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INTRODUCTION

The Earth Science Laboratory Division of the University of Utah Research Institute (ESLD) provided information to the Direct-Heat Market Shares Estimate Program on the nature of geothermal resources, geothermal resource distribution, postulated resource discovery confirmation rates and timing, and the effect of federal programs on geothermal development. The goal of this effort was to estimate the amount of direct-heat geothermal use-on-line by the year 2000.

The Market Shares Estimate is envisioned as an iterative process. In FY81 the ESLD proposes, as a joint effort with other members of the Task Group, to review the first iteration of the study, and modify the direct-heat discovery tables in light of economic modeling, industry activity in 1980, and further understanding of the industry decision-making process.

This report describes the techniques employed and assumptions made in characterizing the resource, in establishing resource confirmation rates and profiles, and in evaluating the effects of federal programs on direct-heat development. Problems with the first iteration of the Direct-Heat Market Shares Estimate program are identified, and recommended changes for the second iteration are discussed.

PROGRAMMATIC AND RESOURCE ASSUMPTIONS

Three Basic Assumptions

We have made three general assumptions in order to predict the number of geothermal resources discovered, the type of geothermal resources discovered and the rate of discoveries to the year 2000. The three general assumptions are:

1. A successful federal geothermal program,
2. A healthy geothermal industry, and
3. An adequate geothermal resource data base.

Each of these general assumptions contain several very important components discussed below.

1. A successful federal geothermal program

A successful federal geothermal program must include elements that produce an economic environment that stimulates geothermal resource development, and advances technology to improve cost effectiveness of exploration, development and exploitation of geothermal resources. We view the following elements to be important to a successful federal geothermal program:

a) Improvement of leasing/permitting regulations:
Federal and state laws and regulations governing geothermal leasing and permitting must be altered and defined in a manner conducive to geothermal resource development. The present laws and regulations are cumbersome, and in some cases do not exist.

b) Continuation of Cost Share Incentive Programs:

Programs that cost share exploration and drilling such as the Industry Coupled Program and the User Coupled Confirmation Drilling Program must be retained until industry has sufficient expertise and economic incentive to explore aggressively and effectively on its own. The level of funding required cannot be specified at present. We must wait until the results of the present discovery schedule have been evaluated by the economic model (a proposed FY81 activity) before this can be done.

c) Assistance in Development of Better:

i) Exploration techniques

ii) Reservoir assessment techniques

iii) Exploitation techniques

Industry expertise in the exploration for and development of most natural resources is based on years of experience characterized by both success and failure. Geothermal exploration and development expertise is in its infancy. It is important to create maturity in the geothermal industry in a short time. The time period needed to realize this maturity can be significantly shortened by government supported research and development and cost share programs.

d) Development of improved geothermal hardware including:

i) drilling equipment

ii) downhole pumps

iii) downhole measurement systems

Many known geothermal resources occur in fractured, hard rocks.

Drilling deep, large-diameter holes in fractured rock is quite expensive. Drilling is further complicated by high-temperatures. It may be necessary to pump many geothermal systems in order to attain adequate flow rates for economic utilization. Pumps need to be engineered for use in geothermal systems. High-temperature logging tools are needed for good reservoir analysis. Altogether the high-temperature technology is needed for cost effective geothermal resource exploration and exploitation.

e) A continuation of USGS geothermal programs to provide data and techniques for advancing the frontier of geothermal exploitation: It is essential that a group such as the USGS continuously update the geothermal resource base and, particularly, note regions of new or greatly enhanced potential.

2. Healthy Geothermal Industry

In order to induce private industry to invest in geothermal resource development, rather than in some other venture, the risk must be understood and the rate of return on investment must be attractive. The cost of utilizing geothermal energy must be compatible with other processes. This return on investment can be made attractive through

a) competitive pricing,

b) tax incentives, and

c) advanced technology.

