IMPACT OF GEOTHERMAL TECHNOLOGY IMPROVEMENTS ON ROYALTY COLLECTIONS ON FEDERAL LAND

VOLUME I

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SAN FRANCISCO OPERATIONS OFFICE
U.S. DEPARTMENT OF ENERGY

DISCLAIMER

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DOE/SF/16299--T9

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EXECUTIVE SUMMARY

The Geothermal Steam Act (P.L. 91-581) authorized the leasing of federal lands for the exploitation of geothermal fluids. Payment of percentage royalties on production is required. The federal government retains half, and the state where the production occurred receives the other half.

The hydrothermal reservoirs suitable for power generation are located in the far western states where many underlie federally owned lands. The rationale of the study was that, by reducing barriers to increased geothermal power development, the Department of Energy (DOE) geothermal research and development (R&D) program will encourage further development, and, thus increase royalties. The question addressed was whether these funds would be sufficiently large with enhanced technology to return the government's "investment" in geothermal energy through the year 2010.

Obviously, the innumerable factors that will impact the future expansion of the U.S. geothermal power base would be impossible to predict. Therefore, this study was conducted with a set of fairly simple assumptions.

A study of the 91 Known Geothermal Resources Areas (KGRA's) embracing hot water reservoirs and some promising non-KGRA areas was undertaken to determine to the extent possible the:

- resource characteristics (e.g., temperature, chemistry)
- surface considerations (e.g., environmental/institutional/economic)
- land ownership

The first two of these categories have a direct impact on <u>development</u> potential; they combine with the third to indicate <u>royalty</u> potential. That is, the resource must be commercially useful for power generation, and the land must be available if development is to occur. If royalties are to accrue, the land must be federally owned.

In the final analysis, 71 KGRA's were determined to be potentially out of reach for significant royalty generating development in the foreseeable future, with or without enhanced technology. The major reasons for "disqualification" included:

- temperature below 125°C (257°F)
- temperature not available
- land status/environmental considerations
- land ownership (e.g., Imperial Valley, California, where the larger capacity development is occurring on predominantly nonfederal land)
- lack of developer interest (e.g., little or no leasing, large numbers of leases relinquished, potential conflicts with wilderness designation)

Thus, 20 KGRA's were determined to be the most likely royalty producing candidates for early or continued development as follows:

California
Coso Hot Springs[a]
East Mesa[a]
Glass Mountain[a]
Lake City-Surprise Valley[b]
Mono-Long Valley[a]
Randsburg[b]

Oregon
Breitenbush Hot Springs[b]
Klamath Falls[b]
Newberry[b]
Vale Hot Springs[b]

Nevada
Beowawe[a]
Brady-Hazen[a]
Darrough Hot Springs[b]
Dixie Valley[a]
Kyle Hot Springs[b]
Rye Patch[b]
Steamboat Springs[a]
Stillwater-Soda Lake[a]

Utah
Cove Fort-Sulphurdale[a]
Roosevelt Hot Springs[a]

[a]Development underway or planned.
[b]No development yet.

Two non-KGRA areas--Fish Lake Valley and Salt Wells Basin in Nevada--are also considered likely prospects, but a lack of information on them in the public domain precluded their inclusion in the royalty calculations.

The geothermal technology available today and the technology that will result from the DOE R&D program, if its objectives are accomplished, provide 1) the base case for royalty accrual, and 2) enhanced accrual with improved technology. The technology achievements accounted for in the royalty calculations included:

- lost circulation well problems decrease 30%
- total cost of an average well decreases 15%
- efficiency of a flash plant increases 5%
- efficiency of a binary plant increases 20%
- wellhead temperature needed decreases 30%
- production well flow needed decreases 50%
- injection well flow decreases 50%
- well flow decline/year decreases 30%

A geothermal R&D impact computer model, IMGEO, was used to estimate the impact of these achievements on the cost of hydrothermal electric power. The 20 selected KGRA's were matched to proxies from the eight areas on which the model is constructed by some or all of the following:

- geological location
- resource temperature
- resource depth
- resource size
- resource knowledge from previous endeavors.

The plant and field costs estimated by IMGEO for each KGRA were then compared to the respective state's projected avoided costs for electricity. When the cost to generate electricity became less than the utility avoided cost, it was assumed that construction of a 50 MWe plant would begin. The subsequent scenario is optimistic in that it predicts construction of an additional 50 MWe plant every third year until the capacity of the field is reached.

The Netback System of the Minerals Management Service was used to calculate royalties. While the value of the resource has several associated interpretations and caveats within this System, essentially the net sales of energy at the busbar minus the generating cost multiplied by the royalty rate (10 percent for hot water plants) equals the royalty. A computer program calculated royalty income from the output provided by IMGEO and data on utility avoided cost and escalation rates for each successive year.

Based on the assumptions in this study, the incremental royalties accruing to the federal government resulting from the success of its geothermal program are only a small fraction of the costs of the R&D program. For the base case assuming a discount rate of 10 percent, the incremental royalty was $34.7 million through 2010. Assuming a geothermal program budget of $20 million from 1987 through 2000 yields a discounted expenditure of $162 million--a return of only 21 cents on the dollar. Even in the nondiscounted case, an estimated R&D expenditure of $280 million resulted in only $181 million in increased revenue.

The methods of analysis used to calculate these incremental royalties are crude, but they probably set an upper bound to the value of incremental royalties. A more refined and more rigorous analysis would only result in less incremental royalties.

This does not mean that the federal government should not conduct geothermal research. The government is not a private investor--it does not need to generate a return on its spending. R&D is funded with the taxpayer's money to benefit the nation as a whole, not to return money to the federal treasury.

1.0 INTRODUCTION

1.1 Background and Scope

The Geothermal Steam Act of 1970 (P.L. 91-581) authorized the leasing of federal lands for the purpose of producing and utilizing the underlying geothermal energy. The Steam Act also requires a payment of royalty to the U.S. government on any production sold or utilized by the lessee. The rate of royalty to be paid is set forth in the lease, and, as required by the Steam Act, will not be less than 10 percent or more than 15 percent "of the amount or value of steam or any other form of heat or energy." Currently, 12.5 percent is charged at The Geysers because of the high quality of the dry steam produced, and 10 percent is the prevailing rate elsewhere.

Since a major share of the country's high-grade hydrothermal resources suitable for power generation underlie federal lands in the western states, royalties from power generation utilizing these resources have the potential for becoming a substantial source of revenue. Approximately $15 million was paid in federal geothermal royalties in 1986, half of which was returned to the states where the royalties originated. The other half was retained by the U.S. Treasury.

The purpose of this study was to predict the value of increased royalties that could be accrued through the year 2010 by the federal government as a result of the accomplishments of the U.S. Department of Energy (DOE) geothermal research and development (R&D) program. The technology improvements considered in this study coincide with the major goals and objectives of the DOE program as set forth in Section 3.0 and will:

- allow the geothermal industry to maintain a long-term competitive posture in the more favorable fields
- permit it to become competitive where the resource is of lower quality.

The study was confined to power generation from liquid-dominated hydrothermal geothermal reservoirs. The technologies for exploiting the liquid-dominated, or hot water, fields for power generation are relatively new and still under development. Thus, each technology enhancement that permits greater economic use of the resource will potentially enhance royalty revenues. Potential royalty revenue from dry steam power production at The Geysers, direct use of geothermal fluids, and use of advanced geothermal technologies (i.e., hot dry rock, magma, and geopressured) has not been considered in this assessment.

