder of the plant is Geothermal Food Processors, Inc., which secured the second loan guarantee (for $2.6 million) approved by DOE after initiation of the loan guarantee program in 1976. The company holds a contract with Gilroy Foods, Inc., to process 15 to 18 million pounds of onions during a 110-day harvest period each year. Use of geothermal heat rather than natural gas is expected to yield a $235,000 per year saving in fuel costs. From the public interest standpoint, the value of this project is that it will avoid the use of 117 million cubic feet of gas per year, a volume sufficient to heat 1,100 average homes in northern Nevada.

5.3.3.2 Space Heating in Elko. DOE has announced a contract for establishment of a space heating district in the town of Elko. Owners of

Table 5.8 Page 1 of 2

Postulated Development Schedule for Nevada Geothermal Areas

Electric Power Generation (in MWe)

	Identified			Inferred / Indicated						Inferred											
AREA	1982	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000	01	02
1										20	20	70	70	120	120	170	170	220	220	245	265
2					20	20	70	70	120	140	190	240	290	310	335	335	360	360	410	410	460
3							20	20	70	70	90	90	90	90	90	90	90	90	90	90	90
4						30	30	80	80	130	130	180	180	180	180	180	180	210	210	260	260
5						20	20	70	70	120	120	170	170	220	220	245	245	245	245	245	245
6				20	20	70	70	120	120	170	170	220	220	245	280	280	380	380	480	500	600
7				20	20	70	70	90	90	90	90	90	90	90	90	90	90	90	90	90	90
8					40	40	90	90	190	190	290	290	390	390	490	490	540	540	570	570	620
9																			20	20	70
10				35	35	135	135	235	235	335	335	435	435	535	535	635	635	685	685	735	735
11																					
12					20	20	70	70	170	170	270	270	370	370	470	470	570	570	670	670	770
13								20	20	70	70	90	90	90	90	110	110	160	160	180	200
14								20	20	70	70	170	170	270	270	370	370	420	420	470	470
15							50	50	50	100	100	100	200	200	200	300	300	300	350	350	350
16	20	20	70	70	120	120	220	220	320	320	420	420	520	535	635	685	730	830	855	905	955
17							25	25	75	75	125	125	125	125	125	125	125	125	125	150	150
18				50	50	150	150	250	250	350	380	430	480	480	580	580	680	680	780	780	880
19						20	20	70	105	155	205	255	305	355	390	415	465	485	535	585	635
20					30	30	80	80	80	80	80	80	80	80	110	110	160	160	160	160	160
21									15	15	65	65	115	115	165	165	165	165	165	165	165
22																					
23										40	40	90	90	140	140	240	240	340	365	415	465
24									40	40	90	90	90	90	130	130	180	180	180	180	220
TOTAL	20	20	70	195	355	725	1120	1580	2120	2750	3350	3970	4570	5030	5645	6215	6785	7235	7785	8175	8855

Identified: Reservoir characertistics at least partially known from one or more deep test wells; economic or apparently economic.
Indicated: Used here as the probable to possible extension of an Identified reservoir.
Inferred: A possible resource which has not been tested by a deep well. It may, for example, be a site characterized by favorable geothermometry, temperature gradient holes, and geophysics, or it may be merely the site of a nondescript, moderately thermal spring or a geothermal leasehold.

Continued on next page

AREA	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	2020
	Inferred																	
1	265	315	315	335	335	335	335	335	360	360	410	410	460	460	460	460	460	460
2	460	490	490	540	540	565	565	615	615	665	665	685	685	715	715	685	685	635
3	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	70	70	20
4	260	260	260	260	260	260	260	260	260	260	260	260	260	260	230	230	180	180
5	245	245	275	275	325	325	375	375	425	425	425	425	425	425	405	405	355	355
6	700	800	900	1000	1100	1200	1250	1320	1320	1420	1440	1480	1510	1580	1550	1620	1570	1590
7	90	90	90	90	90	90	90	90	90	90	90	90	70	90	40	90	70	90
8	620	670	670	720	720	750	750	800	800	850	850	900	900	860	860	810	810	710
9	70	120	120	170	170	220	220	245	245	245	245	265	265	315	315	335	335	335
10	735	735	755	755	805	805	855	855	905	905	955	955	945	945	845	845	745	745
11			20	20	70	70	120	120	170	170	220	220	245	245	245	245	245	245
12	770	870	870	970	970	1070	1090	1190	1240	1290	1340	1340	1390	1390	1440	1440	1490	1410
13	200	250	250	270	270	290	290	340	340	360	360	360	360	380	380	430	410	430
14	490	490	520	520	570	570	620	640	690	740	740	790	790	840	870	920	950	975
15	400	400	400	400	400	400	400	425	425	425	475	475	475	475	475	425	425	425
16	1005	1055	1070	1070	1120	1120	1220	1245	1295	1325	1375	1375	1375	1275	1275	1175	1175	1075
17	200	200	250	250	250	250	270	270	320	320	340	340	340	340	340	315	315	265
18	880	930	955	955	1005	1005	1055	1055	1080	1080	1130	1130	1130	1155	1055	1105	1005	1055
19	635	695	695	745	745	795	830	830	880	880	930	950	950	1000	980	1030	980	945
20	160	160	160	160	160	160	160	160	160	160	160	160	160	130	130	80	80	80
21	165	165	180	180	230	230	280	280	330	330	330	330	330	330	330	330	330	315
23	465	515	515	515	515	515	515	515	515	515	515	515	515	515	545	545	595	595
24	220	270	270	270	295	295	345	345	345	345	375	375	425	425	475	475	525	485
TOTAL	9125	9815	10120	10560	11035	11410	11985	12400	12900	13250	13720	13920	14095	14240	14050	14065	13805	13420