We have basically assumed a healthy industry that explores aggressively. Thus our discovery schedule is more a table of what is available to be discovered than an actual discovery scenario. We have repeatedly emphasized, and we emphasize again, that one or more complete iterations of the discovery schedule will be required in order to develop a discovery schedule with whch we are comfortable and can defend. The economic conditions modeled by the Market Shares Estimate Task Force will then be able to indicate what steps are required to insure a healthy geothermal industry. During Fiscal Year 1981, we must examine our postulated discovery curves in consideration of such economic modeling.

3. Geologic Data Base Adequate

We cannot predict the number of resourcees or the type of resources to be discovered without a reasonable knowledge of the characteristics of a variety of existing resources. While geothermal resource data are in the public domain through technical literature, USGS Circular 790, and government obtained data such as that purchased through the Industry Coupled program, many hydrothermal systems, particularly low-and moderate-temperature systems, are poorly understood. The data needed to assess reservoir productivity are not yet available. Based upon our understanding of the existing data, the following assumptions are made:

a) New Discoveries to the Year 2000 Will Occur in Known Areas of High Geothermal Potential.

We assume that geothermal development in the next 20 years will be from known geologic environments. Volcanic terrains, such as the Cascades, fault terrains, such as the Basin and Range, extensional environments, such as the Imperial Valley and the Rio Grande Rift, and regional aquifers such as the Madison Formation, provide enough unexplored territory to sustain the postulated discovery rates.

and Snake River Plain

Exploration for other minerals and natural commodities has shown that "blind" deposits within known resource areas often contain an additional and significant resource base. There may be numerous unrecognized and moderate-temperature geothermal systems lacking surface thermal manifestations. The discovery of hidden systems may significantly augment the resource base. We do presume, however, that, within these broad environments new target models for specific reservoirs will be developed, and that these new target models will have a positive impact on market penetration during the next 20 years.

b) Current Resource Data Can be Extrapolated to Unknown/Undiscovered Resources.

These data include:

i) temperature

ii) flow rate

iii) salinity

iv) depth

v) size

No two mineral, petroleum, or geothermal deposits are identical. We believe that geothermal resource occurrences, based on any of the above properties, will follow a lognormal distribution similar to temperature distribution in Figure 10, page 29, in USGS Circular 790 (Muffler, 1978). The data in Figure 10, compared to previous data in USGS Circular 726 (White and Williams, 1975), indicate only modest changes in the temperature distribution. Flow rate, size, and depth are the most poorly defined characteristics on the list above. Future data will probably refine these resource parameters more than the others.

c) Each Resource Contains a Spectrum of Temperatures and Flow Characteristics

Each geothermal resource contains temperatures from the maximum down to regional background values. We assume that low- and moderate-temperature systems occur along the margins of many high-temperature resources. In some cases, however, the resource area may be defined by a contour of some temperature below which the system cannot be utilized for its intended purpose. Moreover, the temperature fall-off away from the resource center may be rapid enough that the volume of lower-temperature fluids may not be a significant resource. The flow characteristics of the resource probably vary as much as the temperature.

SOURCES OF DATA

Resource data to support the assigning of generic codes to specific geothermal sites were gathered from many sources. Most of the data currently available for low- and moderate-temperature geothermal systems have been compiled as a result of various federal programs. No major private sector industry for the discovery, confirmation, and development of direct heat geothermal applications exists at the present time.

ESLD reviewed data from the DOE/DGE funded State Coupled Program, Commercialization-Planning Program, PONs, PRDAs, and other DOE contractors. USGS Circular 790 (Muffler, 1978) contains estimates of the characteristics of individual geothermal systems with temperatures of 90°C and above; systems with temperatures less than 90°C are described in general. USGS computer file GEOTHERM was utilized for those states, primarily in the west, in which reliable data exist. Published, proof, or draft copies of state geothermal maps were used for the states of Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, and Utah. Data for midwestern and eastern resouces were gathered from DOE regional contractors.

ESLD staff experience in geoscientific investigation of several low- and moderate-temperature geothermal sites, familiarity in geothermal resources through work on the State Coupled and other DOE programs, and participation in the data compilation phase of USGS Circular 790, were all applied to the Market Share Estimate task.