Although the dry steam plants at The Geysers are currently a significant source of royalties, the technology for development of these fields is fairly mature. Therefore, the DOE Geothermal Program is not conducting research designed to advance dry steam technology. As a result, the incremental royalty revenue due to DOE geothermal R&D is not likely to be significant.

Although geothermal fluid production on federal lands for direct uses is also subject to royalty assessment, the quantities of fluids used in most direct applications are small compared to the much larger quantities consumed by power generation. In addition, the technology for direct use applications is very mature and not likely to measurably benefit from DOE R&D.

While technology advances may permit some early development with geopressured, hot dry rock, and magma resources by 2010, royalty revenues in this period will be minimal. In the case of geopressured brines, there would be no revenue since the land on which the earliest development would be expected to occur in Texas and Louisiana is not subject to federal royalties.

1.2 Conclusions

The rationale of the study was that, by reducing the barriers to geothermal power development, the DOE R&D program will encourage further geothermal development. Some of this development will be on federal lands and therefore will generate royalties. The question addressed by this study is whether these royalties would be sufficiently large to return the government's "investment" in geothermal energy.

Obviously, the innumerable factors that will impact the future expansion of the U.S. geothermal power base would be impossible to predict. Therefore, this study was conducted with a set of fairly simple assumptions. These assumptions were specifically selected to present an optimistic picture of incremental royalties that could be generated from government R&D. For example, the field development scenario of 50 MWe every 3 years once construction begins in an area is very ambitious. It results in more royalties accruing at a faster rate than would less optimistic scenarios.

Based on the assumptions in this study, the incremental royalties accruing to the federal government resulting from the success of its geothermal program are only a small fraction of the costs of the R&D program. For the base case assuming a discount rate of 10 percent, the incremental royalty was $34.7 million through 2010. Assuming a geothermal program budget of $20 million from 1987 through 2000 yields a discounted expenditure of $162 million -- a return of only 21 cents on the dollar. Even in the nondiscounted case, an estimated R&D expenditure of $280 million resulted in only $181 million in increased revenue.

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1.3 Overview of Methodology

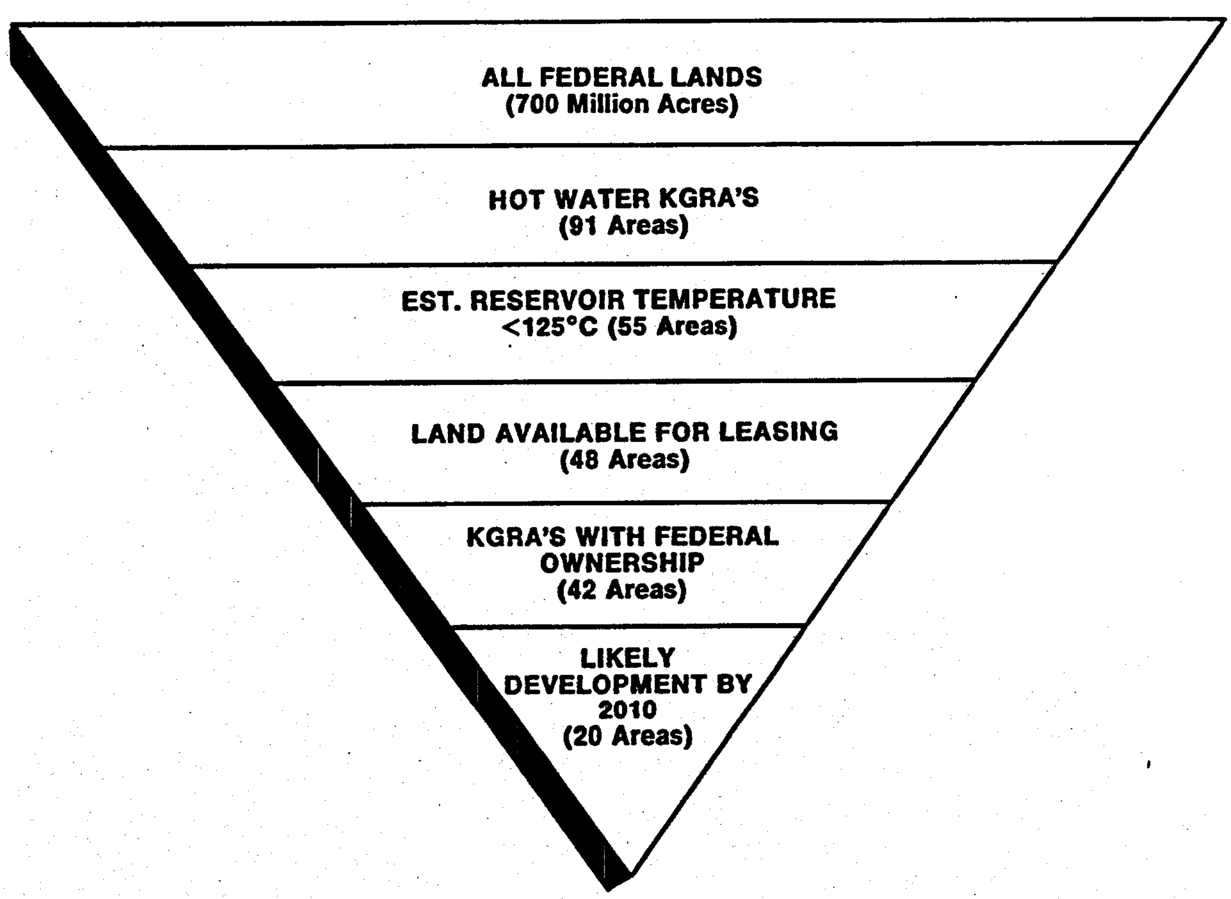
In order to project incremental federal royalty income from geothermal energy it is necessary to estimate likely geothermal development on federal lands. Therefore, this task was undertaken in two distinct phases:

(1) an investigation to identify federal lands where geothermal development is likely to occur prior to 2010; and (2) a site-specific, engineering economics analysis to estimate the cost of development and the anticipated profits and royalties.

The purpose of the first phase of the study was to reduce the number of potential sites to a small enough group that each site could be treated individually for royalty calculations. Starting with all federal lands, the sites were pared to 20 areas that are likely to be the most significant sources of royalties to the federal government by 2010. The filtering process used is shown in Exhibit 1-1, and is described in detail in Section 2.0.

In the second phase of this project, the 20 areas identified in phase one were evaluated to predict expected royalty income. A geothermal costing model, IMGEO, developed previously for DOE, was used to calculate the discounted cost per kW/hr for each area.[1] This calculation was based on available data for each reservoir. The impact of DOE geothermal R&D was applied by reducing plant costs corresponding to anticipated R&D successes. Development costs (with and without R&D impacts) were compared to utility avoided costs (using appropriate cost escalation rates) to construct optimistic development scenarios. Based on these scenarios, royalties from geothermal development were predicted. The details of the assumptions and calculations are presented in Section 3.0 and the results are given in Section 4.0.

Exhibit 1-1
SELECTION PROCESS FOR AREAS TO BE STUDIED



2.0 SELECTION OF FEDERAL LANDS FOR GEOTHERMAL DEVELOPMENT

The federal government owns over 700 million acres of land in the United States, accounting for over 32 percent of the total area of the nation.[2] Obviously, the vast majority of land is not likely to be developed for geothermal electrical power production. In order to predict geothermal development on federal lands and forecast royalty revenue, the number of sites under consideration was culled using the process illustrated in Exhibit I-1. The following sections in this chapter describe the rationale, details, and results of this process.