Table 5.9, Page 1 of 2

Postulated Development Schedule for Nevada Geothermal Areas

Direct Thermal Utilization (in Quads)

-Identified- (78–84) · -Indicated- (85–95) · -Inferred- (90–98)

AREA	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
1																					
2																					
3																					
4																					
5																					
6													.037	.037	.037	.037	.037	.037	.037	.037	.037
7																					
8																					
9										.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.11	.11
10																					
11								.017	.017	.017	.017	.017	.017	.017	.017	.017	.017	.017	.017	.017	.017
12																					
13																		.011	.011	.011	.011
14																					
15						.037	.037	.037	.037	.037	.037	.037	.074	.074	.091	.091	.091	.091	.091	.091	.091
16	.04	.04	.04	.04	.04	.04	.04	.04	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08
17																					
18				.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.06
19																	.05	.10	.10	.10	.10
20				.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.06
21																					
22																					
23																					
24																					
25													.005	.005	.005	.005	.005	.005	.005	.005	.005
26																					
TOTAL	.04	.04	.04	.09	.09	.127	.127	.144	.184	.254	.254	.254	.333	.333	.350	.350	.400	.461	.461	.501	.571

Identified: Reservoir characteristics at least partially known from one or more deep test wells; economic or apparently economic.

Indicated: Used here as the probable to possible extension of an Identified reservoir.

Inferred: A possible resource which has not been tested by a deep well. It may, for example, be a site characterized by favorable geothermometry, temperature gradient holes, and geophysics, or it may be merely the site of a nondescript, moderately thermal spring or geothermal leasehold.

Table 5.9, Page 2 of 2

-Inferred-

AREA	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
1																						
2																						
3																						
4																						
5																						
6	.037	.037	.037	.037	.037	.037	.037	.037	.037	.037	.037	.036	.036	.036	.036	.036	.036	.036	.036	.036	.036	.036
7																						
8																						
9	.11	.11	.11	.11	.11	.11	.11	.11	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.03	.035	.035	.035
10																						
11	.017	.017	.017	.017	.017	.017	.016	.016	.016	.016	.016	.016	.016	.016	.016	.016						
12																						
13	.011	.011	.011	.011	.011	.011	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010
14																						
15	.091	.091	.091	.091	.090	.090	.090	.090	.090	.090	.090	.089	.089	.088	.052	.052	.052	.052	.052	.052	.052	.016
16	.08	.08	.08	.08	.08	.08	.08	.08	.08	.04	.04	.04	.04	.04	.04	.04	.04					
17																						
18	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
19	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.09	.09	.09	.09	.09	.09	.09
20	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.03	.03	.03	.03	.03	.03	.03	.02	.02
21																						
22							.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
23					.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
24																						
25	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	
26												.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
TOTAL	.571	.571	.571	.571	.590	.590	.618	.618	.598	.558	.558	.561	.541	.510	.474	.464	.448	.408	.348	.353	.343	.302

Vogue Laundry, Stockman's Motor Hotel, and the Henderson Bank Building are principals of the Elko Heat Co., which will own the heating district. Chilton Engineering Co., owned by the bank owner, will provide designs and supervise construction. Rights-of-way have been assured by the town and use of them will be facilitated by a large renovation project in which downtown railroad tracks will be relocated.

Initially, heat will be delivered to the three businesses named above. Conversions will be straightforward; the bank has a hot water heating system, the hotel has a steam system which will be more difficult to convert, and the laundry uses are all based on hot water except for the steam presses which require about 360° F steam. The hotel could use geothermal heat in an absorption type refrigeration system for cooling.

The laundry is unusually large for such a small town since it serves retail cleaners in a number of other towns. Future expansion of the system may be dependent on prices asked by Elko Heat Co. Whether or not the company is regulated as a public utility may have a bearing.

5.3.3.3 Multiple Use at Moana Hot Springs, Reno. Hydrothermal Energy Corporation of Los Angeles is the recipient of a second demonstration grant in Nevada, at the Moana Hot Springs in Reno. Details are not available at the time of this writing; however, a multiple use application is proposed.

5.4 Utah

5.4.1 State Approach. The Utah State Team postulated development scenarios for the various known resource sites in the state but in its report expressed cautions as to the reality of many of these scenarios.

Much of the information needed to develop the scenarios is either proprietary or unknown. Most geothermal developers are hesitant to discuss such parameters as reservoir capacities, depths, and other characteristics, or to provide firm time frames for exploratory drilling. Often the company has not developed complete information; a good example is reservoir capacity which usually is not determined until power plants have been in operation for many years. Nevertheless, the Utah team has postulated scenarios for eight electric generation developments in five well-identified sites and several direct thermal sites.

