GEOPRESSURED-GEOTHERMAL RESOURCE DEVELOPMENT ON PUBLIC FREE SCHOOL LANDS

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

The General Land Office of Texas
Bob Armstrong, Commissioner

RPC, Inc.
Austin, Texas

July 1979

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *eb*

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

This report was prepared with the support of the U.S. Department of Energy (DOE) Grant No. DE-FG05-78ET28464. However, any opinions, findings, conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the view of DOE.

CONTENTS

	<u>Page</u>
1. Introduction	1
Purpose of the Study	1
Study Area	2
Research Approach	2
Recommendations	7
2. Financial, Environmental, and Legal Aspects of Resource Development	9
Description of Current Technology	9
Postulated Production Scenarios	12
Financial Analysis	15
Ecological Analysis	22
Social and Economic Analysis	29
Legal Analysis	31
3. Findings and Recommendations	37
Financial	37
Ecological	38
Social and Economic	40
Legal	42
4. Summary of Draft Rules	45
Appendix A: Draft Rules and Regulations to Govern Resource Development on PFSL	47
Appendix B: Lease Forms	59
Geothermal Bibliography	73
Glossary	97

MAPS, FIGURES, AND TABLES

Page

Maps

1	Potential Geopressured-Geothermal Fairways, Frio Formation, Texas Gulf Coast	3
2	Brazoria Geothermal Study Area	4
3	Matagorda Geothermal Study Area	5
4	Corpus Christi Geothermal Study Area	6

Figures

1	Flash Steam and Binary Cycle Power Plants	11
2	Flow Diagram of Financial Analysis	16
3	Typical Geopressured-Geothermal Reservoir Configurations	26

Tables

1	Geothermal Technical Papers	10
2	Assumed Values of Fairway Parameters: Optimistic With Deep ReInjection Scenarios	13
3	Major Assumptions of Financial Analysis Base Case Scenarios	18
4	Field Development Financial Analysis Scenario Summaries	20
5	Activities Associated With Geothermal Development and Ecosystems in Which They May Occur	23
6	Guide to Proposed Draft Rules and Regulations to Govern Resource Development on PFSL	46

ACKNOWLEDGMENTS

RPC, Inc. wishes to acknowledge the efforts of the many contributors to this study. The project was managed by Ann Orzech. The principal researchers were Gail McDonald, legal analysis; Ed Campbell and Alice Cheng, financial analysis; Andrew Reed (team leader), William Brogden, Chris Caran, Denise Girard, and Bruce Snyder, ecological analysis; Leah Pagan and Barbara Haefeli; socioeconomic Analysis. Additional research participants were J. Robert Anderson, Chris Kuykendall, and Vicki Bernstein. The technical editor was Nancy Grona. Production assistance was provided by Kyle Pierce and Lori Snyder. The cover was designed by Kyle Pierce.

Technical assistance and review was provided by Dr. Stephen McDonald, Chairman, Department of Economics, The University of Texas at Austin.

Review of draft working papers and manuscripts was conducted by the Texas General Land Office, The Center for Energy Studies, and The Bureau of Economic Geology (The University of Texas at Austin), and by interested individuals and organizations. We appreciate their thoughtful comments and suggestions.

Ronald T. Luke
President
RPC, Inc.

1. INTRODUCTION

PURPOSE OF THE STUDY

The Geothermal Resources Act (Section 141.001 et seq. Natural Resources Code), passed by the Texas Legislature and signed into law in 1975, states that "the rapid and orderly development of geothermal energy and associated resources located within the State of Texas is in the interest of the people of the State of Texas." The same Act authorizes the commissioner of the General Land Office of Texas to "provide for the orderly exploration of land that belongs to the Permanent School Fund of Texas" and to "issue permits and charge reasonable fees for the permits" in order to facilitate and encourage the rapid and orderly development of geothermal and associated resources . . ." The Act further authorizes the School Land Board, on direction of the commissioner, to lease lands belonging to the Permanent School Fund of Texas and "to set the terms and conditions of leases" and to "adopt rules relating to exploration, development, and production of geothermal energy and associated resources as the board determines in the best interest of the state."

Some of the areas to be identified as potential areas of resource production in previous analyses by the Center for Energy Studies (CES) and the Bureau of Economic Geology (BEG) at The University of Texas at Austin, include substantial portions of nearshore Public Free School Lands (PFSL). Subsequently, this study was formulated to make recommendations to the commissioner and the School Land Board in order to encourage and promote the development of the geopressured-geothermal resource on PFSL so that the mandate of the Geothermal Resources Act might be fulfilled. These recommendations were to be based on analyses of the financial feasibility of resource development, the potential environmental effects, and associated legal issues. In addition, the recommendations were to include draft rules and regulations concerning the leasing, exploration, and production of the resource on PFSL.

The recommendations from this study are designed to contribute to rapid and orderly resource development by providing an initial framework for development on PFSL in an environmentally sound manner, thus reducing uncertainty for the field developer. Consequently, if and when the time comes for exploration and development of the resource on PFSL, the field developer will know what to expect in terms of leasing and permitting procedures, and he will know how to proceed.

The geopressured-geothermal resource is as yet largely unproven, and commercialization remains at least a few years away. The values of key resource variables such as temperature, depth, porosity, fairway extent, and boundaries are presently unknown; these variables will determine the extent of probable resource development, its financial feasibility, and its effects. As development of the resource occurs, the

associated technology will also develop and change. Thus, as more information concerning the resource becomes available, the recommendations should be reviewed for continued applicability and amended if necessary to reflect the expanded knowledge.

STUDY AREA

Five sites in the Texas coastal area, shown on Map 1, have been mapped as possible geopressured-geothermal fairways. These fairways do not indicate precise reservoir boundaries; rather, they depict general areas of potential geopressured-geothermal resource production. They were selected on the basis of limited data concerning formation thickness, porosity, permeability, and temperature. Some of the geopressured-geothermal reservoirs found within the fairways may yield economically recoverable quantities of usable heat energy and methane. Economic production is considered to be most probable from the Brazoria Fairway.

Three of the fairways (Brazoria, Matagorda, and Corpus Christi) contain substantial portions of state-owned lands within their boundaries, as indicated on Maps 2, 3, and 4. PFSL acreage in each fairway is estimated to equal the following:

Brazoria Fairway: 79,205 acres (124 square miles)

Matagorda Fairway: 33,920 acres (53 square miles)

Corpus Christi Fairway: 84,480 acres (132 square miles)

For purposes of this analysis, the study area consists of PFSL within the Brazoria, Matagorda, and Corpus Christi Fairways.

RESEARCH APPROACH

The study's findings and recommendations are based upon analysis of the following:

1. Financial and economic feasibility of geopressured-geothermal resource development
2. Possible ecological, social, and economic impacts of resource development on PFSL
3. Legal issues associated with resource development

Map 1

POTENTIAL GEOPRESSURED-GEOTHERMAL FAIRWAYS,
FRIO FORMATION, GULF COAST OF TEXAS

Source: D.G. Bebout et al., 1978, Frio Sandstone Reservoirs in the Deep Subsurface Along the Texas Gulf Coast, Report of Investigations No. 91, Bureau of Economic Geology, The University of Texas at Austin.

Map 2

BRAZORIA GEOTHERMAL STUDY AREA

Source: U.S. Department of Energy, 1978, Geopressured-Geothermal Drilling and Testing Plan - General Crude Oil - Dept. of Energy, Pleasant Bayour No. 1 Well, Brazoria Co., TX. Nevada Operations Office.

Map 3

MATAGORDA GEOTHERMAL STUDY AREA

Source: D.G. Bebout et al., 1978, Frio Sandstone Reservoirs in the Deep Subsurface Along the Texas Gulf Coast, Report of Investigations No. 91, Bureau of Economic Geology, The University of Texas at Austin.

Map 4

CORPUS CHRISTI GEOTHERMAL STUDY AREA

Source: D.G. Bebout et al., 1978, Frio Sandstone Reservoirs in the Deep Subsurface Along the Texas Gulf Coast, Report of Investigations No. 91, Bureau of Economic Geology, The University of Texas at Austin.

The results of the analysis are summarized in Chapter 2 and are discussed in detail in a series of four technical papers which accompany this volume. Existing rules of the General Land Office (GLO), the School Land Board (SLB), and the Railroad Commission of Texas (RRC) were reviewed in light of the above analysis and were discussed with the agencies.

The study's recommendations resulted from this analytical and review process; they are listed below and discussed in Chapter 3. The preliminary draft rules and regulations to govern resource development on PFSL are presented in Appendix A; the accompanying forms and model lease are found in Appendix B.

In the formulation of preliminary draft rules, emphasis was placed on adapting present rules to the greatest possible extent because of two critical aspects of geopressured-geothermal resource development on PFSL. First, hard information about the exact characteristics of the resource and experience with the resource through all stages of development currently do not exist. Second, uniformity of rules governing the development of Public Free School Lands (PFSL) and adjacent private lands is important if development of the resource is to be encouraged. To ensure maximum consistency between rules governing development on public and private lands, current RRC geothermal rules in particular were examined for applicability.

Existing GLO, SLB, and RRC rules were found to be generally sufficient to manage initial resource development on PFSL. The draft rules recommended for adoption by the SLB are thus adaptations of existing rules; the specific source is cited in Appendix A after each rule.

During the study, steps were taken to ensure the contributions of interested and affected parties. First, a series of working papers which summarized the results of the ongoing analyses was prepared and distributed for review to state agency staffs, representatives of private industry, and interested individuals. Second, interviews with industry representatives were used to provide a source for and a check on assumptions and premises of the financial analysis. Finally, during two public meetings, concerned parties were given the opportunity to comment on the study process and results. Comments and suggestions received during the public meetings have been incorporated into this report and accompanying technical papers.

RECOMMENDATIONS

Based on the analyses undertaken during this study, the following recommendations are made. These recommendations are designed to encourage and promote the development of the geopressured-geothermal resource on PFSL.

1. A financial evaluation of tracts proposed for lease should be undertaken prior to lease to determine minimum bonus payments and royalty rates.

2. The General Land Office should conduct site-specific environmental assessments of the first several geothermal energy and associated resources projects (from drilling through production) proposed on PFSL to determine the risks of development and the adequacy of plans for managing geological and ecological impacts.
3. The General Land Office should conduct site-specific social and economic assessments of the first several geothermal energy and associated resources projects (from drilling through production) proposed on PFSL to determine specific risks associated with resource development.
4. The School Land Board's initial rules on the development and production of geothermal energy and associated resources at a minimum should be consistent with rules of the Railroad Commission of Texas.
5. To facilitate the rapid and orderly development of geothermal energy and associated resources, future oil and gas leases should be changed such that by-products of geothermal energy and associated resources are specifically excluded from the definition of "gas."

The recommended formal financial, environmental, and socioeconomic analyses represent a change in practice from present oil and gas leasing procedures. Methods and procedures which may be used to perform the analyses are discussed in Technical Paper Nos. 2 (financial), 3 (social and economic), and 4 (ecological).

2. FINANCIAL, ENVIRONMENTAL, AND LEGAL ASPECTS OF RESOURCE DEVELOPMENT

The technology likely to be employed in developing and utilizing the geopressured-geothermal resource, and the level of resource production which is likely to be achieved, affect both the financial feasibility and potential effects of resource development. These factors determine to a large degree the activities which occur during development and the costs. The technology which can reasonably be expected to be utilized and potential resource production scenarios were thus considered. The results of the analysis formed the basis for the ensuing detailed examination of the financial feasibility of geopressured-geothermal resource development; the potential ecological, social, and economic effects of such development; and the associated legal issues.

In this chapter current resource development technology and postulated production scenarios are briefly described, and the results of the financial, environmental and legal analyses are summarized. The latter analyses are further detailed in a series of four technical papers, as indicated in Table 1.

DESCRIPTION OF CURRENT TECHNOLOGY

The review of current technology indicated that conventional oil and gas exploration, development, and production techniques can generally be used in geopressured-geothermal energy production. The procedures, equipment, and personnel are essentially the same type as employed in oil and gas exploration and production. The primary difference is that larger production pipe will be necessary for the large quantities of brine that would be produced.

In contrast to exploration and production technology, utilization technology for geothermal energy is not as advanced. A distinguishing feature of geothermal energy is its site-specific nature. It is difficult to transport economically the brine over a great distance without losing the heat content of the brine. Consequently, the developer and user become tied to the specific characteristics of the resource and its site.

Potential uses for the geopressured-geothermal resource include generation of electric power, Frasch technique for sulfur production, process heat applications, coal desulfurization and preparation, lumber and concrete products kilning, makeup for coal slurry pipelines, hydroponics greenhousing, grain drying, and space heating and cooling.

Table 1
GEOHERMAL TECHNICAL PAPERS

<u>Paper Number</u>	<u>Title</u>
1	An Analysis of Legal Issues Related to Geopressured-Geothermal Resource Development
2	An Economic and Financial Evaluation of Geopressured-Geothermal Resource Development
3	Geopressured-Geothermal Energy Development: Social and Economic Issues
4	An Analysis of Ecological Effects of Geopressured-Geothermal Resource Development

Figure 1

FLASH STEAM AND BINARY CYCLE POWER PLANTS

FLASH STEAM POWER PLANT

BINARY CYCLE POWER PLANT

The widest application of geothermal energy in the United States is presently the generation of electric power. Indeed, early analyses of the geopressured-geothermal resource in Texas by CES emphasized use of the resource for electric power generation. Thus, the financial, environmental, and legal analyses assumed electric power generation as the end-use. The same analyses, of course, could be applied to other uses.

Specifically, two types of electric power production processes have been proposed (Figure 1). The first is the flash steam process, whereby part of the geothermal brine is "flashed" to steam by reducing the pressure of the brine to a predetermined point. The resulting steam is passed through a low-pressure expansion turbine which is connected to an electric generator, and the remaining fluid is discarded, most probably by reinjection into disposal wells. Fluid heat recovery can be enhanced by multiple flashings.

The second method is the secondary (or binary) working fluid process in which a heat exchanger is used to transfer heat from the geothermal brine to a secondary fluid. The secondary fluid, such as freon, isobutane, or propane, has a boiling point significantly below the temperature of the brine. As heat is transferred, the fluid is vaporized and passed through an expansion turbine connected to an electric generator. As with the flash steam process, the spent brine is then discarded.

The geopressured-geothermal brine is expected to contain substantial portions of dissolved methane gas. The methane gas is likely to be separated from the brine by the field developer prior to the sale of the brine for its heat content. This process would probably occur at a site adjacent or close to the electric power generation facility.

POSTULATED PRODUCTION SCENARIOS

A production scenario was postulated for each of the fairways containing substantial portions of PFSL. For each scenario, the following elements were described: the fairway, plant, and well locations for wells on and adjacent to PFSL; associated plants, production schedules, and associated resource development and production activities. These scenarios are based on work performed at the Center for Energy Studies (CES), University of Texas at Austin (Zinn, 1977b). To ensure that all types of environmental and socioeconomic effects associated with geothermal development were identified, the scenarios chosen represent the maximum projected development that might occur based on the potential productivity of the brine-holding sand reservoirs that underlie the fairways.