For individual systems for which no information was available, the resource was characterized by extrapolating data from well-known geologically similar systems. In cases where data from similar systems could not be extrapolated, the known characteristics of each site were evaluated, and ranges for the resources parameters required by the economic model were estimated.

Resource Characteristics

The resource parameters evaluated for the Market Shares Estimate task include temperature, pumped and unpumped flow rates, brine contamination index (measured as total dissolved solids), well costs and resource size. The ranges for these resource parameters are shown in Table 1. Tables 2 and 3 are examples of generic charcterizations for resources.

The temperature data used to assign a generic temperature value were obtained by using measurements of recorded subsurface temperature, where possible. If no downhole temperatures were available, chemical geothermometry estimates were used, where evaluation of the data indicated that these estimates were reliable. Surface temperatures were used when these other data were not available. In a few cases, recorded temperatures were arbitrarily increased to bring them into the lowest generic temperature category. (This occurred only for sites that fit the definition of thermal anomalies, but which have indicated reservoir temperatures less than 100°F, generic temperature category 1.)

Unpumped and pumped flow rate data were used when available; these were two of the less well-known data sets required by the model. If no data were available, the ranges were either estimated or extrapolated from other systems.

Surface or subsurface water analyses were used to estimate the range of total dissolved solids in order to assign a brine contamination index value. The total dissolved solids content for a few systems was calculated from specific conductivity measurements (a multiplier of 0.65 was used).

Well cost estimates were obtained by extrapolating known drilling costs from a small number of direct-heat projects. Well costs ranges for the direct-heat model are different from those used in the electric model. The direct-heat model employs a more detailed breakdown at the lower cost range, while the electric model combined all wells with a cost less than $500,000.

Producible acreage estimates were based on ESLD evaluation of the specific geothermal systems as fault-controlled systems ("small") or regional aquifers ("large"). The area of surface manifestations of known systems was extrapolated to give the estimates reported.

Sensitivity studies were performed by Technecon to establish the ranges and impacts of specific parameters reported in the generic codes to the electric economic model. No such sensitivity studies were performed, however, for the application of these generic ranges to the direct-heat model. ~~Such~~ Sensitivity modeling needs to be done during second iteration modifications to the Market Shares Estimate program.

THE DIRECT-HEAT GEOTHERMAL RESOURCE DATA BASE

Introduction

The direct heat geothermal resource data base is composed of two subsets: 1) the non-colocated discovery[1] data base, and 2) the colocated discovery data base. Two separate non-colocated and colocated discovery data bases were established assuming the conditions of 1) an aggressive federal program and 2) no Federal program. The following sections describe the manner in which each data base was developed.

The Non-Colocated Discovery Data Base

We assumed that the distribution of non-colocated discoveries would resemble the distribution of geothermal resources as a whole, and that this distribution is lognormal. For identified geothermal systems, a plot of geothermal temperatures versus the number of systems reveals a lognormal distribution in which there are relatively few high-temperature systems, and many more low-temperature systems (see Muffler, 1978, Figure 10, page 29).

The non-colocated data base was estimated from the distribution of (Wright et al, 1980a) non-colocated high-temperature (categories 8 through 6) discoveries. A

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[1] Discovery is defined as: "a resource site that has had sufficient successful drilling and long-term flow testing to merit serious consideration for development." This term is the rough equivalent of "confirmed reservoir." A "prospect" is a site with geothermal indications.

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lognormal curve was fitted to the non-colocated high-temperature data, and projected to lower temperatures (categories 5 through 2). Since the predicted low-temperature, non-colocated discoveries will consist of both presently known but unquantified systems and presently unidentified systems, we assume that the discovery curve will also be lognormal. There were two curves drawn for each geographic region. The first distribution curve predicts the number of discoveries with an aggressive program of federal aid. The second curve predicts the number of discoveries that will be made without a federal program. Table 1 is the non-colocated discovery table for each region, showing the number of discoveries for each temperature category (8 through 2) both with and without a federal program.