2.1 Known Geothermal Resource Areas

The first step to limit the number of sites considered in this study was to focus almost exclusively on designated Known Geothermal Resource Areas (KGRA's). The Geothermal Steam Act of 1970 requires that KGRA's be designated when:

- the Bureau of Land Management (BLM) (originally, this was the responsibility of the U.S. Geological Survey, but it has since been transferred to BLM) determines that there are reasonable indications that a commercial resource is present under specified acreage (geologic criteria KGRA)

- the acreage applied for in two or more noncompetitive lease applications overlaps by 50 percent or more (competitive interest KGRA)

The major purpose of KGRA designation is to require that leases in such areas be obtained only through competitive bid. In theory, these areas are more likely to be commercially productive (and therefore a larger source of revenue) than the vast public lands available for leasing through noncompetitive application.[3] A noncompetitive application requires only the payment of a relatively small rental fee; bonus bids for competitive acreage range form $2/acre up to several thousand dollars per acre.

All major development to date has occurred on KGRA's.[4] This study found only two discoveries on noncompetitive acreage since the last KGRA's were designated--Fish Lake Valley and Salt Wells Basin, both in Nevada. Published data on these areas were insufficient to include them in the study.

At the time of the study, there were 92 active KGRA's--The Geysers dry steam field and 91 others (Exhibit 2-1). New KGRA's can be designated and existing ones declassified at any time.

A study of the vast differences in the surface and subsurface character and availability among individual KGRA's and their potential effect on development permitted this study to build on "real-world" possibilities rather than across-the-board theoretical projection of geothermal development as one universe. Profiles of the individual KGRA's and surrounding activities within one or two townships were developed and include as much of the information listed in Exhibit 2-2 as was available. There was a wide differential in the finished profiles, ranging from virtually complete information to very little

EXHIBIT 2-1

KGRA'S IN THE UNITED STATES

STATE	NAME OF KGRA	ACRES
Alaska (3)	Geysers Spring Basin	20,960
	Okmok Caldera	44,800
	Pilgrim Springs	22,400
	Subtotal	88,160
Arizona	All KGRA's have been revoked	
California (22)	Bodie	640
	Brawley	28,885
	Calistoga	9,055
	Coso Hot Springs	106,752
	Dune	7,680
	East Brawley	70,211
	East Mesa	37,714
	The Geysers	278,644
	Glamis	25,460
	Glass Mountain	134,254
	Heber	58,568
	Knoxville	1,319
	Lake City-Suprise Valley	72,940
	Lassen	78,705
	Mono-Long Valley	458,514
	Randsburg	12,896
	Saline Valley	3,199
	Salton Sea	102,887
	Sespe Hot Springs	7,035
	South Brawley	12,640
	Wendel-Amedee	18,431
	Westmorland	3,200
	Subtotal	1,529,629
Colorado (3)	Mineral Hot Spring	4,485
	Poncha	3,200
	Valley View Hot Springs	1,913
	Subtotal	9,598
Idaho (7)	Bruneau	5,120
	Castle Creek	79,722
	Island Park	28,539
	Mountain Home	9,520
	Raft River	30,209
	Vulcan Hot Springs	3,836
	Yellowstone	14,164
	Subtotal	171,110
Montana (4)	Boulder Hot Springs	6,343
	Corwin Springs	20,349
	Marysville	19,200
	Yellowstone	12,763
	Subtotal	58,655

EXHIBIT 2-1, Continued

STATE	NAME OF KGRA	ACRES
Nevada (24)	Baltozor	5,617
	Beowawe	26,180
	Brady-Hazen	98,508
	Colado	640
	Darrough Hot Springs	8,363
	Dixie Valley	129,361
	Double Hot Springs	29,326
	Elko Hot Springs	8,960
	Fly Ranch	20,758
	Gerlach	26,326
	Hot Springs Point	8,549
	Kyle Hot Springs	2,560
	Leach Hot Springs	12,846
	Moana Springs	5,120
	Pinto Hot Springs	8,015
	Ruby Valley	5,743
	Rye Patch	801
	San Emidio Desert	7,678
	Soldier Meadow	5,967
	Steamboat Springs	8,912
	Stillwater-Soda Lake	225,260
	Trego	7,013
	Warm Springs	3,812
	Wilson Hot Springs	1,294
	Subtotal	657,609
New Mexico (6)	Baca Location No. 1	164,696
	Gila Hot Springs	3,202
	Lightning Dock	21,667
	Lower Frisco Hot Springs	5,760
	Socorro Peak	28,715
	Radium Springs	6,862
	Subtotal	230,902
Oregon (12)	Alvord	176,835
	Belknap-Foley Hot Springs	5,066
	Breitenbush Hot Springs	13,445
	Carey Hot Springs	7,579
	Crump Geyser	85,663
	Klamath Falls	29,869
	Lakeview	12,165
	McCredie Hot Springs	3,659
	Mt. Hood	8,671
	Newberry Caldera	31,284
	Summer Lake Hot Spring	13,631
	Vale Hot Springs	22,998
	Subtotal	410,865

EXHIBIT 2-1, (Continued)

STATE	NAME OF KGRA	ACRES
Utah (9)	Cove Fort-Sulphurdale	24,074
	Crater Springs	17,321
	Lund	3,840
	Meadow-Hatton	1,927
	Monroe-Joseph	16,364
	Navajo	2,522
	Newcastle	2,636
	Roosevelt Hot Springs	29,791
	Thermo Hot Springs	22,179
	Subtotal	120,654
Washington (2)	Kennedy Hot Springs	3,311
	Mt. St. Helens	29,755
	Subtotal	33,066
GRAND TOTAL IN THE UNITED STATES (92):		**3,310,248**

Source: U.S. Bureau of Land Management (May 1986)

EXHIBIT 2-2

INFORMATION GATHERED TO DEVELOP KGRA PROFILES

Physical/Chemical
Characteristics of Resource

- Temperature
- Flow
- Depth
- Pressure
- Size/Volume
- Chemistry
- Thermal energy
- Suitability for power generation w/wo enhanced technology

Environmental Acceptability
of Development

- Environmental sensitivity of location
- BLM/FS sentiment (lease application rejection long pending applications/withdrawn competitive lease parcels)
- Resource characteristics from above
- Proximity of designated wilderness areas/wildlife refuges/Class I PSD areas
- Land under consideration for wilderness designation

Industry Interest

- Acreage under lease
- Leasing history (major developers, speculators, relinquishments/terminations)
- Degree of exploration/number of wells drilled
- Unitization
- Availability of cooling water
- Availability of transmission lines
- Existing development/announced plans

Land Ownership

- Percent federal ownership

to almost none. However, the information was sufficient to broadly categorize the development potential of the areas prior to 2010. The profiles are summarized in Appendix A. The information in the profiles falls into three broad categories:

- resource characteristics -- e.g., temperature, chemistry -- which will impact its suitability for power generation, with or without technology enhancement
- surface considerations such as environmental/institutional/ economic factors that may exert an equal or greater influence on development than the physical/chemical characteristics of the resource and which often interact with each other
- land ownership

The first two of these categories have a direct impact on development potential; they combine with the third to indicate royalty potential. That is, the resource must be commercially useful for power generation and the land must be available if development is to occur. If royalties are to accrue, the land must be federally owned.