All scenarios are dependent on numerous assumptions that various barriers will be overcome in a timely fashion, these barriers including resource quantity and quality and technological, institutional and economic problems.

The Utah team notes that development of direct thermal uses is more difficult to forecast than electrical applications, even though many direct uses are simpler and less costly. Several reasons are cited for this difficulty. Much more of the geothermal resource is suitable and available for direct use, so that the very volume of the possible scenarios is unwieldy. Development can occur much more quickly and on a smaller scale. A large number of uses are possible. Potential developers are harder to identify.

For purposes of this summary, development profiles provided by Utah for two electric and two non-electric applications will be presented in condensed form as examples, in Sections 5.4.2 and 5.4.3 and accompanying tables below. Following this, two tables aggregating the state's postulated total electric and direct thermal development by years through this century will be shown.

5.4.2 Selected Electric Site Scenarios. For purposes of drawing up scenarios, it was assumed that geothermal reservoirs would be confirmed early in each prospect, that the reservoirs will be of commercial size and quality, that no extraordinary difficulties such as depth and difficutly of drilling will be encountered, that development will be profitable to investors and that capital can be acquired, that federal assistance will be available, and that no unforeseen delays or problems will be encountered due to institutional factors. In other words, the scenarios are realistic only on the basis of quite optimistic assumptions.

Two scenarios, as examples, are:

5.4.2.1 Roosevelt Hot Springs, by Phillips Petroleum Co. This is the only Utah site at which a geothermal reservoir suitable for electric application has been verified. At least two companies or groupings of companies are active in the area and they may either proceed separately or they may unitize their efforts. For scenario purposes, it is assumed that Phillips will proceed independently to bring the field into production. Discussions are underway with Utah Power and Light Co. to use the hot fluids/steam in a generation plant operated by the latter company.

Table 5.10 depicts a development schedule which would put power on line by mid-1982. (Apparently an initial plant of 55 MWe capacity is planned.)

5.4.2.2 Thermo Prospect, by Republic Geothermal, Inc. This scenario covers one of the less-advanced explorations in the state. Republic, a smaller company than many of the major developers, has drilled one well in the area, but the well has not been completely tested and is currently suspended. Since the company is heavily involved with two projects in California, the Thermo prospect carries a somewhat low priority.

No information has been made public as to information gained in the test well, but indications are that the well shows some promise and that no extraordinary geological difficulties were encountered in drilling it. The site is somewhat isolated, increasing costs of moving in drilling rigs and also of construction of power lines.

Table 5.11 shows a postulated schedule to bring power on line from a first plant in this site by mid-1896.

5.4.3 Advanced Direct Thermal Scenarios in Utah. During the second year of the Southwest Program, the Utah team scheduled more detailed work on direct use scenarios and development profiles. Uses will be more completely identified and defined and these will be matched with the resource by location, temperature and quality, leading to classification of the suitability of the resource for various potential uses. Effort will be made to delineate development presently planned or underway. Based on earlier work, very limited scenarios have been prepared in quite general

Table 5.10

Possible Development Forecast: Roosevelt Prospect
(Phillips Petroleum Co.)

	78	79	80	81	82	83
Preliminary Exploration						
Lease Land: State						
Forest						
BLM						
Application for Water Rights	—					
Geophysical Exploration						
Utilization						
Exploratory Wells						
Reservoir Evaluation	—					
Commitment to Develop						
Master Development Plan						
Environmental Baseline Data	—					
Financial Negotiations						
Order Equipment	—					
Environmental Statement		—	—			
Design and Drill Well System	—	—	—	—		
Design and Drill Injection System		—	—	—		
Design and Build Gathering System			—	—		
Design and Install Powerline		—	—	—		
Design and Build 55 MW Plant		—	—	—	—	

Table 5.11

Possible Development Forecast: Thermo Prospect
(Republic Geothermal, Inc.)

	78	79	80	81	82	83	84	85	86	87
Preliminary Exploration										
Lease Land: Private										
State										
BLM										
Geophysical/Geological Exploration	—	—								
Application for Water Rights					—	—				
Exploratory Wells	—	—	—	—						
Reservoir Evaluation			—	—	—					
Commitment to Develop					▼					
Master Development Plan					—					
Environmental Baseline Data					—	—				
Financial Negotiations				—	—	—				
Order Equipment					—					
Environmental Statement					—	—	—			
Design and Drill Well System					—	—	—	—		
Design and Drill Injection System					—	—	—	—		
Design and Build Gathering System							—	—		
Design and Install Powerline						—	—	—		
Design and Build 55 MW Plant						—	—	—	—▼	

terms. Two examples of these are provided in narrative form below.

5.4.3.1 Monroe Hot Springs. Three springs with surface temperatures of 25° to 77° C and subsurface temperatures of 120° to 135° C issue from a hillside immediately east of Monroe City. They have an estimated energy potential of 85 MW thermal for 30 years. The springs are being used presently by a spa to heat a swimming pool, showers, etc. The owners have talked of eventually heating greenhouses and a motel.