Comparison of Geothermal Resource Distribution Characteristics to Other Energy Resources

The assumption that the distribution of geothermal resource temperatures is lognormal is critical to the establishment of the non-colocated geothermal discovery base. We feel that this is a valid assumption since it is well documented that the distribution of many resource commodities is lognormal. For example, Barouch and Kaufman (1977, 1978) show that the size distribution of petroleum deposits is lognormal; there are relatively few large deposits and many smaller deposits. Moreover, they use this lognormal distribution to predict the number and size of future petroleum discoveries. Barouch and Kaufman (1977, 1978) assume that the sizes of petroleum deposits in a given exploration area are a finite number of values that can be determined from the lognormal size distribution of the already discovered resources in that area. Predictions of the size and number of future discoveries can be estimated from

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #1: Northern California

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1996-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450°F)	0	0	0	0	1	1	1	1	0	0
7 (400°-450°F)	0	0	0	0	1	1	1	0	1	2
6 (350°-400°F)	0	0	0	0	1	0	2	1	1	2
5 (300°-350°F)	0	0	1	0	1	0	2	1	2	3
4 (250°-300°F)	0	0	4	1	3	3	2	2	1	1
3 (200°-250°F)	0	0	3	1	7	2	5	6	2	3
2 (150°-200°F)	0	0	4	0	8	1	9	7	10	11

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #2: Southern California

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1996-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450°F)	2	2	0	0	1	1	0	0	0	1
7 (400°-450°F)	1	1	1	0	1	0	2	1	0	0
6 (350°-400°F)	1	1	1	0	1	1	0	1	1	1
5 (300°-350°F)	2	2	0	0	1	0	2	2	1	1
4 (250°-300°F)	0	0	5	2	4	2	0	1	0	1
3 (200°-250°F)	0	0	3	0	6	2	5	5	1	3
2 (150°-200°F)	0	0	0	0	4	1	7	3	13	13

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #3: Oregon, Washington

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1996-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450°F)	0	0	0	0	0	0	0	0	1	1
7 (400°-450°F)	0	0	0	0	0	0	2	1	1	2
6 (350°-400°F)	0	0	0	0	1	1	1	0	3	2
5 (300°-350°F)	0	0	1	0	1	0	3	1	2	3
4 (250°-300°F)	0	0	2	1	3	1	2	5	5	0
3 (200°-250°F)	0	0	1	0	6	2	9	2	4	8
2 (150°-200°F)	0	0	0	0	5	5	16	7	13	8

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #4: Nevada

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1996-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450°F)	0	0	1	1	0	0	0	0	0	0
7 (400°-450°F)	0	0	1	0	3	2	1	2	1	1
6 (350°-400°F)	0	0	1	1	2	1	3	2	1	2
5 (300°-350°F)	0	0	1	1	4	2	3	2	3	3
4 (250°-300°F)	0	0	4	2	6	3	7	4	5	4
3 (200°-250°F)	0	0	4	3	8	5	10	7	8	6
2 (150°-200°F)	0	0	5	4	10	9	15	12	12	10

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #5: Utah

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1996-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450°F)	1	1	0	0	0	0	0	0	0	0
7 (400°-450°F)	0	0	0	0	1	0	1	0	0	2
6 (350°-400°F)	0	0	0	0	2	1	1	1	0	1
5 (300°-350°F)	0	0	1	0	0	0	2	1	2	2
4 (250°-300°F)	0	0	4	3	3	3	1	1	1	0
3 (200°-250°F)	0	0	2	2	6	3	5	3	2	3
2 (150°-200°F)	0	0	2	0	6	4	11	7	7	7

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #6: Arizona

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1996-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450°F)	0	0	0	0	0	0	0	0	0	0
7 (400°-450°F)	0	0	0	0	0	0	0	0	0	0
6 (350°-400°F)	0	0	0	0	1	1	1	1	1	0
5 (300°-350°F)	0	0	0	0	1	0	2	1	2	3
4 (250°-300°F)	0	0	2	2	3	2	3	1	1	1
3 (200°-250°F)	0	0	1	1	4	2	5	2	4	3
2 (150°-200°F)	0	0	2	1	5	1	8	4	8	8