2.2 Resource Factors

U.S. Geological Survey (USGS) Circular 790, "Assessment of Geothermal Resources of the United States - 1978," was the primary source of information on the characteristics of individual geothermal reservoirs. It was supplemented to some extent by information from environmental studies performed by BLM or the U.S. Forest Service and state geothermal resource maps funded by the DOE geothermal R&D program and prepared by state agencies. The major observation that can be made on the search for authoritative resource data is that there is still very little of it in the public domain. Probably due to very tight R&D budgets of recent years at both DOE and USGS, little information from reliable sources after Circular 790 could be found on most of the prospect areas.

The most important resource characteristic--temperature--was, fortunately, the most likely datum point to be found. Temperature is the major controlling factor in the specific technology application for hot water power generation--flash steam or binary--and, indeed, in the ability to use the resource for this purpose with current or enhanced technologies. Very little useful information on other resource characteristics was found for the undeveloped, less well-known KGRA's. In no case were other characteristics alone used as the basis for favorable or unfavorable categorization in this study. Thus, the first cut of the KGRA's was based solely on temperature estimates; the second on the fact that temperature estimates were not found.

According to estimates by USGS in Circular 790, and a few other sources considered reliable, the resource temperature at 28 KGRA's, or 30 percent of the total of the 91 hot water KGRA's, is below 125^{o}C (260^{o}F), as shown in Exhibit 2-3. Of these, the temperature at 19 KGRA's, or 21 percent, is estimated at 100^{o}C (212^{o}F) or below.

In this study, it was assumed that improvements in binary cycle

EXHIBIT 2-3

KGRA'S WITH ESTIMATED RESERVOIR TEMPERATURE BELOW 125°C (260°F)

KGRA	USGS Circular 790 Temperature Estimate °C	°F
CALIFORNIA		
Saline Valley	57	133
COLORADO		
Poncha	71	160
Valley View Hot Springs	37	99
IDAHO		
Bruneau	110	230
Castle Creek	107	224
Mt. Home	72	162
MONTANA		
Corwin Hot Springs	68	154
Marysville	103	217
NEVADA		
Colado	101	213
Elko Hot Springs	86	187
Fly Ranch	100	212
Hot Springs Point	87	189
Moana Springs	96	205
Ruby Valley	96	205
Soldier Meadow	64	147
Trego	124	255
NEW MEXICO		
Gila Hot Springs	77	171
Lower Frisco	99	210
Socorro Peak	33	91
Radium Springs	96	205
OREGON		
Belknap-Foley	106-108	223-226
Carey Hot Springs	118*	244*
Lakeview	96	205
McCredie	96	205
Summer Lake	112	234
UTAH		
Crater Hot Springs	97	207
Meadow-Hatton	48	118
Monroe-Joseph	101-104	214-219

*Circular 790 estimate for Lakeview is 149°C (300°F); Oregon Dept. of Geology and Mineral Industries is 150°C (300°F); above figure represents the temperature found in the deepest well drilled in the area, 5,440 feet; binary plant in the area operated on 105°C (221°F).

performance now under development will lower the temperature for economic operation of commercial-size binary equipment to 125°C (257°F). While several very small binary units are operating at lower temperatures today (e.g., a 600 kW unit at Wabuska Hot Springs in Nevada on 102°C (216°F) fluid), they are economic because of special conditions at each site. The availability of binary technology of sufficient size to produce substantial incremental royalty income prior to 2010 at such low temperatures is not yet in sight. In addition, in order to use the 19 KGRA's with the lowest temperatures for power generation, a breakthrough in technology is needed, perhaps some type of economic hybrid system in which geothermal fluids will furnish only a portion of the heat. A number of these reservoirs are being used for direct applications, however, a practice that is expected to continue to grow in those states endowed with such resources.

Despite the USGS Circular 790 temperature estimate of 104°C (219°F) for the Klamath Falls KGRA in Oregon, it is a special case and is omitted from Exhibit 2-3. This is due to recent DOE work which indicates that temperatures of 150-190°C (302-374°F) exist somewhere in the system (see Appendix B for details) which may make portions of the resource available for power generation.

Another eight KGRA's, listed in Exhibit 2-4, are considered poor prospects for imminent power development. An extensive search of the literature produced no reliable temperature data for these areas. Since so little is known about them at this time, early activity would seem unlikely.

2.3 Land Status and Environmental Factors

The opportunities for geothermal leasing on federal land, and thus royalty accrual, vary from state to state and from KGRA to KGRA. The vast majority of federal land is administered either by BLM, within the Department of the Interior, or the U.S. Forest Service, within the Department of Agriculture. Not all land under the jurisdiction of these agencies is available for leasing. Under the Steam Act, wildlife refuges, national recreation areas, waterfowl production areas, and similarly protected lands are excluded. National parks and wilderness areas are put off limits by other legislation. Furthermore, land adjacent to such areas has always been subject to potential withdrawal from leasing in order to protect the values of nearby areas. The Forest Service's decision not to lease in the Lassen KGRA because of its proximity to the Lassen Volcanic National Park and the legislation to preclude leasing in the Island Park KGRA adjacent to Yellowstone are two prime examples of such action.

Land availability and the conditions of availability become very localized at the KGRA level. These determinations are made, consistent with long range land use plans of the surface management agencies, through Environmental Impact Statements or informal environmental assessments.[3,5] A number of such documents were used in this study to gather the site-specific information on land status and environmental factors. Data in these documents include:

- legal description of lands available for leasing
- identification of parcels not available for leasing and the reasons therefor -- e.g., scenic, recreational, or historic values,

EXHIBIT 2-4

KGRA'S FOR WHICH TEMPERATURE ESTIMATES WERE NOT FOUND

<u>CALIFORNIA</u>

Bodie
Calistoga
Knoxville

<u>COLORADO</u>

Mineral Hot Springs

<u>NEVADA</u>

Wilson Hot Springs

<u>UTAH</u>

Lund

Navajo Lake

<u>WASHINGTON</u>

Mount St. Helen's

threatened or endangered species habitat, interference with orderly multiple use

- description of lands available for leasing with a No Surface Occupancy stipulation

- description of lands being inventoried or evaluated for wilderness designation where no surface disturbance that will interfere with wilderness designation or prevent rehabilitation to wilderness characteristics is permitted

- special concerns that must be addressed in leasable areas -- e.g., unmapped archaeological sites

- mitigation measures that involve time of year or time of day -- avoidance of nesting or strutting grounds of wildlife species on a calendar basis; development activities limited to certain months to protect critical watershed areas; or drilling only during daylight hours

- mitigation measures that involve technology application -- e.g., dry cooling towers, noncondensible gas abatement

- mitigation measures that involve location -- e.g., location of plant and wells so as not to hinder recreational use; location of powerline corridors away from landmark features; drill outside of and a minimum specified distance from all surface waters.

BLM has essentially completed its basic planning for geothermal development on the lands over which it has jurisdiction, although planning is not a static function and changes may be made later. The Forest Service has also made most of its "lease/no lease" decisions (with the Lassen decision being one of the most recent). Thus, developers can now ascertain, at least in a general way, where they may lease federal land and under what circumstances.