The City of Monroe has received a DOE grant for a cost-sharing program under which eventually a large part of the community will be geothermally heated. The thermal waters will be tapped by a well in the vicinity of one of the springs, run through a heat exchanger, and reinjected on the opposite side of a fault from the springs.

The first phase of this project will involve heating a high school, beginning after drilling of the well in late 1978 or early 1979. Remainder of the development will continue until about 1981 and will use about 8 MWt of heat. Depending on reservoir characteristics, development beyond 1981 likely will continue.

5.4.3.2 Crystal Hot Springs. This site has an estimated energy potential of 43 MWt for 30 years from a series of springs with surface temperature of 58° C and subsurface temperature of 80° C. A local land-owner uses some spring water for raising tropical fish. Early in 1978 the Utah Geological and Mineral Survey drilled a series of temperature gradient wells near the site. The Utah State Foresters office plans to drill a test well near the nearby state prison complex.

The first scheduled application at this site will be for heating of the minimum security building at the Utah State Prison, which, along with Utah Energy Office, has secured a DOE award for a demonstration project. Terra Tek, Inc., is providing engineering services.

Heating of greenhouses and housing developments may follow in the future.

5.4.3.3 Greenhouse Heating, Salt Lake Valley. Utah Roses, Inc., has secured a DOE contract for a demonstration project to heat greenhouses of about six acres in area. This company ships cut-roses and other flowers by air freight to retailers nationwide; it is an energy intensive operation due to heat and humidity control requirements.

The heating system now used is an electronically controlled hot water system by which hot water is circulated around the periphery of the building and through forced air heat exchanges. Conversion of this system to use of geothermal fluids appears to be straightforward. It may be possible to dispose of the geothermal fluid in a waste ditch (Galena Canal); in fact, water quality of the ditch may be improved by this action. A $100,000 contingency allowance has been made to provide for reinjection of the fluid if disposal into the ditch is not acceptable.

This project has several demonstration values. The location near Salt Lake City is in a metropolitan area of about one million, thus providing unusual public exposure. The owners of the greenhouse are prominent nationally in greenhousing operations, thus providing for further exposure in that industry. Other industrial heat users are located nearby; creation of an industrial park using geothermal energy is an expansion possibility.

5.4.4 Utah Aggregated Potential Production. Table 5.12 postulates electrical production from various Utah sites beginning in 1982 and continuing through 1992. Figure 5.3 provides the same postulations for direct thermal use beginning in 1978 and continuing to the end of the century.

5.5 Arizona

The geoscience evaluations in Arizona reveal promises that the geothermal energy potential of Arizona may be quite large, but for the reasons noted in Section 4.1 surface manifestations are limited and there has been little exploratory drilling. Thus, site specific data as to the resource is lacking at this time. For this reason it is impossible or at least rather meaningless to develop scenarios showing the steps and time phases of