Assumed values of fairway parameters, reflecting maximum production levels, are shown in Table 2. A maximum flow rate of 128,838 barrels per day (bbls/day) per

Table 2

**ASSUMED VALUES OF FAIRWAY PARAMETERS:
OPTIMISTIC WITH DEEP REINJECTION SCENARIOS**

<u>Parameter</u>	<u>Fairway</u>		
	<u>Brazoria</u>	<u>Matagorda</u>	<u>Corpus Christi</u>
<u>Reservoir Characteristics</u>			
Temperature	350°F	350°F	350°F
Porosity	22%	20%	20%
Permeability (millidarcies)	50	5	5
Percent fluid recovery (with deep reinjection)	45%	15%	15%
Gas content (SCF/bbl)	50	50	50
Fairway extent (square miles)	908	353	632
Fraction of fairway producible	100%	100%	100%
<u>Wells</u>			
Success ratio in drilling producible wells	50%	50%	50%
Use of unsuccessful production wells for disposal wells	100%	100%	100%
Flow rate per well (bbls/day)	128,838	10,931	10,931
Support area per well (square miles)	11.45	4.01	4.01
<u>Fuel and Electric Generating Plants</u>			
Life of facilities (years)	60	60	60
No. production wells per plant	3	9	9
No. disposal wells per plant	6	18	18
Electrical generating capacity per plant (megawatts)	48.3	12.3	12.3
Gas flow capacity per plant (SCF/yr)	7.05×10^9	1.80×10^9	1.80×10^9
<u>Fairway Development</u>			
No. plants:			
Per fairway	16	6	8
Per fairway fed by wells on PFSL	6	4	8
Production wells:			
Per fairway	48	54	72
In PFSL	8	16*	39
Adjacent to PFSL	10	6**	17
No. disposal wells per fairway	96	108	144
Electrical generating capacity per fairway (megawatts)	773.03	73.78	98.38
Gas flow capacity per fairway (SCF/yr)	1.13×10^{11}	1.08×10^{10}	1.44×10^{10}

* Of 16 wells, 9 are assumed to be in eastern portion, and 7 in western portion.

**Of 6 wells, 2 are assumed to be in eastern portion, and 4 in western portion.

Source: C.D. Zinn. 1977. Operations Research and Systems Analysis of Geothermal-Geopressured Resources in Texas - Final Report. Research Report No. 10, Center for Energy Studies, The University of Texas at Austin.

well is assumed for the Brazoria Fairway, and a maximum flow rate of 10,931 bbls/day per well for the Matagorda and Corpus Christi Fairways is assumed. The time required to develop a field and construct a power facility is assumed to be three years (Zinn, 1977b). Of these, two years are required for actual construction of the power/fuel plant.

The production scenarios postulated in this study purposely represent optimistic production levels to aid in environmental impact identification. Recent conversations with staff of both the CES and Bureau of Economic Geology (University of Texas at Austin) suggest, however, that sufficient resources to sustain the postulated maximum production levels probably do not exist on the three selected fairways, especially on the state-owned portions.

During the course of their studies, for example, the CES and BEG have jointly established criteria for an "ideal" reservoir for commercial geopressured-geothermal production. Those criteria included the following parameters: (U.S. Department of Energy, 1978c)

1. Minimum reservoir volume: 3 cubic miles
2. Minimum fluid temperature: 300° F
3. Minimum permeability: 20 millidarcies
4. Salinity of water: range from less than 20,000 to 80,000 parts per million (ppm)
5. Minimum initial bottom hole pressure: 10,000 pounds per square inch (psi)
6. Production rate (per well): 20,000-40,000 barrels per day

The areas that appear to best meet these criteria are the upland (not state-owned) portions of the Brazoria Fairway.

The optimistic production levels assumed in the production scenarios are suitable for identification of maximum potential environmental impacts. However, the postulation of reasonable production levels is more appropriate for an analysis of the financial feasibility of development of a "typical" field and power plant facility. Thus, for the financial analysis, a more reasonable production rate of 40,000 bbl/day per well and a total daily brine flow rate of 432,000 bbl/day to fuel a 25-megawatt power plant are assumed.

FINANCIAL ANALYSIS

The purpose of the financial analysis was to provide the School Land Board and General Land Office of Texas with an analytical framework for analyzing the effect of leasing policies on the financial feasibility of geopressured-geothermal field development. Such an analytical framework was developed and was applied to nine sets of development assumptions. The analytical framework, its applications, and results are summarized below.

DISCUSSION OF ANALYTICAL FRAMEWORK

The analytical system was developed from the perspective of the field developer; specifically, it represents a tool for determining how changes in royalty rates and lease bonus payments will affect the field developer's after-tax rate of return. The system consists of three distinct computer models, as indicated in Figure 2.

The first, the Field Development Model, utilizes engineering and cost data as its primary inputs and provides scheduled capital investment and operating expense estimates, and production parameters to the two remaining models. The second model is the Power Plant Model. It uses as inputs information from the Field Development Model, such as power plant capacity, capital costs, and heat rate, as well as assumptions concerning financial and tax variables. Iterations of this program solve for the maximum price which the power plant can pay for the brine. The brine price, in turn, determines that part of the revenue stream of the field developer originating from use of the heat content of the brine. As a result, both the price and the amount paid for the brine by the utility are data inputs to the third part of the system. Both of these models were created as part of this study using commercially available time-sharing systems.

The third model is a commercially available software package that was originally developed to provide a financial evaluation of oil and gas fields, and which was modified slightly for use for geothermal field evaluation. It receives as data inputs revenue from brine sales from the Power Plant Model, cost schedules and production data from the Field Development Model, and assumptions concerning natural gas prices and taxation and financial variables. The final output is a financial analysis of field development, including a calculation of revenues from methane sales and listings of detailed cash flows, net present value, payout period, and various rates of return. Most important in terms of this study, the model permits a sensitivity analysis of the after-tax internal rate of return to a range of royalty rates and lease bonuses.

Figure 2

FLOW DIAGRAM OF FINANCIAL ANALYSIS

MODEL SIMULATIONS

A base case scenario of geopressed-geothermal resource development was developed utilizing detailed engineering data prepared for CES by Brown and Root, Inc. and Dow Chemical Company (Brown and Root, 1976; Dow Chemical Company, 1976). Key assumptions, listed in Table 3, include a 40,000 bbl/day production well flow rate, total brine production equal to 432,000 bbl/day, and disposal of the produced brine into geologic formations above the producing zone but below fresh-water aquifers (shallow reinjection). All costs were converted to and the analysis performed in terms of constant 1978 dollars. The system does have the capability, though, to perform the analysis given any assumed inflation rate.

Eight additional simulations were performed, which are variations on the base case. These cases are:

1. Reinjection of brine into producing formation. This case takes into account the higher capital and operating costs associated with deep disposal of brine. A major uncertainty associated with geothermal development concerns the potential life of producing wells.
2. Redrilling half of producing wells every six years. By assuming a significantly lower well life than in the base case, this case examines the effects of reduced well life and declining production.
3. Well spacing of five miles. Wider well spacing would increase capital outlays for the transmission-line and brine-disposal pipeline systems. In addition, technological difficulties may be encountered in maintaining brine temperature over a long transmission line distance.
4. Methane priced at the equivalent of fuel oil. A higher price for the methane was assumed in this case in order to determine the effect of natural gas prices on the financial feasibility of field development.
5. Full use of Investment Tax Credit by field developer. It was assumed that the field developer/operator would have sufficient taxable income from other operations to fully utilize the tax credit generated by geothermal production in order to discover whether such utilization would enhance project feasibility.
6. Full use of Investment Tax Credit by both the field developer and the power plant operator. Provided that the power plant is not operated by a utility, current tax provisions designed to encourage geothermal development allow a higher investment tax credit for power plant outlay. The effects of full use of tax credits by the field developer and a nonutility power plant operator are considered in this case.

Table 3

MAJOR ASSUMPTIONS OF FINANCIAL
ANALYSIS BASE CASE SCENARIO

Field Parameters

Total daily brine flow rate (bbl/day)	432,000
Production well flow rate (bbl/day)	40,000
Disposal well flow rate (bbl/day)	20,000
Life of production well (years)	30
Well spacing (miles)	0.5
Methane content (SCF/bbl)	50
Probability of drilling success	50%

Power Plant Parameters

Plant type	single flash
Plant capacity (megawatts)	25
Plant availability	90%
Annual heat consumption (bil BTU)	6,500

Other Parameters

Revenue for methane per MCF	\$2
Annual escalation on methane price	3.4%
Lease bonus payments per acre	\$10-50
Royalty rate on production	0-25%

7. Five-year royalty holiday. A royalty holiday represents a period of time during which the lessee is relieved of the obligation of tendering payment of a production royalty. Such a royalty holiday may enhance project rate of return and mitigate risk associated with potential life of the producing wells.
8. Lease bonus payments substantially higher than assumed in other cases. Bonus payments at the level assumed in the other cases proved to have negligible financial impact. Payments are increased in this case in order to determine whether the financial impact remains negligible with substantially higher payments.

Table 4 summarizes these model simulations and highlights the sensitivity of the after-tax internal rate of return to royalty rates and lease bonus payments. Assuming a royalty rate of 12.5 percent, the after-tax rate of return ranges from 7.5 percent to 21.4 percent. The lowest returns occurred in the cases of wide well spacing and deep disposal of brine into the producing formation; the highest occurred under either of the assumptions that methane be priced at the heating value equivalent of No. 2 fuel oil (formula used for pricing of natural gas supplies offered by Mexico) or that other operations of a nonutility power plant operator and the field developer be such that full use could be made of the Investment Tax Credit.

The results of scenario 5 (Fuel Oil-Gas Price Equivalent) are particularly relevant because they highlight the sensitivity of the profitability of geopressured-geothermal field investment to the price of natural gas. This finding is consistent with prior work performed by CES and is important, in part, because of the classification of geopressured brine from wells spudded before 1990 as an alternative fuel under the Power Plant and Industrial Fuel Use Act (Federal Register, Vol. 44, No. 97). A special market might thus develop for alternative fuels as defined under the Act such that users of such fuels may be willing to pay a premium price. Such a price structure is higher than that assumed even in Scenario 5 and would seem to assure the field developer of profitable operations.

EFFECTS OF LEASING POLICIES

The simulations described above indicate that while the after-tax rate of return is more sensitive to capital costs and the expected price of methane, the rate of return is nevertheless influenced by the royalty rate. On the average, a one percentage point change in the royalty rate resulted in a 0.17 percentage point change in the rate of return. Alternatively, the rate of return will change by one percentage point on average for every six percentage point change in the royalty rate. On the other hand, payments substantially greater than the minimum presently accepted for oil and gas leases have a negligible financial impact.

Table 4

FIELD DEVELOPMENT FINANCIAL ANALYSIS SCENARIO SUMMARIES

Scenario	Power Plant Rate of Return (%)	After Tax Rate of Return Sensitivity to Royalty Rate (%) (Lease Pmt. = \$30/Acre)				After Tax Rate of Return Sensitivity to Lease Payment (%) (Royalty Rate = 12.5%)			
		0%	12.5%	25%	Range	\$10	\$30	\$50	Range
1. Base Case	14.80	19.52	17.44	15.27	4.3	17.45	17.44	17.43	.02
2. Deep Disposal (into producing formation)	14.80	11.52	9.64	7.47	4.1	9.64	9.64	9.63	.01
3. Redrill Half of Wells Each 6 Years	14.80	17.17	15.01	12.79	4.4	15.02	15.01	15.0	.02
4. Well Spacing of 5 miles	14.80	8.83	7.45	5.97	2.9	7.66	7.56	7.45	.21
5. Fuel Oil - Gas Price Equivalent	14.80	23.90	21.42	18.85	5.1	21.43	21.42	21.41	.02
6. Full Use of ITC by Field Developer	14.80	19.84	17.71	15.50	4.3	17.72	17.71	17.70	.02
7. Full Use of ITC by Field and Power Plant Developer	22.57	23.94	21.38	18.73	5.2	21.39	21.38	21.37	.02
8. Royalty Holiday (5 year)	14.80	19.52	18.54	17.44	2.1	18.55	18.54	18.53	.02
		Lease Payment = \$525/Acre				\$250	\$525	\$800	
9. High Lease Payments	14.80	19.23	17.18	15.05	4.2	17.04	17.18	17.32	.28

NOTES:

Power plant capacity - 25 megawatt
 Power plant type - single flash
 Brine price per MMBTU = \$.80; per bbl = 3.31¢ except in Case 7 where price per MMBTU = \$1.74 and price per bbl = 4.14¢
 Power plant investment tax credit = 10% except in Case 7 where a 20% rate was assumed
 Initial natural gas price = \$2.00/MCF escalated at 3.4% annually except in Case 5 where a price of \$2.80 was assumed
 Field rate of production decline - none
 Field extent (Case 4) - 192,000 acres
 Field extent (all others) - 1,920 acres

Compared with the base case scenario, a five-year royalty holiday reduces the payout period by a half year and results in a decreased sensitivity of the rate of return to the royalty rate. More significantly, the higher the royalty rate, the greater the impact of a holiday on the rate of return. A five-year holiday assuming a royalty rate of 25 percent for the project's remaining life results in an increase in the rate of return from 15.3 percent to 17.4 percent; the same holiday assuming a subsequent royalty rate of 12.5 percent results in an increased rate of return from 17.4 percent to 18.5 percent.

Table 4 indicates that a five-year royalty holiday, followed by a 25 percent royalty rate, will yield the same after-tax rate of return to the field developer as a 12.5 percent royalty rate with no royalty holiday. From the perspective of the field developer, the present values of the two royalty payment streams, discounted at the after-tax rate of return, are approximately equal. A governmental unit, however, may use a lower interest rate to discount income streams to present value, because it operates in a different investment and borrowing climate than private industry. From the perspective of the field developer, the present values of the two royalty payment streams, discounted at the after-tax rate of return, are approximately equal. A governmental unit, however, may use a lower interest rate to discount income streams to present value, because it operates in a different investment and borrowing climate than private industry. From the perspective of the SLB, then, the present value of royalties obtained assuming a five-year royalty holiday with a 25 percent royalty rate is approximately \$8.6 million greater than the present value of royalties obtained assuming a 12.5 percent royalty rate and no holiday, given a discount rate of ten percent.

It should be noted that it is unclear whether the royalty income foregone as a result of a royalty holiday would constitute a grant of public money as defined by Article 3, Section 51 of the Texas Constitution. This Article prohibits the giving or granting away of public money. The SLB has never granted a royalty holiday for oil and gas leases, and there is no case law on point. It is recommended that the SLB seek an Attorney General's opinion on this point before granting such a royalty holiday.

The present lack of experience and uncertainties associated with the geopressured-geothermal resource in Texas precluded recommendations concerning lease bonus versus royalty bidding. Competitive bidding for oil and gas leases on PFSL is most often done on the lease bonus payment rather than on the royalty rate. There are advantages and disadvantages to both bonus and royalty bidding. Bonus bidding results in a lump-sum front-end payment which is subsequently considered to be a sunk cost and thus does not affect subsequent exploration, development, and production decisions. The disadvantages of bonus bidding are that the lessee assumes the full burden of risk or uncertainty, and, further, that bonus bidding may result in substantial initial operator capital requirements. Royalty bidding results in a sharing of risk with the lessor and reduced capital requirements. In the case of geopressured-geothermal development, these advantages may encourage development, at least until developers have more experience with the resource. The major disadvantage of royalty bidding is that it may lead to early reservoir abandonment.

Likewise, no recommendations are made concerning the length of time appropriate for the primary lease term. The SLB is presently setting three-year primary lease terms for many leases on PFSL; the term on the federal Outer Continental Shelf is five years. Abuses of the primary term tend to be minimized in the case of bonus bidding; the operator who pays a substantial bonus has an incentive to drill quickly because of the capital costs associated with the bonus payment.

Several caveats bear repeating at this point. While the best available engineering data and cost estimates were used in this analysis, considerable uncertainty exists concerning resource and reservoir characteristics. Furthermore, because there is not presently a field in production in Texas, cost estimates of the development and production phases are subject to wide error. Such estimates will be refined and revised as the resource itself is better defined and as production is actually undertaken. At that point, a financial analysis reflecting the revised information could be easily performed using the analytical framework developed as part of this study.

ECOLOGICAL ANALYSIS

OVERVIEW

The purpose of the ecological analysis was to identify and discuss the ecological impacts that could result from geopressured-geothermal energy production on PFSL. The analysis involved the identification of resource development activities, a determination of the ecological systems in which these activities would likely take place, and an identification of the types of impacts associated with the activities in the various ecosystems. Those activities that are unique to geopressured-geothermal resource development were distinguished from those that are similar to other types of development in order to focus the analysis on factors not previously studied extensively. Finally, methods which may be used to assess environmental impacts of geopressured-geothermal resource development were discussed.