However, more recent legislation, enacted in 1986 (P.L. 99-591), may further preclude geothermal development where it might adversely affect significant thermal features in national parks.[6] If, on the basis of scientific evidence, the Secretary of the Interior determines that exploration, development, or utilization of geothermal resources on land applied for in lease applications would result in degradation of such features, leases must be denied and the land withdrawn. If the determination is made that degradation is "reasonably likely," lease stipulations are mandated that would require the lessee "to suspend activity, temporarily or permanently" if adverse effects occur. It is likely that such a stipulation would effectively preclude leasing. Most of the important designations so far cover areas that were already closed to geothermal development through other mechanisms. However, other designations may be forthcoming.

Based on this survey, land status and environmental factors will exclude seven KGRA's from development, in whole or in part, and are likely to exclude two others, as shown in Exhibit 2-5. The reasons for excluding each of these areas are given in the table.

It can be argued that administrative decisions are not irrevocable and that even statutory prohibitions could be lifted. In today's climate of environmental activism, however, it is not likely that geothermal developers are predicating their early development plans on significant changes in the above situation. Therefore, this study assumed that land that is not available now will not be available before 2010.

2.4 Land Ownership Factors

Another factor in royalty accrual is the extent to which commercial geothermal assets coincide with federal ownership. The overall percent of federal lands in the western states is given in Exhibit 2-6.[2] Although these statistics indicate the likelihood of federal lands within KGRA's, it is still necessary to examine each area independently where possible. For example, in Oregon and Washington, where federal ownership is only 49 and 31 percent respectively, national forests embrace the prime geothermal prospects in the Cascades Range. Thus, if geothermal power development comes to those states, the federal treasury may reap relatively higher benefits than the state percentage totals would indicate because federal ownership and the most likely areas of geothermal production coincide.

While full information on land ownership for individual KGRA's for all pertinent states is not available, it is likely that the single most important impact of this consideration will be felt in Imperial Valley. While there are nine KGRA's listed in the Valley, the East Mesa KGRA will be the only one to provide significant royalty revenues as long as development follows its current and predicted pattern, as explained in the footnotes to Exhibit 2-7. The most critical factor here is that, while 22 percent of the Salton Sea KGRA is federally owned, the major development there will not produce royalty revenues within the foreseeable future for the reasons set forth in Footnote(b).[7]

Based on land ownership data, six KGRA's have been excluded from this study.

2.5 Other KGRA's Not Considered Targets for Early Development

Exhibit 2-8 presents a list of another 19 KGRA's where, on the basis of subjective considerations, development does not appear imminent. Most of these are included in this category because leasing records indicate little or no developer interest at this time.[4] For example, in two KGRA's--Gerlach and Leach Hot Springs in Nevada--a group of noncompetitive leases were unitized--a commitment to development under the regulations implementing the Steam Act--but the unit has since been dissolved and the leases relinquished or terminated. While the same lessee or another developer can still lease the land, it is highly unlikely that the original lessee would have released the acreage if a commercial resource were suspected or proven.

The leasing information used in making these judgments was obtained principally from the BLM computerized data base entitled "History of Geothermal Lease Applications, Format A-3 (dated 12/17/85) which also contains the records on all competitive leases. BLM has now dismantled this data file. The information in it was found to correlate very well with the state geothermal leasing statistics presented in BLM's Public Land Statistics 1986,[2] although the record was incomplete for the period December 1985 to October 1986, when a

EXHIBIT 2-5

KGRA'S WHERE LAND STATUS/ENVIRONMENTAL CONSIDERATIONS MAY INHIBIT DEVELOPMENT

CALIFORNIA	
Lassen	Forest Service has denied geothermal leasing because of proximity to the national park.
Sespe Hot Springs	California Division of Mines and Geology has stated that geothermal development may be retarded in this small extremely isolated area because of its pristine condition and abundant wildlife.
IDAHO	
Island Park	Geothermal leasing is statutorily prohibited.
Yellowstone	National parks are closed to leasing.
MONTANA	
Corwin Hot Springs	Abuts Yellowstone Park on the north and will almost certainly be impacted by the new significant thermal features legislation.
Yellowstone	National parks are closed to geothermal leasing.
OREGON	
Mt. Hood	Mt. Hood Wilderness area precludes leasing.
WASHINGTON	
Kennedy Hot Springs	Lies in Glacier Peak Wilderness area which is closed to leasing.
Mount St. Helens	Leasing is prohibited in the National Monument and stringent stipulations are likely to be attached to leases elsewhere in the area.

EXHIBIT 2-6

FEDERAL LAND OWNERSHIP IN WESTERN STATES

State	Percent Owned By Federal Government
Alaska	86
Arizona	44
California	48
Colorado	36
Hawaii	17
Idaho	64
Montana	1
Nevada	85
New Mexico	34
Oregon	49
Utah	61
Washington	31
Wyoming	50

EXHIBIT 2-7

LAND OWNERSHIP IN IMPERIAL VALLEY KGRA'S

KGRA	TOTAL ACREAGE	TOTAL FEDERAL ACRES	% OF FEDERAL OWNERSHIP
Brawley	28,885	0	0
East Brawley	70,211	9,654	14
South Brawley	12,640	16	~0
Dunes[a]	7,680	7,680	100[a]
East Mesa[c]	13,714	31,986	85[c]
Glamis[a]	25,460	23,539	92[a]
Heber	58,568	5	~0
Salton Sea[b]	102,887	22,324	22[b]
Westmorland	3,200	0	0

[a] Three competitive lease sales have been held for acreage in Glamis and Dunes, and no bids have ever been received. Many special stipulations and advisory notices have been attached to these tracts in the sale notices. For example, the Dunes KGRA has been used by the Army and Navy as a bombing area and for maneuvers, and the government does not guarantee that the area is free of unexploded bombs or other hazardous materials. BLM records indicate that nearly 25 percent of the land in the area is contaminated by military ordinance. The environs of both KGRA's were very active in noncompetitive leasing for a time, but all leases have been relinquished or terminated. These areas, for these and other reasons, do not appear likely candidates for development in the foreseeable future.

[b] Approximately 50 percent of the Salton Sea KGRA lies under water within the present Salton Sea lake bed. Onshore, more than 95 percent of the land is under private control, with only scattered federal acreage in the northern end. Offshore, less than half the lake bottom is federally controlled, and a portion of that is wildlife refuge or Navy seaplane landing areas or mine laying areas, none of which are open to leasing. All of the present geothermal discoveries are in the southern third of the KGRA; all are onshore and on private lands.*

[c] East Mesa is thus the only foreseeable source of geothermal royalties in Imperial Valley.

* Generic Environmental Impact Assessment on Geothermal Leasing, Bureau of Land Management, Department of Interior, 1973.