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #7: Idaho, Montana, Wyoming

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1996-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450°F)	0	0	0	0	0	0	0	0	0	0
7 (400°-450°F)	0	0	0	0	0	0	0	0	0	0
6 (350°-400°F)	0	0	1	0	1	1	1	2	1	1
5 (300°-350°F)	1	1	1	0	2	0	3	1	2	4
4 (250°-300°F)	0	0	4	3	4	4	4	3	4	2
3 (200°-250°F)	0	0	5	3	9	4	9	5	2	11
2 (150°-200°F)	0	0	8	4	12	6	12	13	11	16

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #8: Colorado

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1996-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450^{o}F)	0	0	0	0	0	0	0	0	0	0
7 (400^{o}-450^{o}F)	0	0	0	0	0	0	0	0	0	0
6 (350^{o}-400^{o}F)	0	0	0	0	0	0	1	0	0	1
5 (300^{o}-350^{o}F)	0	0	0	0	0	0	1	1	2	1
4 (250^{o}-300^{o}F)	0	0	1	1	2	1	2	1	1	1
3 (200^{o}-250^{o}F)	0	0	2	1	3	2	3	2	1	1
2 (150^{o}-200^{o}F)	0	0	2	0	5	2	4	2	2	4

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #9: New Mexico

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1996-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450°F)	0	1	0	0	0	0	0	0	0	0
7 (400°-450°F)	0	0	0	0	1	1	0	0	0	0
6 (350°-400°F)	0	0	0	0	1	0	3	2	0	1
5 (300°-350°F)	0	0	0	0	1	0	1	0	3	3
4 (250°-300°F)	0	0	2	1	4	2	2	1	2	1
3 (200°-250°F)	0	0	4	2	6	3	4	2	3	1
2 (150°-200°F)	0	0	4	0	7	4	13	8	5	10

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #10: Texas

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1995-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450°F)	0	0	0	0	0	0	0	0	0	0
7 (400°-450°F)	0	0	0	0	0	0	0	0	0	0
6 (350°-400°F)	0	0	0	0	0	0	0	0	0	0
5 (300°-350°F)	0	0	0	0	1	0	0	0	0	0
4 (250°-300°F)	0	0	0	0	1	1	2	0	1	1
3 (200°-250°F)	0	0	1	1	1	1	1	1	1	0
2 (150°-200°F)	0	0	1	0	1	0	2	2	3	3

TABLE 4. REGIONAL PREDICTED NON-COLOCATED DISCOVERIES WITH AND WITHOUT A FEDERAL PROGRAM

REGION #20: Hawaii

Generic Temperature Category	Pre-1981		1981-1985		1986-1990		1991-1995		1996-2000	
	With	Without	With	Without	With	Without	With	Without	With	Without
8 (>450°F)	0	0	0	0	1	1	1	1	0	0
7 (400°-450°F)	0	0	1	1	1	0	0	0	0	1
6 (350°-400°F)	0	0	0	0	1	0	1	0	1	2
5 (300°-350°F)	0	0	0	0	1	0	2	1	1	2
4 (250°-300°F)	0	0	2	1	3	2	1	3	1	1
3 (200°-250°F)	0	0	2	1	3	3	4	3	3	3
2 (150°-200°F)	0	0	3	0	4	4	8	6	4	6

the distribution of the known deposits in the particular petroleum field. Thus, by assuming a lognormal character of petroleum resources, Barouch and Kaufman (1977, 1978) estimate the size and number of new discoveries from the known resource base. The method used by the ESLD to predict future discoveries of non-colocated geothermal resources is almost identical to the Barouch-Kaufman discovery model.