The first step in determining the ecological effects of geothermal resource production is understanding the activities that create those effects. From a review of existing literature on geothermal and related oil and gas development, a list of typical development activities was compiled. The activities involved at any one site, of course, will differ, depending largely on the ecological system in which the site is located -- particularly whether the site is an upland or marine location. Table 5 shows the activities that would be required to develop a site located in any of the nine ecosystem types occurring within the three geothermal fairways.

These activities are generally identical or similar to typical oil and gas development activities; many have been extensively studied in previous analyses of both oil

Table 5

**ACTIVITIES ASSOCIATED WITH GEOTHERMAL DEVELOPMENT
AND ECOSYSTEMS IN WHICH THEY MAY OCCUR**

<u>Activities</u>	<u>Ecosystem Types</u>								
	<u>I</u> <u>Marine</u>	<u>II</u> <u>Littoral</u>	<u>III</u> <u>Insular/ Eolian</u>	<u>IV</u> <u>Deeper Estuarine</u>	<u>V</u> <u>Wetland/ Shallow Estuarine</u>	<u>VI</u> <u>Grassland</u>	<u>VII</u> <u>Woodland (Riparian)</u>	<u>VIII</u> <u>Woodland (Upland)</u>	<u>IX</u> <u>Artificial/ Unstable</u>
Road Construction			X		X	X	X	X	X
Bridge Construction			X	X	X		X		X
Dredging	X	X	X	X	X	X	X		X
Spoil Disposal and Landfilling	X	X	X	X	X	X	X	X	X
Bulkhead Construction	X	X	X	X	X		X		X
Plant Construction			X			X	X	X	X
Plant Operation and Maintenance			X			X	X	X	X
Geophysical Surveys	X	X	X	X	X	X	X	X	X
Levee Construction			X		X		X		X
Wellsite Construction	X	X	X	X	X	X	X	X	X
Drilling	X	X	X	X	X	X	X	X	X
Production	X	X	X	X	X	X	X	X	X
Brine Storage (Emergency)	X	X	X	X	X	X	X	X	X
Brine Disposal (Reinjection)	X	X	X	X	X	X	X	X	X
Electrical and Telephone Line Construction	X	X	X	X	X	X	X	X	X
Pipeline Construction	X	X	X	X	X	X	X	X	X

and gas and geothermal production. Furthermore, site-specific techniques for location, design, and construction, which can minimize the ecological impacts of these activities, have been identified.

The ecological analysis did identify certain aspects of these activities as unique to geothermal resource development:

1. Well drilling - particularly the release of brine in the event of a blowout; the potential for subsidence
2. Production - particularly accidental brine discharges associated with production well blowout or disposal well failure; the potential for subsidence, fault activation, and enhanced seismicity; the potential for subsurface contamination of water, hydrocarbon, and mineral reservoirs
3. Pipeline operation - failure of pipeline and accidental brine discharges
4. Plant operation - particularly accidental discharges of brine; noise, air pollution, and water consumption
5. Brine storage - need for temporary brine storage facilities and problems associated with their design and use

The analysis thus focused on these "unique" aspects and indicated that the most serious potential ecological effects concern (1) subsidence, (2) fault activation and enhanced seismicity, (3) subsurface contamination of water, hydrocarbon, and mineral reservoirs, and (4) accidental surface brine discharge as a result of a blowout during well drilling.

Geothermal resource development is new to the Texas coast. Consequently, in virtually every aspect of the analysis, information specific to Texas geothermal resource development was found to be inadequate. Of necessity, the potential for such effects as subsidence, fault activation, brine discharges, excessive noise, gas emissions, and water consumption were identified largely by analogy to other geothermal production regions and to oil and gas production. These analyses should be refined as more Texas-specific geothermal resource data and production experience become available.

DISCUSSION OF MAJOR POTENTIAL EFFECTS

Subsidence

Subsidence is potentially a serious consequence of geothermal resource development along the Texas coast. The probability that subsidence will occur, the areal

extent, the magnitude, and the rate of subsidence depend on a number of factors, including the size and geologic properties of the geothermal reservoir and the geologic properties of strata surrounding and underlying the reservoir.

Low-density, high-pressure shales typically surround the permeable sandstones containing the geopressed-geothermal reservoir. The shales act as hydrologic barriers, restricting the movement of reservoir fluids. These shales are thus responsible for maintaining high reservoir fluid pressures. The cumulative thickness of the confining shale beds may exceed 1,300 feet (Gregory, 1977).

Faults may serve a similar function. Permeable aquifer strata may be sealed against impermeable strata which are displaced during faulting. Either of these processes can form a geopressed-geothermal reservoir. (See Figure 3.)

Fluid withdrawal from these confined reservoirs can alter the hydraulic balance between the reservoir fluid pressure and the stress on the reservoir created by overlying strata ("overburden"). A decline in fluid pressure will result in the compaction of reservoir strata and their adjacent confining shale beds. Subsidence occurs when this compaction is transferred upward to the ground surface. This relationship is probably nonlinear; that is, the amount of compaction at the depth of the reservoir may not equal the surface displacement. A thick overburden is more capable of dissipating the effects of compaction at the reservoir depth, thereby lessening the effects at the surface (Geertsma, 1973).

Subsidence could occur over an area equal to that of the portion of the reservoir from which fluids are withdrawn. Over the long projected production life of a geothermal production reservoir, some elevation loss could be expected over the entire reservoir. The amount of subsidence, though, would normally tend to decrease laterally from the well.

The surface effects of subsidence by fairway were examined. Subsidence effects in the Brazoria Fairway will include the expansion of brackish and fresh marshes and flooding of agricultural areas. In the Matagorda geothermal fairway, the greatest ecological effect of increased subsidence will be the expansion of brackish and salt marsh into adjacent coastal prairie and fluvial woodland. Some fresh marsh would also be created. Erosion rates along the Gulf beach would be increased. In the Corpus Christi Fairway, subsidence would cause grassflats to be created in wind tidal flats, with corresponding losses of grassflats in deeper areas. Beach erosion would also increase on the islands. On the mainland, oak groves and coastal prairie areas would be converted to wind tidal flats and salt marsh.

Early detection of subsidence can play an important part in monitoring serious impacts. Aerial and ground surveys are useful tools in monitoring elevation changes during geothermal resource production. Prevention and control of subsidence can be achieved with some success through proper well spacing and density, siting of production facilities in areas least sensitive to elevation losses, judicious use of permeability-enhancement techniques, minimizing fluid pressure drop during fluid withdrawal, and fluid reinjection.

Figure 3

TYPICAL GEOPRESSURED-GEOTHERMAL
RESERVOIR CONFIGURATIONS

Another important aspect of controlling subsidence is the ability to predict it. Subsidence modeling for geothermal resource development is not adequate. Because the geothermal fairways in Texas are largely untested, the data needed to validate model assumptions are generally unavailable. Furthermore, the type of parametric data required by the models is scarce and generally unreliable. The most reliable prediction method at this time appears to be the use of oil and gas production analogies.

Fault Activation and Enhanced Seismicity

Fault activation is the process of initiating or enhancing vertical movement along preexisting faults, and the possible extension of subsurface faults to the surface. Faults are common in the Gulf coastal region, both at the surface and below ground. Movement along most "natural" faults in the region is gradual or imperceptible. Certain of man's activities, chiefly fluid production and injection, may accelerate the rate of movement and increase the total displacement of a fault.

The mechanism by which faults most often may be activated is closely related to the process of inducing subsidence. Production of fluids from a geopressed (or other) reservoir can cause compaction of beds at depth and eventual subsidence. When a reservoir is bounded or divided by fault, compaction is generally restricted to beds on the producing side of the fault. If the fault extends to the surface, compaction on only one side may produce differential subsidence as the effect is transferred upward through the overburden. Increased relief across the fault may eventually form an escarpment. In this way, the fault is said to be "activated" at the surface by the differential movement.

Faults most likely to be activated are those which define the margins of subsurface reservoirs above which subsidence is occurring. These faults delineate the area of subsidence and can be used as guides in siting production and injection wells. Close proximity of the wells to major faults that intersect the production or disposal horizons may increase the probability and magnitude of faulting. Damage to wells and to pipelines and geothermal processing plants can thus be largely avoided by careful siting with respect to potentially active faults.

In contrast to fault activation, seismic activity is detectable vibration of a part of the earth's crust, usually described as an earthquake or earth tremor. The Gulf Coastal Plains of Texas has been characterized as a virtually aseismic region. That is, no appreciable incidence of earthquakes has been recorded or is expected. However, the low frequency and severity of natural seismic events has in recent years been overshadowed by man-induced seismicity (Henley, 1966). For example, Atherton et al. (1976, v. 2) reported eight discrete earthquake events in coastal and east Texas, and seven others in adjacent areas of Louisiana and Oklahoma, which were either clearly or possibly associated with oil and gas production. The earthquakes ranged in intensity from II to V on the Modified Mercalli Scale. A rating of V on this ascending scale corresponds to the minimum intensity at which slight structural damage may be

experienced (Wood and Neumann, 1931). The principal causes of these effects, which may be of importance in the development of geothermal resources, are production of geopressed fluids and reinjection of spent fluids.

There is no clear indication that geothermal resource development along the Texas coast would either result in or be seriously affected by fault activation or induced seismic activity. In the past, though, fault activation on the Texas Coastal Plain is very often the result of groundwater withdrawal and is less often associated with oil and gas production.

As with subsidence, early detection of fault activation can play an important part in preventing serious impacts; aerial and ground surveys are also useful tools in monitoring this potential effect. The use of seismic data with other information on dynamic reservoir behavior would assist in the management of the geothermal resource.

Subsurface Contamination

Underground water, hydrocarbon, and other mineral resources may be contaminated as a result of geopressed-geothermal resource development. Subsurface brine discharges and resulting contamination may be brought about by drilling pipe or casing leaks and leaks through uncased intervals in improperly plugged wells. Corrosion, blowout damage below ground, and movement along intersected faults are the most likely causes of leaks. The risk of subsurface brine discharges in conjunction with geothermal resource development is particularly great because of the large volume of brine involved and its toxicity and high pressure.

It is critical to realize, however, that, through proper use of current technology, such effects can be prevented almost entirely.

Accidental Brine Discharge

Geothermal brines may be accidentally discharged at the surface due to well blowouts, pipeline leaks or breaks, failure of storage facilities, and through accidents in the gas separation and power generation facilities. The amount of brine discharged is expected to be fairly small for pipelines equipped with valves permitting rapid manual or automatic shutdown when a leak is detected. Rapid detection and shutdown should also be possible for power and gas facilities.

Storage ponds are expected to be used for temporary and emergency containment of brines. Since brine storage facilities might be expected to hold several days' brine production, a large spill could result from failure of a storage facility. However, it should be possible to monitor storage facilities closely and detect leaks at an early stage. The most likely time for failure of a storage pond would be during high rainfall and flooding; thus the impact would be reduced by rapid dilution.

Well blowouts are the most unpredictable accidents causing surface brine discharge and are potentially of the greatest magnitude. Postulated well flow rates range from 40,000 to 128,000 barrels of brine per day. A blowout from a well may remain out of control for months, and could release 4 to 16 acre-feet of brine per day.

The most adverse effects of geothermal brine are due to heat, salinity, and toxic substances. Coastal ecosystems vary widely in their response to brine, both in terms of severity of impact and in rate of recovery. Upland ecological systems are more sensitive to brine discharge than marine systems, due to the long recovery rates. Wetland systems are more sensitive than estuarine systems because much less water is available for dilution, and flushing is slow. This has important implications for the design of well fields, production systems, and spill control strategies, as discussed in detail in Technical Paper No. 4.

SOCIAL AND ECONOMIC ANALYSIS

The purpose of the social and economic analyses was to identify the types of socioeconomic impacts likely to result from geopressed-geothermal energy development. Specifically, the focus of the analysis was to determine those potential social and economic effects of resource development, if any, which are sufficiently different from the effects of other types of development such as to potentially require special attention during the leasing and permitting process. Methodologies and models which could be employed in site-specific effects assessment were also discussed. The results of the analysis are discussed in detail in Technical Paper No. 3.

Three major benefits resulting from geopressed-geothermal energy development on PFSL were identified. First, geothermal development would make available an alternative energy source for residential and industrial consumption. Second, leasing of PFSL for development of geothermal energy and associated resources would provide additional funds for the Permanent Free School Fund. Assuming the base case scenario from the financial analysis and a royalty rate of 12.5 percent, lease bonus payments and royalty from production of brine and methane from the wells associated with a single power plant facility could total \$130 million. Third, the methane recovered from the brine will probably be subject to the natural gas occupation tax; the tax rate presently equals 7.5 percent of gross receipts. Again, assuming the base case scenario from the financial analysis, total occupation tax revenues from wells associated with a single power plant facility could exceed \$66 million.

The analysis determined that potential resource development effects on the following factors were not unique to geothermal development but rather are those likely to be associated with any development activity:

1. Employment
2. Regional output

3. Personal income
4. Local government finance
5. Municipal infrastructure
6. Transportation
7. Recreation
8. Historical/archaeological resources

Certainly, energy development activities are not a new phenomenon along the Gulf coast of Texas. The number of wells hypothesized to be drilled for a single power plant facility, for instance, represents ten percent or less of the total number of oil and gas wells drilled in 1977 in the counties encompassing the Brazoria and Corpus Christi Fairways.

Based on the ecological analysis and on geothermal development in other areas, the analysis examined in more detail the social and economic effects of certain aspects of resource development. These aspects were identified as being sufficiently different in magnitude or type so as to potentially warrant special consideration, at least during the initial phases of commercial development, and, with certain exceptions, reflect the social and economic implications of potential ecological effects. These are:

1. Water consumption during plant operation
2. Air emissions during production and plant operation
3. Noise, especially during field exploration and development
4. Potential surface water contamination due to accidental brine discharges, and subsurface contamination of water reservoirs
5. Potential subsidence/fault activation during well drilling and field production
6. Land use implications of all phases of geothermal development
7. Personal safety hazards related to potential blowouts during well drilling and production
8. Sociocultural impacts associated with development of a new energy source; substantial portions of the fairways are primarily rural and thus more susceptible to such impacts

Of these, subsidence/fault activation has the greatest potential for serious socioeconomic effect. The areas most likely to be affected by subsidence in the Matagorda Fairways and the middle to western portions of the Brazoria Fairway are primarily rural agricultural areas. Subsidence in these portions would thus be likely to affect isolated industrial, residential, and agricultural structures, roads, and pipelines. The Corpus Christi Fairway and eastern portion of the Brazoria Fairway are more heavily developed. Subsidence in these areas could potentially affect significant population and industrial centers, causing major property damage.

Geothermal resource development is new to the Texas coast. As more information becomes available concerning the resource and as specific resource development projects are proposed, the social and economic effects analysis should be refined to reflect the expanded knowledge.

LEGAL ANALYSIS

The purpose of the legal analysis was to discuss the legal issues associated with geopressured-geothermal resource development on PFSL. The analysis included the following:

1. An examination of the Texas Geothermal Resources Act of 1975
2. A review of the status of the resource under current federal and state tax statutes
3. An analysis of pricing regulations pertaining to geothermal resource development and electric power generation
4. A review of applicable environmental regulations
5. An analysis of correlative rights
6. An analysis of ownership issues
7. A consideration of potential liabilities associated with subsidence
8. A summary of legislation dealing with geothermal resources that was introduced during the 1979 legislative session

Since the geopressured-geothermal resource has not been commercially produced in Texas, many of the associated legal issues have not been finally resolved but rather represent areas of developing policy and law.