EXHIBIT 2-8

SECOND-TIER KGRA'S
USGS DATA AND OTHER FACTORS INDICATE POTENTIAL DEVELOPABLE RESOURCE, BUT OTHER CONSIDERATIONS TEND TO SUGGEST DEVELOPMENT IS NOT IMMINENT

KGRA	FACTORS UNFAVORABLE TO EARLY DEVELOPMENT
CALIFORNIA	
Dunes	No bids through 3 lease sales; area active in noncompetitive leasing for a time, and all leases have been relinquished or terminated; area contaminated with unexploded military bombs and other hazardous materials; concern for protection of fragile desert environment and water use.
Glamis	Same as above.
Wendel-Amedee	This is the area of the Honey Lake DOE-assisted hybrid binary/wood combustion plant and a 300 kWe binary plant; temperature at estimated 128°C is marginal for other binary development of significant size; USGS stated in 1978 that "based on available data and demonstrated technology the resource at Wendel-Amedee is inadequate for power-generation."
IDAHO	
Raft River	At 140°C, this area is very marginal for sizable binary operations; there are only five active leases in the entire state.
Vulcan	At 138°C, the situation is similar to that of Raft River.
MONTANA	
Boulder Hot Springs	At 136°C, the temperature would be an inhibiting factor, and there are no active leases in the state.
NEVADA	
Baltazor	Many leases have been relinquished/terminated; there is a conflict with a Wilderness Study Area; temperatures obtained in temperature gradient holes disappointing.
Double Hot Springs	No lease sales ever held for competitive leases; nearly 30 noncompetitive leases relinquished/terminated; adjacent to land under consideration for wilderness.

EXHIBIT 2-8, Continued

NEVADA (continued)

Gerlach	A group of noncompetitive leases were unitized, but the unit has been dissolved and the leases terminated; most competitive also terminated; slight overlap with land under consideration for wilderness.
Leach Hot Springs	Leasing situation very similar to Gerlach.
Pinto Hot Springs	There has been little interest in competitive or noncompetitive leasing; no leases remain active; contains Wilderness Study Area.
San Emidio Desert	Same as Pinto.
Warm Springs	With an estimated temperature of only 125°C, it does not appear that this area will be competitive with other much more attractive KGRA's in Nevada in the near future.

NEW MEXICO

Baca Location No. 1	While this area cannot be ruled out for smaller development, it would not support 50 MWe plant; only a few competitive leases remain active; no noncompetitive interest in the area; water difficult to obtain.
Lightning Dock	While the USGS most likely temperature estimate for this area was 158°C (316°F), no power generation capacity capability was noted. The only deep development well recorded has been abandoned. Area in use for direct applications.

OREGON

Alvord	Many of the early flood of noncompetitive applications for leases in this area were withdrawn or rejected; only a few leases in each category remain active.
Crump Geyser	Only 1 out of over 50 leases issued for this area remains active.

UTAH

Newcastle	Only 1 relinquished/terminated lease is recorded; it is a competitive interest KGRA.
Thermo Hot Springs	Only a handful of leases remain active out of nearly 60 issued; it is a competitive interest KGRA.

moratorium was placed on geothermal leasing by the Significant Thermal Features legislation.[6]

Other reasons for including KGRA's in this group in addition to leasing status are:

- potential conflicts with wilderness designations
- disappointing well test results
- lack of access to transmission lines.[8,9,10]

In addition to the KGRA's listed in Exhibit 2-8, the three KGRA's in Alaska were not considered. No lease sales have been held in the state, and no noncompetitive applications have been filed.[4] While preliminary planning for a small development has been reported in the current literature, it cannot be foreseen that sufficient development will occur on Alaskan federal lands through 2010 to significantly impact royalty revenue. All KGRA's in Arizona have been revoked, and Hawaii is not a factor since it contains no land subject to royalty payment.

2.6 Summary of Site Selection Results

On the basis of technical considerations or land status or ownership factors, 49 KGRA's (53 percent) have been excluded from consideration as royalty producers as follows:

• temperature below 125°C	28
• no temperature data	8
• land status	7
• little or no federal ownership	6
	49

Another 22 have been excluded on the basis of factors that tend to indicate that development is not likely prior to 2010 without significant changes in economic incentives.

The 20 KGRA's deemed the most likely royalty producing candidates for early or continued development are shown in Exhibit 2-9.

2.7 State Summaries

The information assembled on the KGRA's and noncompetitive areas in the various "geothermal" states in terms of their potential for power generation from 1987-2010 is summarized in Appendix B. So far as is known, this is the first time that so many different kinds of information have been available in one place for assessing the "real world" situation across these states. While various agencies and interested parties may possibly be able to size up to some extent the probable development scenario in a given state or given area, this is the broadest look yet at all of them.

EXHIBIT 2-9
KGRA's Most Likely to Produce Royalties

California
Coso Hot Springs[a]
East Mesa[a]
Glass Mountain[a]
Lake City-Surprise Valley[b]
Mono-Long Valley[a]
Randsburg[b]

Oregon
Breitenbush Hot Springs[b]
Klamath Falls[b]
Newberry[b]
Vale Hot Springs[b]

Nevada
Beowawe[a]
Brady-Hazen[a]
Darrough Hot Springs[b]
Dixie Valley[a]
Kyle Hot Springs[b]
Rye Patch[b]
Steamboat Springs[a]
Stillwater-Soda Lake[a]

Utah
Cove Fort-Sulphurdale[a]
Roosevelt Hot Springs[a]

[a]Development underway or planned.
[b]No development yet.

3.0 COST AND ROYALTY CALCULATIONS

3.1 Technology and R&D Considerations

The technology available today and the technology that will result from the DOE R&D program, if its objectives are met, provide 1) the base case for royalty accrual, and 2) enhanced accrual with improved technology. This section identifies both the existing technology limitations and the R&D objectives designed to overcome them.

The single most important technological impetus to more rapid development will be the ability to ensure adequate reservoir longevity and producibility while reducing the costs of confirmation drilling. Further improvements in the geosciences as tools for predicting reservoir behavior under production conditions are needed to induce greater investment in geothermal projects.

Reductions in the cost of drilling are needed since drilling of wells is mandatory during every step in geothermal development--field confirmation, production, injection, and long-term utilization--yet the costs remain up to four times as high as those for oil and gas drilling.

Since binary technology is state of the art for power generation with the large proportion of identified reservoirs that are not hot enough for economic flash steam systems, improvements in the efficiencies in commercial-size binary units are needed. While small binary units (<12.5 MWe) are a proven technology, the potential of those large enough to contribute significantly to royalty revenues has not been demonstrated.

Another problem slowing more widespread geothermal use is the short lifetime of materials and equipment components due to the heat and corrosive nature of geothermal fluids. While considerable progress has been made in developing materials for geothermal applications, new materials to enhance system performance and reduce maintenance requirements will enhance the economic use of this resource. Specific needs are elastomeric formulations for dynamic seals and well casing linings and high thermal nonmetallic composite materials for binary cycle heat exchangers.

The behavior of the brines in power plants and injection systems is also associated with materials failures as well as plugging of equipment and injection wells. Better understanding of chemically complex brines and the means to measure and monitor solids contents and to detect adverse conditions before plant failure will help solve these problems.

Another problem that will become increasingly severe and costly is land disposal of geothermal wastes deemed hazardous by federal and state statutes. At The Geysers, where methods used to abate hydrogen sulfide emissions produce most of the hazardous sludges, disposal costs are predicted to increase over 500 percent between 1984 and 1993 to a cost of $1,200 per ton by 1994.[11] In hot water plants, the removal of solids from spent fluids prior to injection produces residual sludges that require similar handling in disposal. The problem is not only one of cost, but of the availability of disposal sites licensed to receive such wastes. Many have been forced to close, and the same fate may await others where conditions do not permit complete compliance with applicable standards. There are only three licensed Class I disposal sites still operating in California, and only one of these is licensed to accept bulk liquids.