Colocated Discovery Data Base

The colocated discovery data base has two components: 1) site-specific colocated discoveries, and 2) phantom-site colocated discoveries. The site-specific colocated data base identifies those geothermal resources that are no more than 5 miles away from a population center. There was no lower-end screen used to define a population center; some of the sites listed have fewer than 100 people. These data were compiled by both the New Mexico Energy Institute and the ESLD. Each resource listed as colocated was given a generic resource code that best fit the information available for that resource. In general, the temperature and salinity information for most of these resources is fairly reliable. However, the data available on pumped and unpumped well flow rates is almost nonexistent. The values provided represent our best estimate of the flow potential of these systems.

The phantom site colocated data base was developed for stratabound aquifer-type geothermal resources that have a broad areal extent such as the Madison aquifer, the Balcones fault zone and radiogenic targets on the East Coast. The counties thought to have potential for these types of resources were identified. One generic resource code matching the known or inferred resource characteristics of the aquifer was assigned to each county with the assumption that the resource is homogeneous over broad areas. NMEI identified the cities in each of these counties.

Timing of Discovery

In order to predict the timing of discovery of both the site-specific colocated and non-colocated direct heat resources, we established regional discovery profiles with and without a federal program. These discovery profiles shown in Table 5, were based upon the current level of geothermal exploration activity for each region, our perceptions of the exploration activity likely to occur in the next twenty years and the geothermal resource potential of the region. In regions where there is currently a significant amount of exploration, such as Southern California, the discovery profile predicts a high near-future discovery rate. In contrast, for areas with high resource potential but relatively little present exploration activity, such as the Cascades, we predict that most discoveries will not occur until the latter part of the time frame. For those areas with apparently limited geothermal resource potential, we predict that there will be no discoveries in the next 20 years with or without a federal program. The existence of a federal aid program was assumed to accelerate the rate of discovery in all regions. However, the effect is less dramatic in regions of high resource potential where exploration activities are already underway. In regions of lesser potential, there may be little or no exploration incentive without a federal program. The discovery profiles reflect these variables.

The prediction of discovery rates for colocated phantom sites was made by

TABLE 5. REGIONAL PREDICTED DISCOVERY PROFILES WITH AND WITHOUT A FEDERAL PROGRAM

REGION	PERCENTAGE OF RESOURCES PREDICTED TO BE DISCOVERED								% Fewer Discoveries Without Federal Program
	1981-1985		1986-1990		1991-1995		1996-2000		
	With	Without	With	Without	With	Without	With	Without	
1) Northern California	15	5	30	10	30	25	25	30	30
2) Southern California	15	5	30	10	30	25	25	30	30
3) Oregon, Washington	5	2	20	10	40	20	35	30	38
4) Nevada	15	10	30	20	35	25	20	30	15
5) Utah	15	10	30	20	35	25	20	30	15
6) Arizona	10	5	25	10	35	15	30	25	45
7) Idaho, Montana, Wyoming	20	10	30	15	30	25	20	35	15
8) Colorado	15	5	30	15	35	20	20	25	35
9) New Mexico	15	5	30	15	35	20	20	25	35
10) Texas	10	5	25	10	35	20	20	30	35
11) North Dakota, South Dakota, Minnesota	20	10	30	20	30	30	20	30	10

12) Nebraska, Kansas, Iowa, Missouri	5	2	20	10	40	20	35	30	38
13) Oklahoma, Arkansas, Louisiana	5	2	20	10	40	20	35	30	38
14) Tennessee, Alabama, Kentucky, Mississippi	0	0	0	0	0	0	0	0	--
15) Wisconsin, Michigan, Illinois, Indiana, Ohio	0	0	0	0	0	0	0	0	--
16) New York, Pennsylvania, New Jersey, Maryland, Delaware	20	5	30	10	30	20	20	20	45
17) Florida, Georgia, S. Carolina, N. Carolina, Virginia W. Virginia	20	5	30	10	30	20	20	20	45
18) Massachusetts, Rhode Island, Maine, Vermont, New Hampshire	5	0	20	10	35	20	40	30	40
19) Alaska	5	5	20	15	35	30	40	35	15
20) Hawaii	15	5	30	20	35	30	20	30	15
TOTAL PERCENTAGE	12.8	5.6	26.7	13.3	34.2	22.3	25.8	28.6	29.9

NMEI by assigning a random distribution of discovery dates to the counties listed as having geothermal potential. We feel that this portion of the discovery data base must be redone. Numerous resources will not be confirmed in these areas (e.g. the East Coast), due to modest geothermal potential of many of these sites, and meager geothermal exploration activity.