TEXAS GEOTHERMAL RESOURCES ACT

In Texas, geothermal resources are controlled by the Geothermal Resources Act of 1975, Section 141.001 et seq. Natural Resources Code. The Act defines "geothermal energy and associated resources," including "by-product," declares state policy concerning geothermal resource development, and specifies the duties and responsibilities of the Railroad Commission of Texas, the School Land Board, and the commissioner of the General Land Office.

The Act was amended in two ways by recent action of the Texas legislature (H.B. 1490). First, the definition of "by-product" in the Act is amended to include any element other than those previously listed under "geothermal energy and associated resources" brought to the surface from a geothermal formation. Second, the Act establishes that all geothermal resource system components are to be treated and produced as mineral resources.

The Act gives no definition of a "geothermal formation." By definition of "by-product," however, it is clear that methane, which is found in a geothermal formation, is a "by-product." Therefore, it seems that the intent of the legislature was that the geothermal heat and pressure must be used and not wasted merely to produce the methane in geothermal formations.

STATUS OF RESOURCE UNDER CURRENT TAX STATUTES

The geopressed-geothermal resource is a relatively recent discovery which is being examined more closely as a result, at least in part, of the emphasis being placed on alternative energy sources. It was only with the passage of the federal Energy Tax Act of 1978, however, that geothermal was mentioned specifically in the federal tax statutes.

For purposes of certain sections of the federal Internal Revenue Code, a geothermal deposit means a geothermal reservoir within the United States and its possessions consisting of natural heat which is stored in rocks or in an aqueous liquid or vapor (whether or not under pressure). Such a deposit shall in no case be treated as a gas well. This definition includes the geopressed-geothermal resources believed to be along the Texas coast.

In the case of geothermal deposits, a reasonable allowance for depletion and for depreciation of improvements is permitted to be deducted in computing taxable income. The depletion percentage is applied to gross income to determine the allowance. An operator of a geothermal property may at his option consider intangible drilling and development costs as capital expenditures or as an expense item. Finally, the Energy Tax Act allows a ten percent energy property tax credit from October 1, 1978, to December 31, 1982. Energy properties qualifying for the energy property tax credit include equipment for producing natural gas from geopressed brine and equipment used to produce, distribute, or use energy derived from a geothermal deposit, but only in the case of electricity generated by geothermal power up to (but not including) the electrical transmission stage by someone other than a public utility.

Geothermal resources are not specifically mentioned in Texas tax statutes. The natural gas occupation tax would probably apply to the methane produced from geopressed brine. In addition, ad valorem taxes are levied by political subdivisions such as the state, cities, counties, and school districts on real property, improvements to real property, and mineral resources.

PRICING REGULATIONS

The Federal Energy Regulatory Commission (FERC) has the authority under the Natural Gas Policy Act of 1978 (NGPA) to set the maximum price at the wellhead of natural gas produced from geopressured brine. For purposes of the Act, natural gas produced from geopressured brine is considered to be "high-cost" natural gas. By January 1980, controls must be eliminated for all high-cost natural gas, including gas produced from geopressured brine.

Both the federal government (through FERC) and the state of Texas (through the Public Utility Commission) have rate-making authority over the generation of electricity by public utilities. No regulations currently exist governing the price of the geothermal brine sold for its heat content.

ENVIRONMENTAL REGULATIONS

The major environmental regulations applicable to geopressured-geothermal resources are those water quality regulations that control brine disposal. Currently, both state and federal regulations apply to the surface discharge and reinjection of brine. A bill (H.B. 1490) recently passed by the Texas legislature amended the Texas Water Code to include geothermal resources, thus giving the Railroad Commission of Texas exclusive responsibility for waste control and water pollution prevention (surface and subsurface) resulting from activities associated with the exploration, development, and production of geothermal resources. The Railroad Commission of Texas would issue waste discharge permits associated with these activities, based on Texas Department of Water Resources water quality standards. If significant air emissions result from production or utilization of the geopressured-geothermal resource, federal and state laws concerning air quality will be applicable.

OWNERSHIP ISSUES

The ownership question exists in part because of a lack of clear legal definition concerning the nature of the resources. If the geopressured-geothermal resource is considered to be "water," ownership rights and control normally lie with the surface owner; if the resource is a "mineral," ownership rights and control belong to the owner of the subsurface or mineral estate. The practical dilemma resulting from this lack of definition is that a potential developer of geopressured-geothermal resources does not know if he should seek a lease from and pay royalties to the owner of the surface estate or to the owner of the mineral estate. This question affects the SLB only for those tracts that the SLB controls or participates only in the mineral estate. These lands include mineral relinquishment lands and lands patented to navigation districts.

A bill (H.B. 1490) recently passed by the Texas legislature amended the Geothermal Resources Act of 1975 to establish that all geothermal resource system components are to be treated and produced as mineral resources. The bill further states, "in making the declaration of policy . . ., there is no intent to make any change in the substantive law of this state." Until this bill, neither the legislature nor the courts of Texas had directly addressed the question of whether a geothermal resource belongs to the surface estate or to the mineral estate. The potential for court action remains, however, as case law is unclear on this point.

Present School Land Board/General Land Office oil and gas leases define gas as "all hydrocarbons and gaseous substances not defined as oil." Methane in solution in geothermal formations would probably be included under this definition. Subsequently, an existing gas lessee may have a claim to methane produced as a by-product by a geothermal lessee.

PROTECTION OF CORRELATIVE RIGHTS

The question of rights to and ownership of a geothermal resource is not certain. Texas will probably use the rule of capture to designate ownership of geothermal resources. Under this rule, whoever lawfully brings the resource to the surface is the owner of that resource. This led to the Railroad Commission of Texas' regulation of oil, gas and geothermal resource production to conserve energy resources; i.e., to prevent the bringing of resources to the surface solely to protect rights, without regard to conservation of the resource. Rule 37, the Statewide Spacing Rule, is the major RRC rule to prevent waste.

SUBSIDENCE LIABILITY

Liability for subsidence caused by geopressured-geothermal energy production is another legal issue that is undecided. There are court cases dealing with subsidence caused by withdrawal of percolating groundwater (*Friendswood Development Co. v. Smith-Southwest Industries, Inc.*) and by production of oil and gas, but not as a result of withdrawal of geopressured-geothermal resources. If geothermal energy and associated resources are held to be underground water, then the holding of the *Friendswood Case* would apply. This case held that " . . . if the landowner's manner of withdrawing groundwater from his land is negligent, willfully wasteful, or for the purpose of malicious injury, and such conduct is a proximate cause of the subsidence of the land of others, he will be liable for the consequences of his conduct." If geothermal energy and associated resources are held to be minerals, then it is likely that landowners would have a cause of action although there are no cases directly on point.

LEGISLATION INTRODUCED IN 66TH LEGISLATURE

Two legislative resolutions and three bills directly related to geothermal energy were introduced in 66th Legislature. Senate Joint Resolution (S.J.R.) 43 proposed a constitutional amendment creating a solar, wind, geothermal, and alternate energy fund within the state treasury under the administration of the comptroller. S.J.R. 44 also proposed a constitutional amendment, this one to authorize the legislature to grant geothermal energy devices an exemption from property taxation. Such an exemption already exists for solar and wind-powered energy devices. Neither resolution was passed by the legislature.

Senate Bill (S.B.) 793 would have amended state tax statutes to exempt receipts from the sale, lease, rental, use, storage, or consumption of geothermal energy devices. These devices would have also been exempt from ad valorem taxation, except for repair and replacement parts not incorporated as integral components. The ad valorem exemption would not have become effective until the proposed constitutional amendment on geothermal property tax exemptions (S.J.R. 44) was approved by the voters. S.B. 796 was a statutory followup to the proposed constitutional amendment (S.J.R. 43) creating a solar, wind, geothermal, and alternate energy fund. It would have taken effect if the voters approved the amendment. Neither bill was passed by the legislature.

House Bill 1490 has been passed by the legislature and is effective August 27, 1979. As discussed above, this bill amended the Geothermal Resources Act of 1975 to redefine "by-product" and to establish as a matter of policy that all geothermal resource system components are to be treated and produced as mineral resources. In addition, the bill amended the Water Code to give the Railroad Commission of Texas responsibility for regulating the discharge of wastes associated with geothermal as well as oil and gas production.

3. FINDINGS AND RECOMMENDATIONS

The findings and recommendations which were formulated as a result of the detailed financial, ecological, socioeconomic, and legal analyses are presented in this chapter.

FINANCIAL

1. *The capital requirements of resource development, the expected price to be received from associated methane, and the royalty rate will influence the financial feasibility of reservoir development.*

The attractiveness of the investment hinges primarily upon the capital required and the price of methane. The School Land Board has control over two variables, the royalty rate and the lease bonus payment. Of these, the royalty rate does affect the project's financial feasibility.

This study's financial analysis indicated that on the average, a one percentage point change in the royalty rate produced a 0.17 percentage point change in the field developer's after-tax rate of return. If the project goes to completion with a 30-year life expectancy, a royalty holiday of five years would enhance the project's attractiveness by providing for a slightly quicker payout, and by increasing the rate of return. Lease payments significantly greater than the minimum presently accepted for oil and gas leases have a negligible financial impact.

2. *Uncertainties presently associated with geopressured-geothermal resource development in Texas cause the results of any financial feasibility analysis to be tentative at this time.*

At this writing, successful completion of a test well has yet to be accomplished in Texas. Resource characteristics remain undefined to a great extent, cost estimates of the development and production phases are subject to wide error, and associated risks are uncertain. The best available engineering data and cost estimates, which are used in this study, are based on assumed reservoir characteristics. Such information will be refined and revised as the resource itself is better defined and as production is actually undertaken. At that time, the financial analysis undertaken as part of this study should be revised to reflect the updated information.

3. *The financial models developed as part of this study or similar techniques are an appropriate tool to be used by the SLB in determining proper royalty rates and lease payments.*

The SLB has not made it a practice to conduct a formal financial evaluation of tracts proposed for oil and gas leases to determine the proper royalty rates and lease payments. Minimum bonus payments have been set during discussions of Board members, based on an average of payments received for previous leases.

The exploration, development, and production of oil and gas, in contrast to the geopressured-geothermal resource, are established activities, and reservoir and field characteristics and associated risks are better defined. The influence of royalty rates on the financial feasibility of field development, and the risks and uncertainties associated with geopressured-geothermal resource development, make the determination of royalty rates more critical than for oil and gas development.

The use of the financial models developed as part of this study, or similar techniques, to determine proper royalty rates and lease payments for specific tracts proposed for lease, would ensure that, on the one hand, rates and payments are not too high such that resource development is discouraged, and, on the other hand, that terms are not so low as to preclude a fair return to the Permanent School Fund.

Recommendation: A financial evaluation of tracts proposed for lease should be undertaken prior to lease to determine minimum bonus payments and royalty rates.

ECOLOGICAL

4. *The development of geothermal energy and associated resources has the potential to cause subsidence of large magnitudes.*

The probability that subsidence will result from geopressured-geothermal resource production, as well as the areal extent, the magnitude, and the rate of subsidence, are dependent upon several factors:

1. The size and geologic properties of the geothermal reservoir
2. The geologic properties of strata surrounding and underlying the reservoir
3. The volume of fluid withdrawn
4. The rate of fluid withdrawal

A subsidence rate of 0.12 feet per year has been reported from production of oil and gas at depths of 8,600 to 12,200 feet in geopressured portions of the Frio Formation. The rate of fluid withdrawal per well under oil and gas production is

considerably less (e.g., one-fourth) than prospective geothermal development rates. (Recovery efficiency, of course, is considerably greater in oil and gas production.)

Early detection of subsidence can play an important part in preventing serious impacts. Aerial and ground surveys are useful in monitoring elevation changes during geothermal resource production.

5. *The development of geothermal energy and associated resources has the potential to activate faults and enhance seismicity.*

There is no clear indication that geothermal resource development along the Texas coast would either result in or be seriously affected by fault activation or induced seismic activity. However, fault activation on the Texas Coastal Plain is very often the result of groundwater withdrawal and is less often associated with oil and gas production. The activation process is identical to production-related subsidence, and the rate and cumulative extent of fault movement at a given location is closely related to local subsidence. Seismic data, when combined with other information on dynamic reservoir behavior, would be a useful tool for management of geothermal resources. Consideration should be given to the hazards of fault activation, increased seismicity, and other subsurface effects in designing waterflood or pressure maintenance programs and selecting disposal well sites.

6. *The development of geothermal energy and associated resources has the potential to cause contamination of groundwater resources and economically important mineral resources and hydrocarbons; these impacts can be virtually prevented with current technology.*

Contamination of potable groundwater and valuable minerals and hydrocarbons can result from the movement of geothermal brine into other geologic formations. Such contamination can be caused by movement along faults, through a failing well casing or uncased well intervals, from contiguous strata, or by infiltration from the surface. These impacts can be virtually prevented by the use, proper installation, and maintenance of effective control devices, and through monitoring at both the geothermal well and in neighboring wells.

7. *The development of geothermal energy and associated resources has the potential for accidental surface brine discharges of large magnitude.*

Well blowouts appear to have a higher potential for adverse impact than other types of accidents. Specifically, the potential for greatest impact would occur during early stages of development drilling of the first production wells. Once a geothermal power facility is under development, when a holding pond and reinjection wells are in place, it is likely that an emergency brine disposal system could be developed which would handle brine from a blown out well.

8. *The probability of an adverse environmental impact occurring is dependent upon characteristics of the development site.*

The environmental analysis undertaken as part of this study indicated general variables that are relevant to any detailed site-specific environmental assessment of geothermal development. Each geothermal resource production site will contain features that will determine the types of expected impacts, their probability, magnitude, and duration. These features must be considered through a case-by-case analysis.

9. *Due to the lack of development of geothermal energy and associated resources along the Texas coast and due to the site-specific nature of potential geological and ecological impacts, sufficient data are not available at this time to justify the formulation of more detailed rules to govern development of geothermal energy and associated resources than currently exist. The review of existing rules determined that these concerns are sufficiently addressed to manage initial development on PFSL, given the present level of information concerning both the resource and probable development technology.*

In virtually every aspect of this study, information specific to Texas geothermal resource development was found to be inadequate. Thus, the potential for such effects as subsidence, fault activation, and brine discharges were identified largely by analogy to other geothermal production regions and oil and gas production. These analyses should be refined as more Texas-specific geothermal resource data and production experience become available. To that end, an assessment methodology has been proposed as part of this study which is appropriate for use in a site-specific assessment. Such a methodology should be used to determine the risks of development and the adequacy of plans for managing potential geological and ecological impacts.

Recommendation: The General Land Office should conduct site-specific environmental assessments of the first several geothermal energy and associated resources projects (from drilling through production) proposed on PFSL to determine the risks of development and the adequacy of plans for managing geological and ecological impacts.

SOCIAL AND ECONOMIC

10. *Leasing of PFSL for geopressured-geothermal resource development would make available an alternative energy source for residential and industrial consumption, would provide additional funds for the Permanent School Fund, and would increase natural gas occupation tax revenue accruing to the State Treasury.*

The availability of an alternate energy source for residential and industrial consumption is a major benefit of resource development and is one with potentially significant economic implications for both the regional economies and the nation. Additionally, state government should realize increased revenue from two sources. First, the leasing of PFSL will provide additional funds for the Permanent Free School Fund in the form of lease bonus payments and royalty payments on brine and associated methane production. Second, the methane recovered from the brine will be subject to the state natural gas occupation tax; the tax's current rate is 7.5 percent of gross receipts.

11. *Most potential social and economic effects from resource development are similar to those associated with any development activity.*

The activities associated with geopressed-geothermal energy development are similar to other energy development activities already occurring along the Texas coast. At this time, it appears that the drilling procedures and equipment used will be essentially the same as those involved in oil and gas production. Similarly, the construction and operation of power plants are not unique activities to the Texas coast.