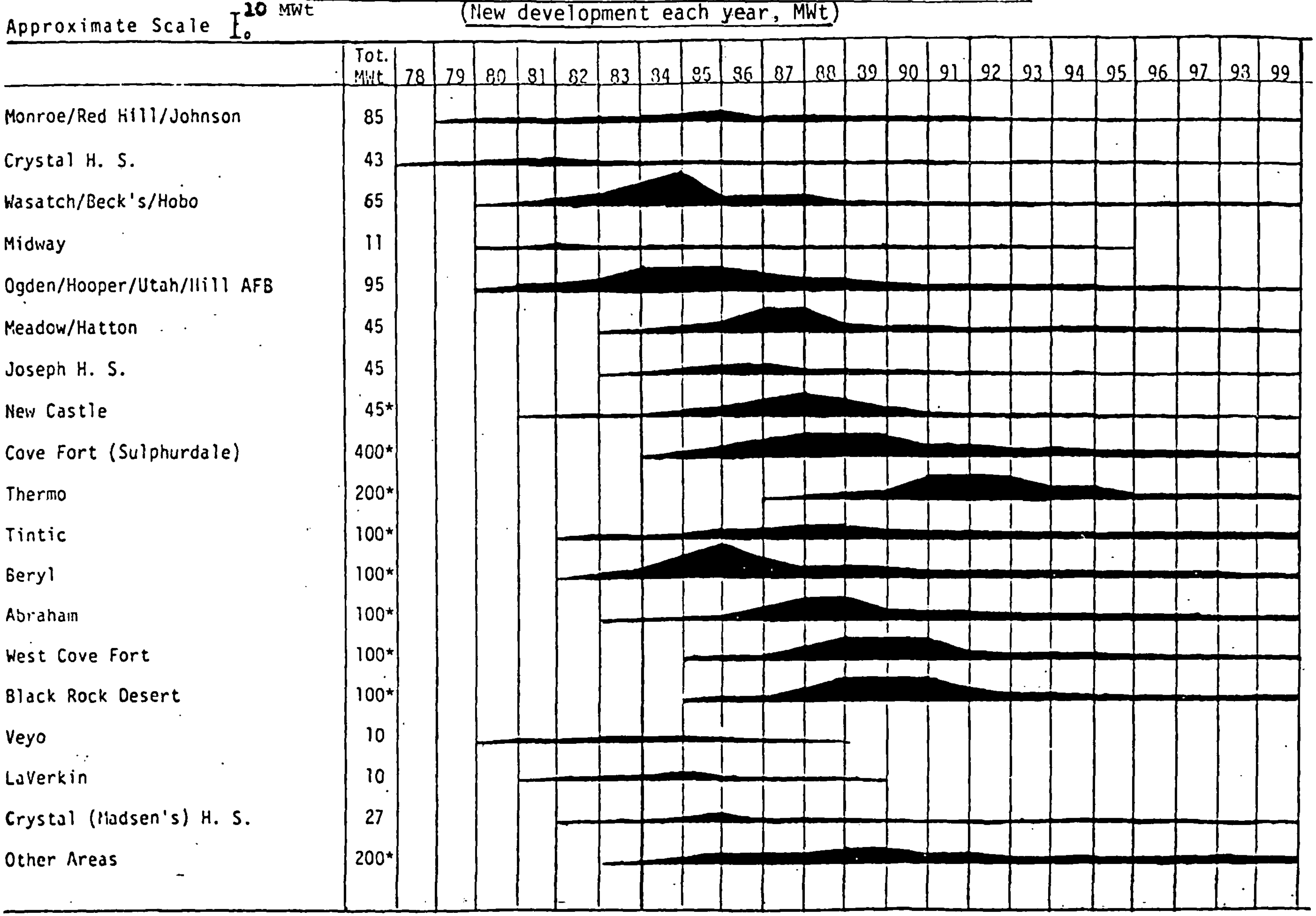
Table 5.12

Aggregated Scenario--Utah Geothermal Electrical Production

	Total MWe	80	81	82	83	84	85	86	87	88	89	90	91	92
Roosevelt Prospect	400			50		50		50				100		100
Cove Fort Sulphurdale	200					50		50		50		50		
West Cove Fort	200						50		50		50		50	
North Cove Fort	200						50		50		50		50	
Thermo	100							50		50				
Other Areas (Sevier Lake, Black Rock Desert, Delta Area)	200								50		50		50	50
TOTAL FOR YEAR				50		100	100	150	150	150	150	150	150	150
CUMULATIVE TOTAL				50		150	250	400	550	700	800	1000	1150	1300

Figure 5.4

Postulated Geothermal Direct Use Development Profile for Utah
(New development each year, MWt)



specific developments.

The Arizona State Team, therefore, took the approach of describing 22 different uses which might be made of geothermal energy in the state, which are listed by title in Section 5.5.1 below. Then, in what might be called "trial" scenarios, case studies were made of one specific application under each of these 22 different usages. One of these, the cooling of an electronics factory in Phoenix, is summarized in Section 5.5.2 below.

5.5.1 Geothermal Utilization Scenarios Defined for Arizona.

1. Heating and Cooling of Buildings
2. District Heating and Cooling
3. New Communities
4. New Industries
5. Energy Storage for Heat Pump Systems
6. Central Arizona Projects/Peak Power
7. Wind Energy/Geothermal Energy Storage
8. Hot Igneous Rock/Pure Steam/Power Production
9. Coal Mining Operations
10. Preheating/Sulfur Removal in Coal Fired Power Plants
11. Solution Mining
12. Hot Water for Conventional Mining
13. Hot Mines
14. Salt Production
15. Production of Potable Water
16. Bio/Salinity Agriculture
17. Greenhouse Production of Winter Vegetables
18. Irrigation Pumping/Peak Power/Winter Uses of Off-Peak Energy
19. Alfalfa Dehydration/Cattle Feed Lots
20. Kiln Drying of Lumber
21. Lettuce Chilling
22. Sugar Beet Plant Energy Load

5.5.2 Case Study of Space Cooling for Electronics Firm in Phoenix.

This study is principally concerned with cooling because summer temperatures of 90-120°F in daytime and 80-100°F at night dictate extensive cooling to keep buildings comfortable. The electronics firm under consideration has two main buildings, an office building of 57,000 square feet and a factory building of 110,000 square feet. The cooling load for these two buildings together is 3,228,690 KWH per year with a peak load demand of 1450 KW.

A scenario for geothermal cooling of these buildings calls for the use of 125,000 pounds per hour of geothermal fluid (from one 1,200 foot production well) having a well-head temperature of 250°F. It would be run through a heat exchanger, due to its presumed high salinity. Water heated to 200°F in the exchanger would be fed into 17 Arkla absorption chillers and the spent geothermal fluid would be reinjected through a 1,000 foot well.

Costs of the system are estimated at:

1.	Wells	$100,000
2.	Heat Exchanger.	15,000
3.	Chillers.	272,000
4.	Pumps for Wells	20,000
5.	Transmission Pipe	15,000
6.	Reinjection Pipe.	10,000
7.	Installation of above . .	110,000
8.	Retrofitting of cooling systems in buildings. .	90,000
9.	Design.	40,000
10.	Permits & procedures for development of geothermal resource.	60,000
	Total Capital Cost	$732,000

Given this $732,000 capital investment, the scenario produces a sample payout as follows:

Present cooling cost (3,230,000 KWH @ $.036 per KWH) . . . $116,280

Gross geothermal cost

Operating $50,000/yr.
Depreciation, 20 yr., 36,600/yr. 86,600

Gross profit, geothermal use	$29,680
Less Income Tax (50%).	14,840
Net Profit	14,840
Credit depreciation.	36,600
Total applicable to payout	$51,440

Payout $\frac{\$732,000}{\$\ 51,440}$ = 14.2 years.