The R&D program of the DOE Geothermal Technology Division is addressing all of the above technology limitations, with many projects being cost-shared with industry. They are working toward specific performance goals as follows:

TECHNOLOGY	PERFORMANCE GOAL	COMPLETION YEAR
Reservoir Technology	Expand current knowledge of hydrothermal reservoirs and develop improved prediction and management tools that will reduce uncertainty in reservoir performance	2000
Hard Rock Penetration	Develop components and field test an improved drilling system to reduce well costs by 20 percent	1994
Conversion Technology	Develop technology to improve cycle efficiencies of binary conversion technology by 30 percent	2000
	Develop advanced materials resistant to hostile geothermal environment	1992
	Evaluate technique for microorganism decontamination of toxic metals from geothermal wastes. Complete field tests of particle meters and advanced brine monitoring instruments.	1989

If these goals are accomplished as projected, industry will approach the year 2000, at which time a vastly improved market for power is predicted, equipped with new technologies. For example, more reliable reservoir prediction and management techniques may reduce the number of wells needed to confirm the existence of reservoirs, to delineate their geological and geochemical character, and to locate and characterize the fluid-filled natural fractures. Less costly wells may increase the optimum size of geothermal power plants. Binary performance may be extended to plant sizes that would bring considerably more royalty revenue from Federal lands than the typical binary plant of today. Accomplishment of binary technology R&D objectives may also extend economic binary performance to reservoirs not amenable to that technology today, except under very favorable site-specific conditions that are not generally available.

All of these improvements, along with those expected in materials, waste treatment to reduce quantities of wastes requiring hazardous waste disposal, and other technology areas will serve to increase the use of geothermal energy in the western states. With increased use comes the greater possibility that new development or expanded development of reservoirs already under development will occur on federal lands, and royalty revenues will increase accordingly.

3.2 Plant Costing and Development Scenarios

IMGEO, a geothermal R&D impact computer model, estimates the impacts of future R&D achievements on the cost of developing geothermal electric power.[1] The costing "engine" within IMGEO provides a method of estimating the plant and field costs of a 50 MWe plant on the KGRA's under consideration.

For the purposes of this study, the model contains a technology baseline compiled by the experts who developed the model for eight different resource areas with a history of geothermal development. The KGRA's considered in this study were matched to proxies from these eight areas by some or all of the following characteristics:

- geologic location
- resource temperature
- resource depth
- resource size
- resource knowledge from previous endeavors.

These proxies and the data used for them are presented in Appendix C.

By substituting the known data for a KGRA into IMGEO, it would calculate a detailed working cost for a 50 MWe plant on that KGRA at today's technology and price levels (see Appendix D). A second run of the model, applying the DOE Geothermal Program's R&D goals and objectives, provided a set of costs for the same 50 MWe plant which reflects R&D achievement. The R&D achievements input into IMGEO for this study are:

• lost circulation well problems decrease	30%
• total cost of an average well decreases	15%
• efficiency of a flash plant increases	5%
• efficiency of a binary plant increases	20%
• wellhead temperature needed decreases	30%
• production well flow needed decreases	50%
• injection well flow decreases	50%
• well flow decline/year decreases	30%

The total generating costs for each KGRA were then compared to the respective state's projected avoided costs for electricity. Avoided cost data was obtained from the various states and is included in Appendix E. When the cost to generate electricity became less than the utility avoided cost, it was assumed that plant construction would begin.

A spot check of the data presented in Appendix D reveals that no plants would be on-line before 1990 in this scenario. However, it should be noted that electric plants are already in operation on some of these KGRAs. This anomaly is explained by the fact that contracts have been negotiated at higher avoided cost rates through regulations implementing the Public Utilities Regulatory Policies Act (PURPA), such as California Standard Offer No. 4, a ratemaking vehicle of the California Public Utility Commission.

3.3 Calculation of Royalties

No set formula exists for geothermal energy derived royalties. All royalty formulas are determined on a case-by-case basis by individual consultation with the Minerals Management Service (MMS) of BLM in Denver, Colorado. This consultation permits the potential geothermal operator to prepare a royalties contract that will satisfy all parties involved with the process. The royalties approximation used in this study evolved from telephone conversations with geothermal royalties experts at MMS.[12]

The Code of Federal Regulations--Title 30 CFR 206 Sec. 300--presents general statements on the system of calculating royalties. The specific details of this so-called "Netback System," however, have never been published and are not available to the general public. Simply stated, this system relates royalties to the value of the geothermal resource. Dry steam resources traditionally are assessed 12.5 percent of the resource value towards royalties (as at The Geysers), whereas the value of hot water resources is assessed at 10 percent. Of all royalties collected, 50 percent goes to the individual states where the production occurred while the remainder goes to the Federal Treasury.

The value of the resource has several associated interpretations and caveats within the Netback System. Succinctly, the net sales of energy at the plant outlet minus the generating cost multiplied by the royalty rate equals the royalty. The net sales at the plant outlet is the amount of generated electricity (in kWh) multiplied by the selling price of the electricity less allowable transmission costs. The generating cost is the actual cost of generation and can be up to two-thirds of the net sales price.

Mathematically represented:

Royalties = [A - Generating $] x [Royalties Rate]

and

Royalties ≥ [A] x [1/3] x [Royalties Rate]

Where A = Net revenue at plant outlet = [Electricity Amt. x Price - Transmission $]

A simplistic way of looking at this formula is to consider the generating cost as the price of operating the plant. We can then assume that the electricity price equals the field and plant costs plus the profit, and the price of electricity minus the plant costs multiplied by the royalty rate equals the royalties paid out. We must assume in this case that the total price includes all allowable deductions and the plant cost is no more than two-thirds that of the total.

In other words:

Cost = Field Cost + Plant Cost + Transmission

Price = Cost + Profit

and

Royalties = [Field Cost + Profit] x [Royalties Rate]

or

Royalties = [Price - Plant Cost - Transmission $] x [Royalties Rate]

or at a minimum

Royalties ≥ [(Price - Transmission $)/3] x [Royalties Rate]

A short computer program was written to calculate royalty income from the output provided by IMGEO and the data on utility avoided cost and escalation rates. The royalties program computes the following:

- year in which avoided cost exceeds plant cost
- plant construction scenario
- royalty rate
- discounted value of royalties to 1987 dollars.

For each year, the royalties program calculates a new avoided cost using the cost escalator and calculates the plant cost reduced by R&D impacts, if appropriate. When the utility avoided cost exceeds the plant cost ($/kw-hr), the first 50 MWe plant comes on line. The R&D impacts are applied gradually through 2000. Each year, beginning in 1991, an additional 10 percent of the total R&D impact is applied to reduce plant cost.

Following the first plant an optimistic general development scenario was chosen. This scenario causes an additional 50 MWe plant to be constructed every third year until the capacity of the field is reached.

The royalties program requires 14 input factors that transfer the raw data into the royalty estimate for each particular site. The input factors are shown in Exhibit 3-1.

The Global Factors that remained constant throughout the royalty runs are identified in Exhibit 3-2. The programming code for the royalties program is presented in Appendix F.

The royalty program generates a year-by-year royalty stream in both non-discounted and discounted dollars. By subtracting the results of the "no R&D" cases from "R&D impacts" cases, the incremental royalties are calculated. These numbers must then be reduced by:

- 50 percent to reflect the fact that the Federal Government returns one-half of the royalties to the states

- the percentage of federal land in the specific KGRA.