12. *Certain social and economic issues may demand special attention during the development process.*

Certain issues were identified as being sufficiently different in magnitude or type so as to potentially warrant special consideration, at least during the initial phases of commercial development. These concern land use, noise, personal safety, sociocultural effects, and the social and economic consequences of certain environmental impacts, including subsidence/fault activation.

13. *The social and economic impacts likely to result from resource development are dependent upon characteristics of the development site and surrounding social and economic systems.*

The social and economic analysis indicated the general kinds of impacts likely to result from resource development. Specific impacts (type, probability, magnitude, and duration) will vary depending upon the development site; these can be determined only through a case-by-case analysis.

14. *Due to the lack of development of geothermal energy and associated resources along the Texas coast and due to the site-specific nature of potential social and economic impacts, sufficient data are not available at this time to justify the formulation of more detailed rules to govern development of geothermal energy and associated resources than currently exist. The review of existing rules*

determined that these concerns are sufficiently addressed to manage initial development on PFSL, given the present level of information concerning the resource.

The activities associated with geothermal development and the social and economic effects appear to be similar to other on-going energy development activities along the coast. Hard data, however, are lacking on the exact characteristics of this resource and associated activities. The potential costs of development must be balanced against the very real benefits associated with development of an alternative energy source. Present analyses should be refined as more Texas-specific resource data and production experience become available. Methodologies and models which could be employed in a site-specific assessment are presented as part of this study.

Recommendation: The General Land Office should conduct site-specific social and economic assessments of the first several geothermal energy and associated resources projects (from drilling through production) proposed on PFSL to determine specific risks associated with resource development.

LEGAL

15. *The Railroad Commission of Texas has the statutory duty, except for duties given to other agencies, to regulate exploration, development, and production of geothermal energy and associated resources for the purpose of prevention of waste and protection of correlative rights. The Railroad Commission's rules must include rules for the protection of the environment, prevention of waste of natural resources, protection of the general public against injury or damage, and protection of correlative rights.*

The duties of the RRC as discussed above are set out in the Texas Geothermal Resource Act of 1975 TEX. NATURAL RESOURCES CODE sec. 141.001 - 141.079.

16. *At this time the Railroad Commission of Texas is set up to administer the exploration, development, and production of geothermal energy and associated resources for the purpose of protection of correlative rights and prevention of waste on all lands in Texas.*

The Railroad Commission of Texas has promulgated statewide rules controlling geothermal resources with no exclusion for Permanent School Fund Lands.

The oil and gas division of the Railroad Commission of Texas handles geothermal resources and employs 25 engineers. The oil and gas division has worked with the Center for Energy Studies at the University of Texas at Austin and recently amended its rules after consultation with staff of the Center for Energy Studies.

17. *At this time there is no indication that the Rules of the Railroad Commission of Texas conflict with a purpose of maximizing revenues to the Permanent School Fund balanced by a purpose of prevention of waste.*

The Railroad Commission of Texas has promulgated Rules after consultation with the General Land Office and Center for Energy Studies, that have brought very little, if any, comment from the public.

The Rules of the Railroad Commission of Texas include geothermal resources in the statewide Rules for oil and gas. As there is no commercial geothermal resources production in Texas at this time, the Railroad Commission of Texas expects the Brazoria test well to provide considerable information on the technical characteristics of geothermal resources. The Railroad Commission of Texas prefers to use field rules for oil and gas and currently will not on its own adopt permanent field rules until the 12th well is drilled in a field. At this time, there are no field rules for geothermal resources, but the Railroad Commission of Texas has the procedure for adopting field rules.

18. *At this time, conflict between School Land Board Rules and Railroad Commission of Texas Rules would probably not facilitate and encourage rapid and orderly development of geothermal energy and associated resources.*

The initial Bureau of Economic Geology reports indicate that, like oil and gas, there may be geothermal fields that lie under both private lands and PFSL. One Railroad Commission of Texas employee said he believed that dual regulation systems would be "chaotic."

19. *Uncertainty presently exists concerning whether the SLB or RRC has authority to promulgate and administer rules regulating the exploration, development, and production of geopressured-geothermal energy for the purpose of protection of correlative rights and prevention of waste.*

The Geothermal Resource Act authorizes the School Land Board to, in part, "adopt rules relating to exploration, development, and production of geothermal energy and associated resources as the Board determines to be in the best interest of the State" TEX. NATURAL RESOURCES CODE sec. 141.073(b). The RRC, on the other hand, has promulgated statewide rules controlling geothermal resources with no exclusion for PFSL. This study purports to express no legal opinion concerning this jurisdictional question.

Recommendation: The School Land Board's initial rules on the development and production of geothermal energy and associated resources at a minimum should be consistent with rules of the Railroad Commission of Texas.

20. **An existing gas lessee may have a claim to methane produced as a by-product by a geothermal lessee.**

There is no case law directly on point. Currently, the School Land Board/General Land Office oil and gas leases define gas as "all hydrocarbons and gaseous substances not defined as oil". This definition would probably include methane. The holder of an existing gas lease may thus lay claim to the methane produced under a geothermal lease. The inability of a geothermal lessee to produce methane would probably hamper development of the geothermal resource because it appears at this time that the major economic value of the resource is the value of the methane.

Recommendation: To facilitate the rapid and orderly development of geothermal energy and associated resources, future oil and gas leases should be changed such that by-products of geothermal energy and associated resources are specifically excluded from the definition of "gas."

4. SUMMARY OF DRAFT RULES

The draft Rules, which are given in Appendix A, are indexed in Table 6. These draft Rules can be divided into four sections. This scope of the draft Rules and the definitions are in .001 and .002. The scope is adapted from the Texas Geothermal Resources Act of 1975. The definitions are adapted from the Texas Geothermal Resources Act of 1975 and existing Railroad Commission of Texas Rules.

The leasing draft Rules are in .003 - .008. These draft Rules are adapted from existing General Land Office and School Land Board Rules dealing with leasing of oil and gas. Draft Rule .007 is based upon § 141.077 of the Texas Geothermal Resources Act of 1975.

The royalty reporting draft Rules are in .000 - .023. These draft Rules are adapted from existing General Land Office and School Land Board Rules dealing with royalty reporting for oil and gas. The royalty reporting Rules for oil and gas were chosen because the technical characteristics of geothermal resources are much closer to the characteristics of oil and gas than to the characteristics of any other mineral on permanent school fund land. The designation of the reporting form as MA-6 was chosen because the General Land Office currently uses forms MA-1 - MA-5. Draft Rule .009 requires all reports to be tendered to the General Land Office on or before the 25th day of the second month succeeding the month of production. The 25th day was chosen because the oil reports are required on the first of the month and the gas reports are required on the 15th of the month.

Rule .024 requires that lessees of geothermal energy and associated resources comply with Railroad Commission of Texas Rules for prevention of waste and protection of correlative rights.

Rule .025 provides that all General Land Office and School Land Board Rules that are relevant, particularly School Land Board proposed Rules 135.18.04, .001 - .009 and Rules 135.16.03.001 - .016, should apply to geothermal energy and associated resources activities. Not included within these draft Rules are provisions for exploration permits. The General Land Office's proposed amendments to Rules 126.16.01.001 - .012 can be used for geothermal energy and associated resources exploration permits. However, since there is a question as to whether or not geothermal energy and associated resources are minerals, proposed Rule 126.16.01.001(D) should be amended by adding "geothermal energy and associated resources." School Land Board Rules 135.16.02.002(c) and .004(c) should be amended to include "geothermal energy and associated resources."

Table 6

GUIDE TO PROPOSED DRAFT RULES AND REGULATIONS TO GOVERN RESOURCE DEVELOPMENT ON PFSL

<u>Scope and Definitions</u>	<u>Leasing</u>	<u>Royalty Reporting</u>	<u>Conservation</u>
.001 - Scope	.003 - Nominations of Tracts for Lease	.009 - Geothermal Energy and Associated Resources Royalties and Reports	.024 - Prevention of Waste and Protection of Correlative Rights
.002 - Definitions	.004 - Land Offered for Lease	.010 - Form of Payment	.025 - Application of Other Rules
	.005 - Lease Approval	.011 - Royalty Summary with General Land Office Lease Numbers	
	.006 - Lease Sale Practices and Procedures	.012 - Royalties Paid by Purchaser or Other Nonlessee	
	.007 - Governmental Lease for Experimental Research	.013 - Responsibility of Lessee	
	.008 - Notice of Termination	.014 - In-Kind Royalties and Reports	
		.015 - Shut-In Geothermal Royalties	
		.016 - Compensatory Royalties	
		.017 - Sundays and Legal Holidays	
		.018 - Basis for Computing Royalties	
		.019 - Penalties	
		.020 - Forfeiture of Rights	
		.021 - Accrued Interest	
		.022 - Documentation to Accompany the MA-6 Report	
		.023 - Preparation for Form MA-6, Geothermal Report	

NOTE: The source for each Rule is given in brackets following the Rule in Appendix A.

Appendix A
Draft Rules and Regulations
To Govern Resource Development on PFSL

These Rules are by authority of § 141.073 - 141.078, Texas Natural Resources Code.

.001 Scope

Rules 000.00.00.001 - .025 apply only to the leasing, development and production of geothermal energy and associated resources on permanent school fund land exclusive of wildlife refuges and recreational areas.

.002 Definitions

- (a) Board means the School Land Board
- (b) Commissioner means the Commissioner of the General Land Office.
- (c) Geothermal energy and associated resources means
 - (1) products of geothermal processes, embracing indigenous steam, hot water and hot brines, and geopressured water;
 - (2) steam and other gasses, hot water and hot brines resulting from water, gas or other fluids artificially introduced into geothermal formations;
 - (3) heat or other associated energy found in geothermal formations; and
 - (4) any by-product derived from them.
- (d) By-product means any other element found in a geothermal formation which is brought to the surface whether or not it is used in geothermal heat or pressure inducing energy generation.
- (e) Geothermal resources means geothermal energy and associated resources.
- (f) Geothermal resource well means a well drilled within the established limits of a designated geothermal field. A geopressured-geothermal well must be completed within a geopressured aquifer.
- (g) A geopressured aquifer is a water-bearing zone with a pressure gradient in excess of .5 pounds per square inch per foot and a temperature gradient in excess of 1.6° F per 100 foot of depth.

.003 Nominations of Tracts for Lease

Written requests that designated tracts of permanent school fund land be offered for lease for geothermal energy and associated resources may be submitted to the Commissioner of the General Land Office at any time; provided that wildlife refuges and recreational areas (TEX. NAT. RES. CODE 141.073(a)) are ineligible for such leases. The School Land Board will from time to time schedule a lease sale and the announcement of a sale will include a final date for nominations to be considered for that sale. Interested State and Federal Agencies, including the Texas Department of Water Resources, Texas Air Control Board, and Railroad Commission of Texas (TEX. NAT. RES. CODE 141.074), will be requested to submit recommendations on tracts nominated so that a prospective bidder is informed in advance as to any drilling and development restrictions which might be expected on a specific tract. [SLB Rule 135.06.01.001]

.004 Land Offered for Lease

After nominations are approved by the School Land Board, a list of tracts to be offered for lease will be compiled, printed, and distributed in the form of a Notice for Bids. Lease sale procedures, terms, conditions, and submerged tract recommendations will be included in the Notice for Bids, which will be made available on request to the public. The lists describing lands offered for lease shall be prepared and advertised thirty (30) days in advance of the sale date. [SLB Rule 135.06.01.002]

.005 Lease Approval

On the day of the lease sale, after all bids are received and recorded, the School Land Board shall review all bids and may reject any or all bids but otherwise shall accept the best bid offered. All bonuses and fees shall be returned to the makers of rejected bids. Executed leases will be delivered to the successful bidders. [SLB Rule 135.06.01.003]

.006 Lease Sale Practices and Procedures

(a) The board may schedule a lease sale for the first Tuesday of any month. The board will determine the terms and conditions for the lease sales.

(b) At least thirty (30) days prior to a lease sale date, the board will advertise in at least four (4) daily newspapers for at least three (3) issues. The advertisement will state the Tuesday upon which the lease sale will be held, the terms and conditions of that sale as determined by the board, and will provide that a list of the lands that are offered may be obtained from the General Land Office.

(c) The board may reject any and all bids, but otherwise will accept the best bid.

(d) Awards and leases will be issued by the Commissioner of the General Land Office in accordance with minutes approved by the School Land Board. [SLB Rule 135.01.00.004]

.007 Governmental Lease for Experimental Research

The board may lease permanent school fund lands to state and federal institutions, organizations, or groups desiring to do exploratory or experimental research of geothermal energy and associated resource potentials; provided that wildlife refuges and recreational areas (TEX. NAT. RES. CODE 141.077(b)) are ineligible for such leases. (TEX. NAT. RES. CODE 141.077(a)) These leases may be granted without regard to the procedures for leasing to the public. TEX. NAT. RES. CODE 141.077(a)

.008 Notice of Termination

Upon termination of a lease the General Land Office will, as a courtesy, issue a notice of termination letter to the owner of record indicated by General Land Office files. Since a lease automatically terminates under its own terms, failure of the General Land Office to send such notice or failure of any present or previous owner of the lease to receive such notice of termination shall in no way be construed to invalidate or nullify the termination nor diminish any liabilities accruing either before or after termination. [GLO Rule 126.12.01.014]

.009 Geothermal Energy and Associated Resources Royalties and Reports

All geothermal energy and associated resources royalties, reports and required supporting documents must be received in the General Land Office on or before the twenty-fifth (25th) day of the second month succeeding the month of production. [GLO Rule 126.12.01.001]

.010 Form of Payment

Royalties and other sums of money due may be paid by cash or check, money order, or sight draft made payable to the Commissioner of the General Land Office. [GLO Rule 126.12.01.002]

.011 Royalty Summary with General Land Office Lease Numbers

All royalty payments including each royalty check, money order, or bank draft must be accompanied by a check stub, schedule, or other summary showing by the assigned General Land Office Lease Number the amount of royalty being paid on each lease covered by that check, money order or bank draft. (The General Land Office Lease Number is shown at the top of each lease agreement and is also used when reporting geothermal energy and associated resources production of Form MA-6 to the General Land Office). Royalty payments not allocated and identified by use of the General Land Office Lease Numbers shall be considered delinquent and shall be subject of the delinquency provisions. [GLO Rule 126.12.01.003]

.012 Royalties Paid by Purchaser or Other Nonlessee

Lessees shall make all necessary arrangements with purchasers or other parties paying the royalty to provide for the use of the appropriate General Land Office Lease Numbers when remitting royalties. Upon written request the General Land Office will aid purchasers in obtaining the proper General Land Office Lease Numbers. [GLO Rule 126.12.01.004]

.013 Responsibility of Lessee

(A) Although as a matter of convenience the General Land Office permits parties other than the lessee to remit royalties to the State on the lessee's behalf, this practice in no way relieves the lessee of any statutory or contractual obligations concerning either the proper and timely payment of royalties or the proper and timely filing of reports and supporting documents. The General Land Office will look to its lessees to satisfy payment and reporting requirements and will not look to the purchaser or other third party. The lessee bears all responsibility for paying or causing royalties to be paid in the required manner by the appropriate due dates and for filing reports, supporting documents, assignments and releases in the required manner by the appropriate due dates.