The scenario provides three alternative cases resulting in faster payouts. In one case, a tax incentive allowing 5 year depreciation leads to a 3.4 year payout. In a second case, a DOE grant of 50 percent of costs leads to a 7.1 year payout. In a third case, a combination of a 5 year depreciation tax incentive plus a 50 percent DOE cost grant leads to a 2 year payout.

CHAPTER 6

6.0 Recommended Actions for Promoting and Accelerating Geothermal Development

This chapter lists and describes briefly a number of actions which can be taken to promote and accelerate geothermal development. They are not formally recommended by the Southwest Program or its participants, although they probably represent a concensus of opinion among the participants.

The recommended actions are drawn largely from a paper provided to the project by Richard T. Meyer, Ph.D., which is the only comprehensive listing of such actions drawn up during the first year of activity. The recommendations are derived from discussions with state and core team participants in the program, discussions with geothermal industry people, and reading of other studies on the subject.

These suggestions are provided as food for thought among those who study the subject further and among public officials who establish policy, with due recognition that these officials must consider policies affecting geothermal development within the context of their overall responsibilities to the public.

Constraints to geothermal development may be categorized as economic, institutional and technological, although such categorization is largely beside the point except in the early phases of analysis. The three categories are interwoven and impact on one another. Relatively little attention has been given by the Southwest Program to technological constraints; most of the needed technology is well in hand and more will be perfected in natural order if economic and institutional constraints are lowered sufficiently to cause development to commence on a significant scale.

Most of the recommended actions listed here involve government action. Most such government actions will affect the costs of geothermal development, to the end of making these more competitive with the costs of conventional fuels. Some can be justified on the ground that they provide more fairness and equity to geothermal developers; other may be justified on the grounds that it is in the national interest to encourage and even subsidize the development of this alternative energy source in order to reduce national dependence on diminishing natural gas supplies and expensive and insecure foreign oil imports.

6.1 Recommended Federal Actions.

6.1.1 Revise Taxation. At the federal level and at state/local levels to be discussed below, changes in taxation practices can substantially ease the economic burden facing geothermal developers.

Allowance of the 22 percent depletion allowance and the expensing of intangible drilling costs as allowed in oil and gas exploration will do much to reduce economic risk and to attract venture capital.

The newly-enacted National Energy Act has responded to this need, although certain limitation in that Act on the expensing of intangible drilling allowance may need revision.

An investment tax credit of 10 percent is advocated for the geothermal development industry, this credit being applicable to physical equipment and facilities necessary for the production, conversion and transmission of energy of geothermal origin. As with other investment tax credits, this credit would stimulate investment of venture capital.

A retrofit tax incentive provided by tax credits for energy users who retrofit existing buildings, equipment or processes to use direct thermal geothermal energy is recommended; this incentive would complement the incentives recommended above for producers. The technology does exist for many low temperature direct thermal applications and the low temperature resource is available in many places. A stimulus is needed to encourage retrofit of facilities to use the resource. The substitution of geothermal heat for natural gas can contribute to the conservation of a particulary scarce fuel.

Early adoption of tax incentives is recommended, by the early 1980s at least. The incentives are needed promptly to stimulate initial development, growth and competition for the geothermal industry. The industry is small enough now that such tax incentives will not substantially affect overall revenues.

6.1.2 Encouragement of Developmental Drilling. Geologists, developers, researchers and state government representatives all agree that developmental drilling must be expanded to (1) define geophysically the resource areas and (2) to reduce the development risks to the geothermal industry. Such development drilling can be encouraged by provision of tax incentives, easing of stringent environmental restrictions, and continuation of the present DOE case study program under which DOE provides a portion of the cost of a privately-drilled deep test well in return for public access to the valuable data (e.g. bottomhole temperatures) obtained by such drilling. In connection with the environmental issue, it must be noted that the drilling of a single or a few deep test wells has negligible impact on the environment as compared with extensive drilling for production purposes; therefore, fewer protective restrictions are needed until after the resource has been proven out and planned for commercial production.

6.1.3 Speed Action on Forest Service Land Leases. A majority complaint from the states of Arizona, Colorado, and New Mexico is the inability of the U.S. Forest Service to process geothermal lease applications. The Forest Service has had applications pending since 1974 or early 1975 in these three states. It is recommended that the Forest Service act more expeditiously; if it lacks personnel or other facilities to proceed more promptly, these should be provided.

6.1.4 Reduce Time Delays in Federal Agencies. As noted in Chapter 3, a complicated and lengthy series of steps must be taken in leasing and securing drilling permits, environmental impact statement reviews, etc. Compliance with land management and regulatory procedures of the various federal agencies is costly, time-consuming and frustrating at best; if there are delays, these burdens are multiplied. Developers report apparently unnecessary delays. The Southwest Program evaluation has revealed that in almost all cases no time limits are specified for agency action by applicable legislation or regulative procedures within the agencies. Correction of this problem would reduce costs significantly.