As discussed in Section 2.0, most KGRAs comprise a mixture of federal, state, and private land. The Federal Government collects a royalty only on production from federal land. To account for this, the total royalties calculated are multiplied by a factor representing the percentage of federal land in the KGRA. These figures are listed in Exhibit 3-3 for the 20 KGRA's considered in this study.

EXHIBIT 3-1
Input Factors for Royalty Estimate

Global Factors

- Discount Rate
- Offset of $ Years
- Royalty Rate
- Transmission Cost ($/kWh)
- First Year of Analysis
- Years Between Plants
- Capacity Factor

State Factors

- Avoided Cost, $/kWh in 1990
- Escalator Percentage for Avoided Cost beyond 1990

Site Factors

- Capacity of Site, MW
- Electricity, NO FURTHER R&D ACHIEVEMENTS, $/kWh in 1987 $
- Electricity, AFTER ALL R&D GOALS ACHIEVED, $/kWh in 1987 $
- Plant Only, NO FURTHER R&D ACHIEVEMENTS, $/kWh in 1987 $
- Plant Only, AFTER ALL R&D GOALS ACHIEVED, $/kWh in 1987 $

EXHIBIT 3-2
Constant Global Factors in Royalty Estimates

- Discount Rate = 10% (base case)
- Offset of $ Years = 3 --> Offset of 1987 $ to 1990 $
- Royalty Rate = 10% --> Hot water resource standard
- Transmission Rate --> Kept at 0 to show a maximum royalty revenue scenario. Increased to 1 cent/kWh to show increases for total generating cost which delay the plant on-line date.

- First Year of Analysis = 1990
- Capacity Factor = 80%

EXHIBIT 3-3

FEDERAL OWNERSHIP IN 20 KGRAs

State	KGRA	% Federal Land
California	Coso Hot Springs	94
	East Mesa	85
	Glass Mountain	97
	Lake City-Surprise Valley	50
	Mono-Long Valley	77
	Randsburg	96
Nevada*	All KGRA's	85
Oregon	Breitenbush Hot Springs } Klamath Falls	49
	Newberry	99
	Vale Hot Springs	61
Utah	Cove Fort-Sulphurdale	82
	Roosevelt Hot Springs	78

* Data unavailable; percentage of federal land in entire state used.

Source: U.S. Bureau of Land Management

4.0 RESULTS AND CONCLUSIONS

4.1 Results of Royalty Projections

The 20 KGRA's identified in Section 2.0 were subjected to the royalty projection technique described in Section 3.0. The results are summarized in Exhibit 4-1. For the base case, the incremental royalties accruing to the Federal Government attributable to the attainment of DOE Geothermal Program R&D objectives is $34.7 million (in discounted 1987 dollars). This is assuming no transmission costs, a 10 percent discount rate, and excluding the 50 percent of the royalties that are returned to the states. Also presented in Exhibit 4-1 is the present value of federal geothermal R&D assuming a $20 million annual budget beginning in 1987 and terminating in 2000. Under the base case discount rate of 10 percent, this is worth $162 million in discounted 1987 dollars.

Sensitivity studies were conducted varying the discount rate from 0 percent (i.e., nondiscounted) to 12.5 percent. These results are also presented in Exhibit 4-1. Cases were also run assuming a transmission cost of $0.01/kw-hr. The incremental royalties were reduced by approximately 2 percent in this case.

Detailed summaries of the results are included in Appendix G for each KGRA. The data in Appendix G do not take into consideration the percent of federal ownership of the KGRA's (see Section 3.3) and the 50 percent of royalties returned to the states. These factors are incorporated into Exhibit 4-1.

4.2 Conclusions

The intent of this study was to predict the value of increased royalties that could be accrued by the federal government as a result of DOE Geothermal Program accomplishments. The rationale was that, by reducing the barriers to geothermal power development the DOE R&D program will encourage further geothermal development. Some of this development will be on federal lands and therefore will generate royalties. The question addressed by this study is whether these royalties would be sufficiently large to return the government's "investment" in geothermal energy.

Obviously, the innumerable factors that will impact the future expansion of the U.S. geothermal power base would be impossible to predict. Therefore, this study was conducted with a set of fairly simple assumptions. These assumptions were specifically selected to present an optimistic picture of incremental royalties that could be generated from government R&D. For example, the field development scenario of 50 MWe every 3 years once construction began in an area is very ambitious. It results in more royalties accruing at a faster rate than would less optimistic scenarios.

Based on the assumptions in this study, the incremental royalties accruing to the Federal Government resulting from the success of its geothermal program are only a small fraction of the costs of the R&D program. For the base case assuming a discount rate of 10 percent, the incremental royalty was $34.7 million through 2010. Assuming a Geothermal Program budget of $20 million from 1987 through 2000 yields a discounted expenditure of $162 million -- a return of only 21 cents on the dollar. Even in the nondiscounted case, an estimated

EXHIBIT 4-1: RESULTS OF INCREMENTAL ROYALTY ANALYSIS (No Transmission Costs)

DISCOUNT RATES

YEAR	NONE 0%	BASE CASE 10%	SENSITIVITY CASES 5%	7.5%	12.5%
0	$ 0	$ 0	$ 0	$ 0	$ 0
1	765,112	522,582	629,460	572,915	477,656
2	3,773	2,343	2,956	2,628	2,094
3	2,302,094	1,299,472	1,717,858	1,491,668	1,135,554
4	955,675	490,413	679,181	576,038	419,028
5	38,525	17,972	26,075	21,601	15,015
6	5,178,179	2,196,053	3,337,900	2,700,853	1,793,925
7	7,046,962	2,716,909	4,326,223	3,419,143	2,170,085
8	1,778,667	623,412	1,039,950	802,789	486,874
9	10,672,103	3,400,461	5,942,626	4,480,727	2,596,688
10	18,166,013	5,262,047	9,633,824	7,094,954	3,928,953
11	10,714,047	2,821,343	5,411,322	3,892,558	2,059,768
12	27,444,927	6,570,097	13,201,479	9,275,453	4,690,015
13	31,338,646	6,820,202	14,356,595	9,852,463	4,760,361
14	23,076,723	4,565,607	10,068,298	6,748,857	3,115,884
15	38,778,494	6,974,653	16,113,265	10,549,663	4,654,205
16	35,038,727	5,729,112	13,866,014	8,867,220	3,738,096
17	25,637,896	3,810,910	9,662,653	6,035,498	2,431,263
18	46,660,012	6,305,194	16,748,255	10,218,028	3,933,162
19	43,931,751	5,396,839	15,018,064	8,949,367	3,291,721
20	33,936,610	3,789,978	11,048,786	6,430,930	2,260,271
TOTAL	363,464,936	69,315,599	152,830,785	101,983,353	47,960,617
50% FEDERAL SHARE	181,732,468	34,657,799	76,415,392	50,916,677	23,980,308
R&D EXPENSES ($20 MILLION/ YEAR 1987-2000)	280,000,000	162,067,124	207,871,459	182,516,805	145,395,132

R&D expenditure of $280 million resulted in only $181 million in increased revenue.

The methods of analysis used to calculate these incremental royalties are admittedly crude, but, as described earlier, they probably set an upper bound to the value of incremental royalties. A more refined and more rigorous analysis would only result in less incremental royalties.

This does not mean that the federal government should not conduct geothermal research. The government is not a private investor -- it does not need to generate a return on its spending. R&D is funded with the taxpayer's money, to benefit the nation as a whole, not to return money to the federal treasury.

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