(B) Operators and Purchasers. For practical reasons the General Land Office often will make direct requests for reports and other records from lease operators and purchasers rather than from lessees. Operators and purchasers should be aware that their actions may unwittingly subject leases to delinquency penalties or forfeiture. It is therefore in the best interests of all operators, lessees and purchasers to cooperate in responsibly discharging their obligations to each other and to the State. [GLO Rule 126.12.01.005]

.014 In-Kind Royalties and Reports

Producers meeting royalty obligations by delivering the State's royalty in-kind shall contact the General Land Office for specific instructions pertaining to reporting in-kind royalties. Purchasers of the State's in-kind royalty of geothermal energy or associated resources must make payment by separate check. [GLO Rule 126.12.01.006]

.015 Shut-in Geothermal Royalties

To maintain a lease in effect by payment of shut-in royalties, such shut-in royalties must be received in the General Land Office on or before the last day of the primary term if the well is shut-in during the primary term and if the well is shut-in after the primary term, payment must be received within sixty (60) days after the well is shut-in or ceases to produce geothermal therefrom, allowing for Sundays and legal State and Federal holidays. Upon receipt of a shut-in geothermal royalty payment by the General Land Office, a Shut-in Geothermal Affidavit will be sent to the lease operator for completion to be returned to the General Land Office. Shut-in royalties should be calculated in accordance with the lease agreement under which the well or wells were shut-in. At the end of the maximum shut-in period the operator must begin making sales or the lease will terminate for cessation of production. [GLO Rule 126.12.01.007]

.016 Compensatory Royalties

If while a geothermal well is shut-in, production should begin from another geothermal well situated within one thousand (1,000) feet of the shut-in lease premises and completed in the same producing reservoir, or in any case where drainage is occurring, the right ceases to further extend the State's lease by shut-in geothermal payments. In lieu of such shut-in payments, compensatory royalty payments must be made monthly to the State. Such payments shall be made at the royalty rate specified in the State's lease and shall be based on the value of geothermal energy and associated resources sold from the well causing drainage. In no event shall compensatory royalties paid during a year be less than the shut-in royalties which would have otherwise been due. Nothing herein shall relieve the Lessee of reasonable development nor the obligation to drill offset wells as required by law. [GLO Rule 126.12.01.008]

.017 Sundays and Legal Holidays

In all cases where a royalty due date falls on a Sunday or a legal State or Federal holiday, the royalty due date shall be considered to be the next calendar day which is not a Sunday or a legal holiday. In no event will a royalty payment physically received in the General Land Office after the appropriate royalty due date, as that term is construed in this Paragraph, be deemed by virtue of its postmark to have been received timely. [GLO Rule 126.12.01.009]

.018 Basis for Computing Royalties

(A) **Gross Value.** Geothermal energy and associated resources royalties under each lease must be computed strictly on gross value and be paid without deduction for production or severance taxes, and without deduction for the cost of producing, gathering, storing, separating, treating, dehydrating, compressing, processing, transporting and otherwise preparing the geothermal energy and associated resources produced therefrom for sale or use, or for the cost of disposing of spent geothermal fluids.

(B) **Amount Subject to Royalty.** Royalties are due and payable on 100% of each lease's gross production of geothermal energy and associated resources unless the lease agreement contains language expressly exempting certain dispositions of geothermal energy and associated resources from State royalties.

(C) **Market Value.** Nothing in these rules shall limit or waive the right of the State to receive its royalties based on market value of the geothermal energy and associated resources. [GLO Rule 126.12.01.010]

.019 Penalties

Any royalty not paid when due or affidavits and supporting documents not filed when due shall become delinquent and shall have added to the sum owing a delinquency penalty of one percent (1%) of such sum for each 30 day period of delinquency or a fractional period thereof; provided however, that each such penalty shall never be less than five dollars (\$5). Royalty payments not allocated and identified by use of General Land Office Lease Number shall be considered delinquent and shall be subject to the penalty provided herein. Payment of the delinquency penalty in no way operates to prohibit the State's right of forfeiture. For example, payments or reports one day late would bear a 1% penalty to be not less than \$5. Payments or reports 31 days late would bear a 2% penalty to be not less than \$10. [GLO Rule 126.12.01.011]

.020 Forfeiture of Rights

Failure to pay royalties and other sums of money within 30 days of the due date or the failure to file reports completed in the form and manner prescribed by the General Land Office shall constitute grounds for forfeiture. Forfeiture may also be invoked as otherwise provided by the statutes of the State of Texas. The State has a first lien on all geothermal energy and associated resources produced from the leased area to secure the payment of all unpaid royalty or other sums of money that may become due. [GLO Rule 126.12.01.012]

.021 Accrued Interest

Accrued interest at a rate not to exceed ten percent (10%) per annum may be applied to any monies owing which are not subject to the delinquency penalty. [GLO Rule 126.12.01.013]

.022 Documentation to Accompany the MA-6 Report

(a) General Statement. All affidavits of production shall be completed in the form and manner prescribed by the General Land Office and must be accompanied by and attached to all supporting documents necessary to substantiate the gross production and market value of the geothermal energy and associated resources produced therefrom.

(b) Required Documentation. The following documentation must be stapled to the back of each MA-6 Report:

(1) Geothermal Steam or Water. A settlement statement furnished by each purchaser which delineates for each lease all of the following:

(a) Total volume of geothermal and geopressed steam, water, and brine, in pounds X 10^6 at temperature and pressure PSIA RRC Forms GI-2, GT-3;

- (b) BTU content;
- (c) Price per MMBTU; and
- (d) Gross value.

(2) Separated methane gases. A statement furnished by each purchaser which delineates for each lease all of the following:

- (a) Total volume (MCF) separated and delivered to the purchaser;
- (b) BTU content;
- (c) Price per MCF; and
- (d) Gross value.

(3) Other Documents. Other documents which may be required by the General Land Office to verify production, disposition and market value.

(c) Internal Statements. In no event shall an internal volume and value statement prepared by the operator be acceptable unless the operator is also the purchaser of the geothermal energy and associated resources or uses all the geothermal energy and associated resources on the lease. If the purchaser does not furnish a settlement statement, a copy of the invoice or purchaser's check stub will be sufficient provided all criteria shown above are satisfied.

(d) Penalties. Failure to comply with statutes and reporting requirements subjects a lease to forfeiture (cancellation), delinquency penalties or both. [GLO Rule 126.12.07.001]

.023 Preparation of form MA-6, Geothermal Report

(a) All reports must be typed or legibly printed in black ink. White photocopies are not acceptable.

(b) Remarks and Footnotes. Much time and effort will be saved by trying to anticipate General Land Office questions concerning the reporting of geothermal energy and associated resources production and disposition. The MA-6 Report should be used creatively by noting appropriate remarks and explanations needed to clarify the report detail. (Examples are prior months' adjustment, unit cross-referencing, re-working operations, shut-in wells, plugged and abandoned wells, etc.).

(c) Prior Month's Adjustments; Credits. Corrected reports should not be filed unless requested by the General Land Office. Routine adjustments of prior months due to obvious corrections made by the purchaser should be shown on the succeeding month's MA-6 Report with a concise explanation (including month(s), adjusted volumes or values, etc.) shown in the Remarks Section. All non-routine corrections, adjustments or credits must first receive the prior written consent of the General Land Office and must be accompanied by supporting schedules detailing the make-up and method of calculating the amounts requested.

(d) Non-Unitized Leases.

(1) Complete and file one affidavit (Geothermal Report) on Form MA-6 for each lease covering all nonunitized reservoirs from which the lease is producing geothermal energy and associated resources. In all cases where geothermal energy and associated resources production from any State lease are marketed under two or more purchase contracts specifying different contract prices, the reporting party must file a separate MA-6 Report covering the geothermal energy and associated resources sold from the lease under each contract.

(2) Staple all required supporting documents to the MA-6 Report.

(3) Notwithstanding anything contained in these rules to the contrary, the General Land Office reserves the right to require that geothermal energy and associated resources production from any or all leases be reported separately for each producing reservoir.

(e) Unitized Leases.

(1) Who Must Report. The party responsible for reporting unitized State leases shall be determined by whether the Unit Operator either markets the production attributable to all State Leases or tracts participating in the unit or pays all royalties on those State Leases to the General Land Office. A Unit Operator doing either of the above is responsible for filing all MA-6 Reports and all supporting documents pertaining to the unit as explained in Case #1 below. If any State tract participant separately markets its allocated portion of unit production, then the procedure described in Case #2 below must be utilized.

(2) Balancing Agreements. The State of Texas is not subject to over and under balancing arrangements governing working interests. Reports and royalty payments must be based on each State lease's participation in unit production rather than on the actual amount taken or sold by a tract participant in any given month.

(3) Report Each Unit Separately. Many State leases are separately unitized for each reservoir. Each unit must therefore be reported separately in accordance with the requirements set out below. Do not consolidate and report several separately unitized reservoirs as one unit.

(4) Right to Require Reporting by Reservoir. Notwithstanding anything contained in these rules to the contrary, the General Land Office reserves the right to require that geothermal energy and associated resource production from any or all leases be reported separately for each producing reservoir.

(5) Geothermal Energy and Associated Resources Sold Under Two or More Contracts. In all cases where geothermal energy and associated resources production from any State lease are marketed under two or more purchase contracts specifying different contract prices, the reporting party must file a separate MA-6 Report governing the geothermal energy and associated resources sold from the lease under each contract.

(f) Examples.

(1) Case No. 1 Unit. A unit operator markets the production from all State tracts within the unit or disburses all royalties on such tracts.

(A) Unit Operator Responsibility.

(i) **Unit Report.** The Unit Operator, as designated in the Unit Agreement, must file a Unit MA-6 Report based on total unit production, disposition and gross value. The Unit Report must be filed under the lowest State Lease number in the Unit and labelled "Unit Report."

(ii) **Unit Royalty Allocation.** The Unit Operator must attach to the Unit MA-6 Report a unit royalty allocation statement showing for each lease the (a) unit name (b) production month (c) unit tract number (d) General Land Office Lease number (e) tract participation factor (f) State royalty decimal (g) unit royalty interest (h) the royalty due each State Lease on (1) energy from geothermal and geopressured steam, water, or brine (2) separated hydrocarbon gases and (i) any other information which the General Land Office may find necessary for proper allocation and identification. The space reserved for remarks may be used for allocations if all the leases can be allocated within the space provided.

(iii) **Supporting Documents.** Purchase or settlement statements and other documents which may be required by the General Land Office must be attached to the Unit MA-6 Report and unit royalty allocation statement. The Unit MA-6 Report, unit royalty allocation and supporting documents should be stapled together.

(B) **Tract Participant Responsibility.** Individual State lessees shall not file any reports under a Case No. 1 Unit unless requested to do so by the General Land Office. Each lessee of a unitized State lease shall supply the designated unit operator with all information necessary to satisfy the requirement of these rules and regulations.

(2) **Case No. 2 Unit.** A State tract participant separately markets its allocated portion of unit production.

(A) **Unit Operator Responsibility.**

(i) **Unit Report.** The unit operator as designated in the Unit Agreement, must file a Unit MA-6 Report based on total unit production and disposition. No values may be shown on this report. The Unit Report shall be filed under the lowest General Land Office Lease Number in the unit and be labeled "Unit Report."

(ii) **Tract Reports.** The unit operator must file a separate Tract MA-6 Report for each State lease for which the unit operator markets the production; showing the total production, disposition, sales, gross value and royalty attributable to each State lease for which the unit operator markets the production.

(iii) **Supporting Documents.** Purchase statements from each purchaser and other supporting documents which may be required by the General Land Office must be attached to the Unit MA-6 Report and Tract MA-6 Reports. The Unit Report, Tract Reports and supporting documents should be stapled together.

(B) **Tract Participant Responsibility.**

(i) **Tract MA-6 Reports.** Each State tract participant in the unit who separately markets its allocated production from a unitized State lease must complete and file a separate Tract MA-6 Report for each State lease for which it markets the production. Each Tract MA-6 Report shall be based only on the production, gross value and royalty attributable to that lease.

(ii) **Supporting Documentation.** The Tract Reports and supporting documents should be stapled together. [GLO Rule 126.12.07.002]

.024 Prevention of Waste and Protection of Correlative Rights

On Permanent School Fund Land, all exploration, production, and development of geothermal energy and associated resources shall comply with applicable Railroad Commission of Texas general and special Rules for the purpose of prevention of waste and protection of correlative rights.

.025 Application of Other Rules

All General Land Office or School Land Board Rules relevant to the exploration, development, or production of geothermal energy and associated resources shall apply, in particular School Land Board Rules 135.16.03.001-.016.

Appendix B

Lease Forms

THE HISTORY OF THE UNITED STATES

The history of the United States is a story of growth and change. From the first settlers to the present day, the nation has evolved through various stages of development. The early years were marked by exploration and settlement, followed by a period of rapid expansion and industrialization. The American Revolution and the subsequent years of the 18th and 19th centuries saw the nation's political and social structure take shape. The Civil War was a pivotal moment in the nation's history, leading to the abolition of slavery and the strengthening of the federal government. The 20th century brought significant changes, including the rise of the industrial revolution, the Great Depression, and the American Civil Rights Movement. Today, the United States continues to evolve, facing new challenges and opportunities in the 21st century.

The history of the United States is a story of growth and change. From the first settlers to the present day, the nation has evolved through various stages of development. The early years were marked by exploration and settlement, followed by a period of rapid expansion and industrialization. The American Revolution and the subsequent years of the 18th and 19th centuries saw the nation's political and social structure take shape. The Civil War was a pivotal moment in the nation's history, leading to the abolition of slavery and the strengthening of the federal government. The 20th century brought significant changes, including the rise of the industrial revolution, the Great Depression, and the American Civil Rights Movement. Today, the United States continues to evolve, facing new challenges and opportunities in the 21st century.

The history of the United States is a story of growth and change. From the first settlers to the present day, the nation has evolved through various stages of development. The early years were marked by exploration and settlement, followed by a period of rapid expansion and industrialization. The American Revolution and the subsequent years of the 18th and 19th centuries saw the nation's political and social structure take shape. The Civil War was a pivotal moment in the nation's history, leading to the abolition of slavery and the strengthening of the federal government. The 20th century brought significant changes, including the rise of the industrial revolution, the Great Depression, and the American Civil Rights Movement. Today, the United States continues to evolve, facing new challenges and opportunities in the 21st century.

The history of the United States is a story of growth and change. From the first settlers to the present day, the nation has evolved through various stages of development. The early years were marked by exploration and settlement, followed by a period of rapid expansion and industrialization. The American Revolution and the subsequent years of the 18th and 19th centuries saw the nation's political and social structure take shape. The Civil War was a pivotal moment in the nation's history, leading to the abolition of slavery and the strengthening of the federal government. The 20th century brought significant changes, including the rise of the industrial revolution, the Great Depression, and the American Civil Rights Movement. Today, the United States continues to evolve, facing new challenges and opportunities in the 21st century.

GENERAL LAND OFFICE LEASE NUMBER
GEOTHERMAL ENERGY AND ASSOCIATED RESOURCES

Production Month _____, 19__

Part or Area	Section or Tract	Block	Grantee	Acres	County
--------------	------------------	-------	---------	-------	--------

1. _____
2. Name of Operator _____
3. Address _____
4. Purchaser(s) _____
5. Royalty Paid By _____
6. Name of Field(s) _____
7. Lease or Unit Name _____
8. Number of Wells _____

9. GEOTHERMAL AND GEOPRESSURED STEAM, WATER, BRINE

- A. Total Mass Delivered to Purchaser _____ lbs. $\times 10^6$
- B. Flow Temperature Delivered to Purchaser _____ $^{\circ}\text{F}$
- C. Flow Pressure Delivered to Purchaser _____ PSI
- D. Energy Value Delivered to Purchaser _____ MMBTU
- E. Gross Price \$ _____ per MMBTU
- F. Royalty _____ \$
Decimal

10. SEPARATED METHANE

- A. Separating Plant Name _____
- B. Gross Price \$ _____ per MCF or \$ _____ per MMBTU
Disposition	MCF	Gross Value
C. Returned for Gas Lift and Injection on Lease	_____	\$ _____
D. Returned for Other Use on Lease	_____	\$ _____
E. Returned and Used Off Lease	_____	\$ _____
F. Vented or Flared	_____	\$ _____
G. Methane Sales	_____	\$ _____
H. Totals	_____	\$ _____
I. Royalty	_____ \$
Decimal	\$ _____

11. TOTAL ROYALTIES DUE STATE (9F and 10I) \$ _____

12. REMARKS

I certify that this is a true and correct statement of the production and disposition thereof for the period indicated.