6.1.5 Ease Lease Acreage and Time Limitations. Federal geothermal leases are limited to 2,560 acres per tract and 20,480 per state. These limitations were conceived primarily to promote competition among investors and developers and to prevent speculative holdings, but in practice are found to be excessively restrictive. The limitation of 2,560 acres per tract is particulary restrictive because of the still undefined geophysical characteristics of most geothermal resources and the absence of proven knowledge of resource requirements for the economic application of geothermal energy. Exploration may show that a given geothermal resource of sufficient capacity to be commercially developable may span several tracts belonging to different leaseholders; this creates severe engineering and financing problems for each developer.

The 20,480 acres per state limitation and the time limit of 10 years of exploration of a lease pose another kind of problem. The period from lease application to commercial production is 6 to 12 years, with a majority of this time being required for completing various regulatory and institutional processes (permits, EISs, etc.) and thus not being available for actual physical development. The acreage limitation thus can force a developer to release lands from lease before exploration and development can be completed. The developer is forced to make speculative judgements on which lands to release and which to hold in order to keep an active program underway in a state.

It is recommended that legislation be passed to ease both acreage and time limitations.

6.1.6 Eliminate Restrictive Features of KGRAs. Federal law provides for the designation of Known Geothermal Resource Areas (KGRAs) on federal lands in two fashions: (1) by U.S. Geological Survey geoscientific findings that a particular area is a proven resource and (2) by the filing of two or more lease applications for the same or adjoining land areas. Competitive bidding for leases is required where a KGRA is designated. The use of the second device described above for designating a KGRA has had severe consequences. Existing applications for non-KGRA federal lands are voided in case of such designation. This has substantially decelerated geothermal exploration, for developers are reluctant to expose themselves to competitive bidding on lands for which they have only limited information on the potential. Considerable costly exploration is required to determine the potential of the resource in such areas and costs associated with competitive bidding on unproven resources are risky.

6.1.7 Improve Competitive Postition. Federal actions can improve the competitive position of geothermally-derived energy. Pricing of oil and gas at world market values or at replacement values will provide greater possibilities of profit and thereby attract more venture capital into geothermal development. Additionally, a more quantitative analysis of geothermal energy supply and demand is needed to define the economic conditions required to support its development.

6.1.8 Reduce Environmental Restraints. This recommendation takes two forms. In a general and non-specific way, it is suggested that the actions of zealous environmental protection advocates are not representative of the attitudes of the majority of citizens and they have in many general and specific ways hampered exploration and development. This is not to suggest that environmental protection be ignored in the usually fragile ecologies of the Southwest; it is rather to suggest that more careful judgments be used in weighing the representations of the environmentalists. As a relatively new "cause", environmentalism is enjoying a heyday of attention that sooner or later must be modified.

More specifically, environmental constraints to geothermal exploration must be eased. At this stage, every dollar spent is a hundred percent risk capital, but represents an investment for the nation in seeking and defining a new energy resource. Each new hole drilled is based on information gained from preceding holes and its location is decided largely in the field as experience is gained. Drilling, locations, depths, and other factors usually cannot be precisely defined in advance. Wells more often than not are promptly abandoned after data has been obtained from them. Therefore, the exploration phase does not lend itself to the highly specific requirements of EISs and regulatory proceedings which may be appropriate for more extensive development of permanent facilities.

Drilling of test holes and exploratory wells does require movement of equipment over land which previously may have been relatively untouched and does cause damage to very small areas of surface land at drill sites, but the impact of such limited activity is trivial.

In particular, the industry finds that protection of archeological sites gives rise to frequent time delays and to additional costs.

6.1.9 Encourage Low Temperature Demonstrations. Large size provides glamour and conventional approaches gain acceptance; therefore much of the interest in geothermal development revolves around generation of electricity from high temperature resources. But in inventorying geothermal resources, the State Teams have identified extensive opportunities for direct thermal use of low temperature resources throughout the Southwest. Such applications usually are simpler, quicker and more economical to carry out than electric generation. While direct applications must be made in the immediate vicinity of the resource, the State Teams have identified a number of localities in which these applications can be made. In some cases these resources, while small, are of particular value because they can be used instead of unavailable natural gas and can provide economic stimulus in depressed communities.

Therefore it is recommended that additional federal contracts be made, on cost sharing terms, for direct thermal use demonstration projects. Several communities in the region have feasibility studies underway and an increasing number of small businesses are becoming interested in using this alternative form of energy for such things as greenhouse heating and process heat. These communities and individuals can benefit from technical assistance as well as grants and contracts.

6.1.10 Enhance the Loan Guarantee Program. The program of federal guarantees for geothermal development loans is more effective at the commercialization level than in exploratory phases. Several applications for these guarantees have been approved or are being processed. Many commercialization activities must perforce be carried out by large companies which previously found the loan guarantee program not fully useable (a) because of the limitation of guarantees to $25 million (now $100 million) per project and $50 million (now $200 million) per borrower and (b) because no large company will risk default on such loans anyway.