GENERAL AREAS POSTULATED TO HAVE HIGH POTENTIAL FOR THE DISCOVERY OF DIRECT-HEAT QUALITY RESOURCES

The Relationship Between Electric and Direct Heat Sites

All areas thought to have potential for electric-quality resources are also considered as high probability sites for the discovery of resources suitable for direct-heat applications. These areas are discussed in detail in Wright and others (1980a, 1980c) and are listed in Table 6. High-temperature fluids may be attractive for cascaded direct-heat applications following their use in the power generation cycle. In addition, we feel that there is considerable potential for lower-temperature resource discoveries on the margins of most higher-temperature systems.

Low- to Moderate-Geothermal Resource Sites

In addition to the high-temperature prospect areas listed in Table 6, there are many other sites with potential for lower-temperature resource discoveries. These additional resource areas are listed in Table 6. The areas in Table 6 include both colocated and non-colocated sites.

TABLE 6. GENERAL AREAS POSTULATED TO HAVE HIGH POTENTIAL FOR THE DISCOVERY OF GEOTHERMAL RESOURCES

Region	STATES(S)	General Areas with Potential for High- Temperature Discoveries, with Moderate- and Low-Temperature ~~Discoveries~~ Halos	General Areas with Potential for Moderate- and Low-Temperature Discoveries
1	Northern California	The Geysers Mono-Long Valley Cascades	Susanville Area Surprise Valley Area
2	Southern California	Imperial Valley Coso	Los Angeles Basin
3	Oregon Washington	Cascades Alvord Desert Brothers Fault Zone Vale Area	Klamath Falls Area Lakeview Area
4	Nevada	NE-trending Battle Mountain heat flow high (from Steamboat to NE-corner of Nevada)	Las Vegas Area Ely Area Carson-Eagle Valley
5	Utah	SW Utah geothermal district Tintic-Fish springs trend	Wasatch Front
6	Arizona	Safford-Morenci Area San Francisco Volcanic Field	Tucson Area Phoenix Area
7	Idaho Montana Wyoming	Snake River Plain (Margins) Island Park Area Overthrust Belt	Snake River Plain (interior) Madison Formation Aquifer
8	Colorado	Mt. Princeton Area	Northern Extension of Rio Grance Rift

9	New Mexico	Rio Grande Rift	Lordsburg Area Tularosa Basin
10	Texas	Trans Pecos Trend	Balcones Fault Trend
11	North Dakota South Dakota Minnesota	None	Madison Aquifer Deep Sedimentary basins
12	Nebraska Kansas Iowa Missouri	None	Sedimentary basins - deep aquifers
13	Oklahoma Arkansas Louisiana	None	Extension of Balcones Fault Trend Hot Springs, Arkansas (geopressured resources not considered)
14	Tennessee Alabama Mississippi Kentucky	None	None (geopressured resources not considered)
15	Wisconsin Michigan Illinois Indiana Ohio	None	Illinois Basin - deep aquifers
16	New York Pennsylvania New Jersey Maryland Delaware	None	Areas of buried radiogenic plutonic rocks Isolated hot springs locations

17	Florida Georgia S. Carolina N. Carolina Virginia West Virginia	None	Various hot spring locations Areas of buried radiogenic plutonic rock
18	New Hampshire Vermont Massachusetts Rhode Island Maine	None	Isolated hot spring locations
19	Alaska	Aleutian Volcanic Chain	Seward Peninsula Southeastern Alaska
20	Hawaii	Rift Zones on Big Island	Rift zones on Maui

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