Reporting Company _____

Signature _____

Telephone _____ Title _____

Sworn and subscribed to me before the undersigned authority,

on this _____ day of _____, 19__.

_____, Notary Public on and for

_____, County, State of _____.

LAND OFFICE USE ONLY

RECEIVING STAMP

THE STATE OF TEXAS
GENERAL LAND OFFICE
Austin, Texas

GEOTHERMAL ENERGY AND ASSOCIATED RESOURCES LEASE

No.

WHEREAS, pursuant to § 141.071 et. seq. of the Texas Natural Resources Code, and subject to all rules and regulations promulgated by the Commissioner of the General Land Office and/or the School Land Board pursuant to § 141.071 and 141.073 of the Texas Natural Resources Code, and all other applicable statutes and amendments thereto, the following area, to-wit:

was, after being duly advertised, offered for lease on the _____ day of _____, 19____, at 10:00 o'clock A.M., by the Commissioner of the General Land Office of the State of Texas and the School Land Board of the State of Texas, for the sole and only purpose of prospecting and drilling for, and producing geothermal energy and associated resources that may be found and produced from the above described area.

WHEREAS, after all bids and remittances which were received up to said time have been duly considered by the Commissioner of the General Land Office and the School Land Board at a regular meeting thereof in the General Land Office, on the _____ day of _____, 19____, and it was found and determined that _____

whose address is _____ had offered the highest and best bid for a lease of the above described and is, therefore, entitled to receive a lease thereon.

NOW, THEREFORE, I, BOB ARMSTRONG, Commissioner of the General Land Office of the State of Texas, hereinafter sometimes referred to as "Lessor", whose address is Austin, Texas, by virtue of the authority vested in me and in consideration of the payment by the hereinafter designated Lessee, the sum of _____ Dollars (\$ _____), receipt of which is hereby acknowledged and of the royalties, covenants, stipulations and conditions contained and hereby agreed to be paid, observed and performed by Lessee, do hereby demise, grant, lease and let unto the _____ the exclusive right to prospect for, produce and take geothermal energy and associated resources from the aforesaid area upon the following terms and conditions, to-wit:

1. Subject to the other provisions hereof, this lease shall be for a primary term of _____ and as long thereafter as geothermal energy and associated resources is produced in paying quantities.

2. If no well be commenced on the land hereby leased on or before the _____ day of _____, 19____, this lease shall terminate as to both parties unless the Lessee on or before said date shall pay or tender to the Commissioner of the General Land Office of the State of Texas at Austin, Texas, the sum of _____ Dollars (\$ _____), per acre, which shall operate as a rental and cover the privilege of deferring the commencement of a well for twelve (12) months from said date. In like manner and upon like payments or tenders the commencement of a well may be further deferred for like periods of the same number of months successively during the primary term hereof.

3. When production of geothermal energy and associated resources is secured, the Lessee agrees to pay or cause to be paid to the Commissioner of the General Land Office in Austin, Texas, for the use and benefit of the State of Texas, during the term hereof:

(A) As a royalty on geothermal energy and associated resources, which is defined as products of geothermal processes, embracing indigenous steam, hot water and hot brines, and geopressured water; steam and other gasses, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations, heat or other associated energy in geothermal formations, and any other element found in geothermal formation which is brought to the surface, whether or not it is used in geothermal heat or pressured inducing generating, as hereinafter provided, _____ part of the gross production or the market value thereof, at the option of the Lessor, such value to be determined by (1) the highest price, plus premium, if any, offered or paid for geothermal energy and associated resources, respectively, of a like type for the field where produced and when run, or (2) the highest market price thereof offered or paid for the field where produced and when run, or (3) the gross proceeds of the sale thereof, whichever is the greater. Lessee

agrees that before any geothermal energy and associated resource produced from the land hereby leased is sold, used or processed in a plant, it will be run free of cost to Lessor through an adequate separator of conventional type or other equipment at least as efficient to the end that all by products recoverable from the geothermal energy and associated resources by such means will be recovered. Upon written consent of Lessor, the requirement that such geothermal energy and associated resources be run through such a separator or other equipment may be waived upon such terms and conditions as prescribed by Lessor; provided that where appropriate the maximum pressure base in measuring a resource produced under this lease contract shall not at any time exceed 14.65 pounds per square inch absolute, and the standard base temperature shall be sixty (60) degrees Fahrenheit, correction to be made for pressure according to Boyle's law, and for specific gravity according to test made by the Balance method or by the most approved method of testing being used by the industry at the time of testing.

(B) For purposes of this lease "field" means the general area in which the land covered by this lease is located.

(C) Lessee agrees that all royalties accruing to Lessor under this lease shall be without deduction for the cost of producing, gathering, storing, separating, treating, dehydrating, compressing, processing, transporting, and otherwise making the geothermal energy and associated resources produced hereunder ready for sale or use.

(D) Notwithstanding anything contained herein to the contrary, Lessor may, at its option, upon not less than 60 days notice to Lessee, require at any time or from time to time that payment of all or any royalties accruing to Lessor under this lease be made in kind without deduction for the cost of producing, gathering, storing, separating, treating, dehydrating, compressing, processing, transporting and otherwise making the geothermal energy and associated resources produced hereunder ready for sale or use.

(E) During any year beginning with the anniversary date of this lease, if this lease is maintained by production, the royalties paid to Lessor in no event shall be less than an amount equal to the total annual delay rental herein provided; otherwise, there shall be due and payable on or before the last day of the month succeeding the anniversary date of this lease a sum equal to the total annual rental less the amount of royalties paid during the preceding year.

4. All royalties not taken in kind shall be paid to the Commissioner of the General Land Office at Austin, Texas, in the following manner:

Royalty on geothermal energy and associated resources shall be due and payable on or before the 25th day of the second month succeeding the month of production, accompanied by the affidavit of the owner, manager or other authorized agent, completed in the form and manner prescribed by the General Land Office and showing the gross amount and disposition of all geothermal energy and associated resources

produced and the market value of the geothermal energy and associated resources, together with a copy of all documents, records or reports confirming the gross production, disposition and market value including meter readings, pipeline receipts, line receipts, and other checks or memoranda of amount produced and put into pipelines, tanks, or pools and lines or storage, and any other reports or records which the General Land Office may require to verify the gross production, disposition and market value. In all cases the authority of a manager or agent to act for the Lessee herein must be filed in the General Land Office. Each royalty payment shall be accompanied by a check stub, schedule, summary or other remittance advice showing by the assigned General Land Office lease number the amount of royalty being paid on each lease. Any royalty not paid or affidavits and supporting documents not filed when due shall become delinquent and shall have added to the sum owing a delinquency penalty of one percent (1%) of such sum for each thirty (30) day period of delinquency or a fractional period thereof; provided, however, that each such penalty shall never be less than Five Dollars (\$5). The lessee shall bear all responsibility for paying or causing royalties to be paid as prescribed by the due date provided herein. Payment of the delinquency penalty shall in no way operate to prohibit the State's right of forfeiture as provided by law nor act to postpone the date on which royalties were originally due. The above penalty provisions shall not apply in cases of title dispute as to the State's portion of the royalty or to that portion of the royalty in dispute as to fair market value.

5. Lessee shall annually furnish the Commissioner of the General Land Office with its best possible estimate of geothermal energy and associated resources reserves underlying this lease or allocable to this lease and shall furnish said Commissioner with copies of all contracts under which geothermal energy and associated resources are sold or processed and all subsequent agreements and amendments to such contracts within thirty (30) days after entering into or making such contracts, agreements or amendments. Such contracts and agreements when received by the General Land Office shall be held in confidence by the General Land Office unless otherwise authorized by Lessee. All other contracts and records pertaining to the production, transportation, sale and marketing of the geothermal energy and associated resources produced on said premises, including the books and accounts, receipts and discharges of all wells, tanks, pools, meters, and pipelines shall at all times be subject to inspection and examination by the Commissioner of the General Land Office, the Attorney General, the Governor, or the representative of any of them. The State shall have a first lien upon all geothermal energy and associated resources produced from the area covered by this lease, to secure payment of all unpaid royalty and other sums of money that may become due under this lease.

6. Notwithstanding any provision of this lease to the contrary, after a well producing or capable of producing geothermal energy and associated resources has been completed on the leased premises. Lessee shall exercise the diligence of a reasonably prudent operator in drilling such additional well or wells as may be reasonably necessary for the proper development of the leased premises and in marketing the production therefrom.

7. If geothermal energy and associated resources should be produced in commercial quantities in a well on land privately owned or on State land leased at a lesser royalty, which well is within one thousand (1,000) feet of the area included herein, the Lessee shall, within sixty (60) days after such initial production on such land, begin in good faith and prosecute diligently the drilling of an offset well on this area, and such offset well shall be drilled to such depth as may be necessary to prevent the undue drainage of this area, and the Lessee, manager or driller shall use all means necessary in a good faith effort to make such offset well produce geothermal energy and associated resources in commercial quantities.

8. If, during the primary term hereof and prior to discovery and production of geothermal energy and associated resources on said land, Lessee should drill a dry hole or holes thereon, or if after discovery and production of geothermal energy and associated resources the production thereof should cease from any cause, this lease shall not terminate if on or before the rental paying date next ensuing after the expiration of sixty (60) days from date of completion of said dry hole or cessation of production Lessee commences additional drilling or reworking operations thereon, or commences or resumes the payment of annual delay rental in the same manner as provided in Paragraph Number 2 of this lease. If a dry hole be completed and abandoned during the last year of the primary term, Lessee's rights shall remain in full force and effect without further operations until the expiration of the primary term. Should the first well or any subsequent well drilled on the above described land be completed as a shut-in geothermal energy and associated resources well within the primary term hereof, Lessee shall resume payment of annual rental in the same manner as provided in Paragraph Number 2 in the lease on or before the rental paying date next ensuing after sixty (60) days from the date of completion of such shut-in geothermal energy and associated resources well and the failure to make such annual rental payment shall subject the lease to forfeiture under the provisions of Paragraph Number 18 hereof. If at the expiration of the primary term or at any time thereafter a shut-in geothermal energy and associated resources well is located on the leased premises payments shall be made in accordance with the provisions of Paragraph Number 10 hereof.

9. In the event production of geothermal energy and associated resources and by products on the leased premises after once obtained shall cease from any cause at the expiration of the primary term hereof or at any time or times thereafter, this lease shall not terminate if Lessee commences additional drilling or reworking operations within sixty (60) days thereafter, and the lease shall remain in full force and effect so long as such operations continue in good faith and in workmanlike manner without interruptions totaling more than sixty (60) days during any one such operation; and if such drilling or reworking operations result in the production of geothermal energy and associated resources the lease shall remain in full force and effect so long as geothermal energy and associated resources are produced therefrom in paying quantities or payment of shut-in geothermal energy and associated resources well royalties or compensatory royalties is made as hereinafter provided or as provided elsewhere in the statutes of the State of Texas Lessee shall give written notice to the General Land Office within five (5) days of any cessation of production.

10. If, at the expiration of the primary term or at any time thereafter, there is located on the leased premises a well or wells capable of producing geothermal energy and associated resources in paying quantities and is not otherwise produced for lack of a suitable market and this lease is not otherwise being maintained in force and effect, Lessee may pay as royalty a sum of money equal to double the annual rental provided for in this lease but in no event to be less than \$1,200.00 per annum for each well capable of producing geothermal energy and associated resources in paying quantities; such payment shall be made prior to the expiration of the primary term of this lease or if the primary term has expired within sixty (60) days after Lessee shuts in such well or ceases to produce geothermal energy and associated resources therefrom or within sixty (60) days after this lease ceases to be otherwise maintained in force and effect; and if such payment is made, this lease shall be considered to be a producing lease and such shut-in geothermal energy and associated resources well royalty payment shall extend the term of this lease for a period of one (1) year from the end of the primary term or, if after the primary term, from the first day of the month next succeeding the month in which such well was shut-in or production ceased or this lease ceased to be otherwise maintained in force and effect; and thereafter, if no suitable market for such geothermal energy and associated resources exists, Lessee may extend this lease for four (4) additional and successive periods of one (1) year each by the payment of a like sum of money each year as above provided, on or before the expiration of the extended term. Provided, however, that if, while this lease is being maintained in force and effect by payment of such shut-in geothermal energy and associated resources well royalty, geothermal energy and associated resources should be sold and delivered in paying quantities from a well situated within 1,000 feet of the leased premises and completed in the same producing reservoir, or in any case where drainage is occurring, the right to further extend this lease by such shut-in geothermal energy and associated resources well royalty payments shall cease and this lease shall remain in force and effect for the remainder of the current one-year period for which the shut-in geothermal energy and associated resources well royalty has been paid and for an additional period not to exceed five (5) years from the expiration of the primary term by payment of Lessee of compensatory royalty at the royalty rate provided for herein, of the value at the well of production from the well completed in the same producing reservoir from which geothermal energy and associated resources is being sold and delivered and which is situated within 1,000 feet of or draining the lease premises on which such shut-in geothermal energy and associated resources well is situated, such compensatory royalty to be paid monthly to the Commissioner of the General Land Office beginning on or before the last day of the month next succeeding the month in which such geothermal energy and associated resources is sold and delivered from the well situated within 1,000 feet of or draining the leased premises and completed in the same producing reservoir, provided further that in the event such compensatory royalties paid in any twelve-month period are in an amount less than the annual shut-in geothermal energy and associated resources well royalties provided for herein, Lessee shall pay an additional sum of money equal to the difference between such compensatory royalties paid and such shut-in geothermal energy and associated resource well royalties within thirty (30) days from the end of such twelve-month period; provided further that nothing herein shall relieve Lessee of the obligation of reasonable development, nor of the obligation to drill offset wells as required by law.

11. If, at the expiration of the primary term of this lease, production of geothermal energy and associated resources and by products have not been obtained on the leased premises but drilling operations are being conducted thereon in good faith and in a good and workmanlike manner, Lessee may, on or before the expiration of the primary term, file in the General Land Office written application to the Commissioner of the General Land Office for a thirty (30) day extension of this lease, accompanied by payment of Three Thousand Dollars (\$3,000.00) if this lease covers six hundred forty (640) acres or less and Six Thousand Dollars (\$6,000.00) if this lease covers more than six hundred forty (640) acres and the Commissioner shall, in writing, extend this lease for a thirty (30) day period from and after the expiration of the primary term and so long thereafter as geothermal energy and associated resources are produced in paying quantities; provided further, that Lessee may, so long as such drilling operations are being conducted, make like application and payment during any thirty (30) day extended period for an additional extension of thirty (30) days and, upon receipt of such application and payment, the Commissioner shall, in writing, again extend this lease so that same shall remain in force for such additional thirty (30) day period and so long thereafter as geothermal energy and associated resources are produced in paying quantities, provided, however, that this lease shall not be extended for more than a total of three hundred ninety (390) days from and after the expiration of the primary term unless production in paying quantities has been obtained.

12. Written notice of all operations on a State of Texas lease shall be submitted to the Commissioner of the General Land Office by Lessee or operator within five (5) days of spud date, workover, re-entry, temporary abandonment or plug and abandonment of any well or wells. Such written notice to the General Land Office shall include copies of forms for application to drill, well tests, completion reports and plugging records.

(A) Lessee shall supply the General Land Office with any records, memoranda, accounts, reports, cuttings and cores, or other information relative to the operation of the above described premises, which may be requested by the General Land Office, in addition to those herein expressly provided for.

(B) Lessee shall have an electrical and/or radioactivity survey made on the bore-hole section, from the base of the surface casing to the total depth of well, of all wells drilled on the above described premises and shall transmit a true copy of the log of each survey on each well to the General Land Office within fifteen (15) days after the making of said survey.