To enhance the loan guarantee program, it is recommended that: (1) the Congressional limit of $300 million for the outstanding amount of loans be increased to provide for the surge of projects that are potentially possible in the 1980s; (2) the requirement that the borrower put up 25 percent of the project cost be modified to allow credit for actual prior investments leading up to the commercialization stage; and (3) the allowable interest rate be reduced to the prime rate rather than 25 percent over the prime rate.

6.1.11 Increase Public Education. Geothermal energy has not received the public attention and financial support enjoyed by other alternative energy sources, particularly solar. There is little public understanding, or even awareness, of the geothermal potential. Solar energy, at least in the direct sunlight form, is brightly visible everywhere while geothermal energy is distant and hidden from most people. Solar energy is seen as environmentally pure, while geothermal energy is suspect as damaging to land, air, and water. State Teams have witnessed repeatedly this disparity in public perceptions.

It is recommended that DOE (and other institutions) implement a public information program explaining the potentials and advantages of geothermal energy use.

6.2 Recommended State Actions

Recommended state actions in many cases parallel the federal actions suggested above. This is self-evident in cases of concurrent state and federal actions or jurisdictionally divided state and federal actions in the same subject area. In such cases, descriptions below of recommended state actions will be appropriately condensed to minimize redundancy. This section will list recommendations applicable to all the states in general; Section 6.3 following will list recommendations applicable to each particular state.

6.2.1 Revise Taxation. Where applicable in state income tax laws, the same incentives are recommended as in the case of federal taxation. In this connection, it should be noted as an example that many states, like the Federal government, now offer income tax credits for solar and energy conservation expenditures. At least one state, Colorado, now permits deductions from income for tax purposes of expenses of alternative energy applications, including geothermal.

In addition, some forms of taxation are within state jurisdiction. Property taxes levied by local jurisdictions ordinarily are controlled by state law. It is recommended that property taxes on geothermal land values and physical installations be deferred until commercial energy production begins. This is particularly appropriate in view of the long time lag in the geothermal development process between initial investment and realization of revenues.

Non-productive leases should be exempted from property taxes. Special provisions may be necessary to disallow this advantage to speculative holders of leases.

6.2.2 Ease and Expedite Leasing. Where acreage and time of development limitations in state land leases are unduly restrictive, they should be eased along the same lines recommended for federal leases. Each state should process applications promptly.

6.2.3 Ease and Expedite Regulations. Various state agencies play major roles in regulating well drilling, environmental protections, water rights, etc. As in the case of federal regulatory agencies, these state agencies must enforce laws as written but should avoid time delays in carrying out their responsibilities. In view of the infancy of the geothermal industries, regulations promulgated for it may not need to be so demanding as those imposed on mature industries.

6.2.4 Standardize State Regulatory Provisions. Some states have not generated legislative and regulatory provisions specifically for geothermal energy. Legal definitions of the resource often are non-existent or inadequate. Some states are in the process of developing regulations, defining leasing terms, etc. Unfortunately, the fluid and unsettled nature of regulations at the state level have delayed exploration and development. It is recommended that a detailed examination of state laws and regulations be a major component of the continuing Southwest Program and that following this examination the states attempt to standardize their provisions.

6.2.5 Provide Handboods of Regulatory Procedures. The State Teams and the NMEI Team for the Southwest Program are compiling future details on the institutional and regulatory procedures for the entire geothermal process. The often complex regulations and procedures vary between states. While large development companies and utilities may understand the procedures, smaller investors, community officials, potential small business and industrial users, and individual lease applicants usually do not.

It is recommended that handbooks of instructions and flow charts be prepared for each state covering regulatory procedures and roles of each agency or institution from lease application through specific end uses of geothermal energy.

6.3 Recommended State-by-State Actions.

Most of the recommended actions listed above apply to all of the states in the Southwest. In addition, particular needs of various states have led to state-specific recommendations for actions by federal, state, and private institutions.

6.3.1 Arizona.

Improve and implement proposed new state geothermal rules and regulations in order to active leasing. (Editor's Note: This recommended action now has been taken.)

Expand exploratory drilling to assess the resource potential of the state.

6.3.2 Colorado.

Issue or deny leases (one or the other) on Forest Service lands having lease applications pending since 1974.

Develop space heating applications to relieve the demand on natural gas.

Provide financing and planning assistance for community and small business geothermal projects.

6.3.3 Nevada.

Participation by geothermal industry in formulation of state laws and regulations affecting geothermal development.

Integrate state and federal leasing and regulatory activities to accomodate fact that 86 percent of Nevada land is federal.

Expand federal lease acreage limits per tract and per state to allow access to and use of adjoining state and federal land.

6.3.4 New Mexico.

Extend state lease duration from five to ten years to conform to federal limitations and to re-activate leasing of state lands.

Eliminate federal drilling restrictions on depth in order to promote deeper drilling for space heat applications.

Reject unreasonable demands by environmentalists which would halt geothermal development.

6.3.5 Utah.

Industry should acquire more drilling rigs to match requirements indicated by Utah development sceanrios for drilling of production wells during the next 20 years.

Authorize higher dollar limits for federal loan guarantee program and make the program applicable to larger companies.

Specify state tax rates on geothermal developments so that industry can calculate that element of costs.