13. Lessee shall have the right to use water produced on said land necessary for operations hereunder and solely upon the leased premises; provided, however, Lessee shall not use potable water or water suitable for livestock or irrigation purposes for water flood operations without the prior written consent of Lessor. Lessee shall have the right to use so much of the surface of the land that may be reasonably necessary for drilling and operating wells and transporting and marketing the production therefrom, such use to be conducted under conditions of lease injury to the surface of the land.

14. In developing this area, Lessee shall use the highest degree of care and all proper safeguards to prevent pollution. In the event of pollution, Lessee shall use all means at its disposal to recapture all escaped hydrocarbons or other pollutant and shall be responsible for all damage to public and private properties. Lessee shall build and maintain fences around its slush, sump, and drainage pits and tank batteries so as to protect livestock against loss, damage or injury; and upon completion or abandonment of any well or wells, Lessee shall fill and level off all slush pits and cellars and completely clean up the drilling site of all rubbish thereon.

15. Lessee shall erect, at a distance not to exceed 25 feet from each well on the premises covered by this lease, a legible sign on which shall be stated the name of the operator, the lease designation and the well number. Where two or more wells on the same lease or where wells on two or more leases are connected to the same tank battery, whether by individual flow line connections direct to the tank or tanks or by use of a multiple header system, each line between each well and such tank or header shall be legibly identified at all times, either by a firmly attached tag or plate or an identification properly painted on such line at a distance not to exceed three (3) feet from such tank or header connection. Said signs, tags, plates or other identification markers shall be maintained in a legible condition throughout the term of this lease.

16. The lease may be transferred at any time. All transfers must be recorded in the county where the area is located, and the recorded transfer or a copy certified to by the County Clerk of the county where the transfer is recorded must be filed in the General Land Office within ninety (90) days of the execution date accompanied by a filing fee of Five Dollars (\$5.00).

17. Lessee may relinquish the rights granted hereunder to the State at any time by recording the relinquishment in the county where this area is situated and filing the recorded relinquishment or certified copy of same in the General Land Office within ninety (90) days after its execution accompanied by a filing fee of Five Dollars (\$5.00). Such relinquishment will not have the effect of releasing Lessee from any liability theretofore accrued in favor of the State.

18. If Lessee shall fail or refuse to make the payment of any sum within thirty (30) days after it becomes due, or if Lessee or an authorized agent should knowingly make any false return or false report concerning production or drilling, or if Lessee shall fail or refuse to drill any offset well or wells in good faith as required by law and the rules and regulations adopted by the Commissioner of the General Land Office and the School Land Board, or if Lessee should fail to file reports in the manner required by law or fail to comply with General Land Office and School Land Board rules and regulations or refuse the proper authority, access to the records pertaining to operations, or if Lessee or an authorized agent should knowingly fail or refuse to give correct information to the proper authority or knowingly fail or refuse to furnish the General Land Office and School Land Board a correct log of any well, or if Lessee shall knowingly violate any of the material provisions of this lease, or if this lease is assigned and the assignment is not filed in the General Land Office and School Land Board as required by law, the rights acquired under this lease shall be subject to

forfeiture by the Commissioner, and he shall forfeit same when sufficiently informed of the facts which authorize a forfeiture, and when forfeited the area shall again be subject to lease to the highest bidder, under the same regulations controlling the original sale of leases.

19. Forfeitures may be set aside and this lease and all rights thereunder reinstated before the rights of another intervene upon satisfactory evidence to the Commissioner of the General Land Office and School Land Board of future compliance with the provisions of the law and of this lease and the rules and regulations that may be adopted relative thereto.

20. Upon the termination of this lease for any cause, Lessee shall not, in any event, be permitted to remove the casing or any part of the equipment from any producing, dry, or abandoned well or wells without the written consent of the Commissioner of the General Land Office or his authorized representative; nor shall Lessee, without the written consent of said Commissioner or his authorized representative remove from the leased premises the casing or any other equipment, material, machinery, appliances or property owned by Lessee and used by Lessee in the development and production of geothermal energy and associated resources and by products therefrom until all dry or abandoned wells have been plugged and until all slush or refuse pits have been properly filled and all broken or discarded lumber, machinery, or debris shall have been removed from the premises to the satisfaction of the said Commissioner or his authorized representative.

21. Should Lessee be prevented from complying with any express or implied covenant of this lease, from conducting drilling operations thereon, or from producing geothermal energy and associated resources therefrom, after effort made in good faith, by reason of war, rebellion, riots, strikes, acts of God, or any order, rule or regulation of governmental authority, then while so prevented, Lessee's obligation to comply with such covenant shall be suspended upon proper and satisfactory proof presented to the School Land Board in support of Lessee's contention and Lessee shall not be liable for damages for failure to comply therewith (except in the event of lease operations suspended as provided in the rules and regulations adopted by the School Land Board); and this lease shall be extended while and so long as Lessee is prevented, by any such cause, from drilling, reworking operations or producing geothermal energy and associated resources from the leased premises, provided, however, that nothing herein shall be construed to suspend the payment of rentals during the primary or extended term.

22. The covenants, conditions and agreements contained herein shall extend to and be binding upon the heirs, executors, administrators, successors or assigns of Lessee herein.

IN TESTIMONY WHEREOF, Witness the signature of the Commissioner of the General Land Office, under the seal of the General Land Office, this _____ day of _____, 19__.

Commissioner of the General Land Office

GEOHERMAL BIBLIOGRAPHY

 

- Alpay, O.A. 1973. Application of aerial photographic interpretation to the study of reservoir natural fracture systems. *Journal of Petroleum Technology* 25:37-45.
- American Geological Institute. 1962. *Dictionary of Geological Terms*. Doubleday and Company, Inc. Garden City, New York.
- American Petroleum Institute. 1962. *Primer of Oil and Gas Production; Book 1 of Vocational Training Series*. Dallas.
- Antia, N.J. and J.Y. Cheng. 1975. Cultural studies on the effects of borate pollution on the growth of marine phytoplankters. *J. Fish. Res. Bd. Can.*, 32:2487-94.
- Appel, C.A. and J.D. Bredehoeft. 1976. Status of ground-water modeling in the U.S. Geological Survey. *Geological Survey Circular 737*, U.S. Department of the Interior. Washington, D.C.
- Atherton, R.W., E.J. Finnemore, M.L. Gillam, D.E. DeGance, G.P. Grimsrud, and R.B. Schainker. 1976. *The Analysis of Subsidence Associated with Geothermal Development*. Vols. 1, 2. Systems Controls, Inc. Palo Alto, California.
- Atlanta Economic Review. 1971. Power - undreamed of geothermal energy is America's untapped resource from the earth's inexhaustible heat supply.
- Axtmann, R. 1975. Environmental impact of a geothermal power plant. *Science* 187:4179.
- Baer, W.S., L.L. Johnson, and E.W. Merrow. 1976. *Analysis of Federally Funded Demonstration Projects: Final Report*. Rand. Santa Monica, California.
- Baker, V.R. 1978. The Spokane flood controversy and the Martian outflow channels. *Science* 202:1249-1256.
- Ballentine, R.K., S.R. Reznick, and C.W. Hall. 1972. *Subsurface Pollution Problems in the United States*. U.S. Environmental Protection Agency, Technical Studies Report TS-00-72-02. Washington, D.C.
- Barnard, W.D. 1978. *Prediction and Control of Dredged Material Dispersion Around Dredging and Open-Water Pipeline Disposal Operations*. U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory. Vicksburg, Mississippi.
- Beall, J. 1976. Riserless shallow blowout-control method is safe and effective. *Oil and Gas Journal*, August 2, 1976, pp. 125-129.
- Bebout, D.G. 1976. *Proceedings Second Geopressed Geothermal Energy Conference, Vol. II: Resource Assessment*. Center for Energy Studies, The University of Texas at Austin.
- Bebout, D.G., O.K. Agagu, and M.H. Dorfman. 1975. *Geothermal Resources, Frio Formation, Middle Texas Gulf Coast*. Geological Circular 75-8. Bureau of Economic Geology, The University of Texas at Austin.

- Bebout, D.G., M.H. Dorfman, and O.K. Agagu. 1975. Geothermal Resources, Frio Formation, South Texas. Geological Circular 75-1. Bureau of Economic Geology, The University of Texas at Austin.
- Bebout, D.G., V.J. Gavenda, and A.R. Gregory. 1978. Geothermal Resources, Wilcox Group, Texas Gulf Coast. Bureau of Economic Geology, The University of Texas at Austin.
- Bebout, D.G., R.G. Loucks, S.C. Bosch, and M.H. Dorfman. 1976. Geothermal Resources, Frio Formation, Upper Texas Gulf Coast. Geological Circular 76-3. Bureau of Economic Geology, The University of Texas at Austin.
- Bebout, D.G., R.G. Loucks, and A.R. Gregory. 1977a. Study looks at Gulf Coast geothermal potential. Oil and Gas Journal, Sept. 26, 1977.
- _____. 1977b. Texas geothermal prospect slated to begin operations at Martin Ranch. Oil and Gas Journal, Oct. 3, 1977.
- _____. 1978. Frio Sandstone Reservoirs in the Deep Subsurface along the Texas Gulf Coast - Their Potential for Production of Geopressed Geothermal Energy. Report of Investigations Number 91, Bureau of Economic Geology, The University of Texas at Austin.
- Bechtel Corporation. 1976. Conceptual Design of Commercial 50 MWe (NET) Geothermal Power Plants at Heber and Niland, California - Final Report. San Francisco.
- _____. 1977. Advanced Design and Economic Considerations for Commercial Geothermal Power Plants at Heber and Niland, California - Final Report. San Francisco.
- Beckhelm, T.L., J.A. Chalmers, and W.M. Hannigian. 1975. A Description of the ATOM 3 and of the Research Related to Its Development. Four Corners Regional Commission. Washington, D.C.
- Belaire, C.E. and K. Knudson. 1974. Mortality of oysters in Cedar Lakes. A report to the environmental branch, Texas Parks and Wildlife Department.
- Bella, D.A. 1975. Tidal flats in estuarine water quality analysis. A report to U.S. EPA, EPA-660/3-75-025.
- Bella, D.A., A.E. Ramin, and P.E. Peterson. 1972. Effects of tidal flats on estuarine water quality. JWPFC 44:541-556.
- Benefield, R.L. 1976a. Shell Dredging Sedimentations in Galveston and San Antonio Bays 1964-69. Technical Series, No. 19. Texas Parks and Wildlife Department. Austin.
- _____. 1976b. Evaluation of Various Coastal Construction Methods. Technical Series, No. 21. Texas Parks and Wildlife Department. Austin.
- Berkshire County Regional Planning Commission. 1974. Evaluation of Power Facilities. Pittsfield, Massachusetts.

- Bernstein, L. 1958. Salt tolerance of grasses and forage legumes. Agriculture Bulletin No. 194. U.S. Department of Agriculture. Washington, D.C.
- Blake, G.L. (ed.). 1978. Semiannual Progress Report for the Idaho Geothermal Program. EG&G Idaho, Inc. Idaho Falls.
- Bloomster, C.H. 1976. Economic analysis of geothermal energy. Chemical Engineering Progress 72(7):89-95.
- Bloomster, C.H. and C.A. Knutsen. 1977. An Analysis of Electricity Production Costs from the Geopressed Geothermal Resource.
- Bolt, B.A., W.L. Horn, G.A. MacDonald, and R.F. Scott. 1975. Geological Hazards: Earthquakes, Tsunamis, Volcanoes, Avalanches, Landslides, Floods. Springer-Verlag. New York.
- _____. 1977. Geological Hazards, 2nd ed. Springer-Verlag, New York.
- Booth, J.R., Jr., B.P. Shepherd, and W.F. McIlhenny. 1972. Final Disposal of Effluent Brines from Inland Desalting Plants. Dow Chemical Company. Freeport, Texas.
- Boyd, D.S. 1974. Legal Aspects of State-Owned Oil and Gas Energy Resources. The State of Texas Governor's Energy Advisory Council. Austin.
- Boyd, W.E. n.d. Completion Techniques for Geothermal-Geopressed Wells--Final Report. Center for Energy Studies, The University of Texas at Austin.
- _____. n.d. Testing and Sampling Procedures for Geothermal-Geopressed Wells. Center for Energy Studies, The University of Texas at Austin.
- Brah, W.J. and L.L. Jones. 1978. Institutional Arrangements for Effective Groundwater Management to Halt Land Subsidence. Texas Water Resources Institute, Technical Report No. 95. Texas A&M University. College Station.
- Brown, F.L. and L.B. Zink. 1977. New Mexico Economic and Demographic Model, Final Report. University of New Mexico Institute for Applied Research Sciences. Albuquerque.
- Brown, L.F., Jr. and W.L. Fisher. 1974. Environmental Geologic Atlas of the Texas Coastal Zone. In: Approaches to Environmental Geology. Report of the Investigations Number 81, E.G. Wermund, Bureau of Economic Geology, The University of Texas at Austin.
- Brown, L.F., Jr., W.L. Fisher, and J.F. Maline, Jr. 1972. Evaluation of Sanitary Landfill Sites, Texas Coastal Zone - Geologic and Engineering Criteria. Bureau of Economic Geology, The University of Texas at Austin.
- Brown, L.F., Jr., R.A. Morton, J.H. McGowen, C.W. Kreidler, and W.L. Fisher. 1974. Natural Hazards of the Texas Coastal Zone. Bureau of Economic Geology, The University of Texas at Austin.

- Brown and Root. 1976. Appendix A: Engineering Report. In: Proceedings Second Geopressured Geothermal Energy Conference, Vol. IV: Surface Technology and Resource Utilization, G.K. Underhill et al. (eds.). Center for Energy Studies, The University of Texas at Austin.
- Brown, W.M. 1976. A huge new reserve of natural gas comes within reach. *Fortune*, Oct. 1976, pp. 219-222.
- Burchell, R.W. and D. Listokin. 1978. The Fiscal Impact Handbook. Center for Urban Policy Research. New Brunswick, New Jersey.
- Bureau of Land Management. 1977. Environmental Statement - Proposed 1979 Outer Continental Shelf Oil and Gas Lease Sale 58 - Western and Central Gulf of Mexico. 2 Vols. U.S. Department of the Interior.
- Butler, E.W. and J.B. Pick. 1977. Geothermal Development in Imperial County, California: 1976 Public Opinion Survey. Paper prepared for the Annual Conference, American Association of Public Opinion Research, Pacific Chapter, March 1977. Marina del Rey, California.
- Cappello, P., A. LoBascio, and G. Luongo. 1974. Seismic noise survey at Solfatara Crater, Phlegraean Fields, Italy. *Geothermics* 3(2):76-80.
- Castrantas, H., T. Turner, R. Rex. 1976. Hydrogen sulfide abatement in geothermal steam. In: Geothermal Environmental Seminar-'76. October 27-29, 1976, Lake County, California, F. Tucker and M. Anderson, eds.
- Center for Energy Studies. 1979. CES Publications, 1979. The University of Texas at Austin.
- Chalmers, J.A., et al. 1977. Economic/Demographic Assessment Manual. Mountain West Research, Inc. Tempe, Arizona.
- Chapman, V.J. 1960. Salt Marshes and Salt Deserts of the World. *Plant Sci. Mono.*, Leonard Hill Ltd. London.
- Chipman, R.K. 1959. Studies of tolerance of certain freshwater fishes to brine water from oil wells. *Ecology* 40(2):299-302.
- Clark, J., J. Zinn, and C. Terrell. 1978. Environmental Planning for Offshore Oil and Gas, Vol. I, Recovery Technology. The Conservation Foundation. Washington, D.C.
- Cluett, C., M.T. Miertaugh, and M. Micklin. 1977. Demographic Model for Assessing the Socio-Economic Impacts of Large-Scale Industrial Development Projects. Paper presented at 1977 annual meeting of the Southern Regional Demographic Group, October 21-22. Virginia Beach, Virginia.

- Coffman, J.L. and C.A. von Hake. 1973. Earthquake History of the United States. rev. ed. National Oceanic and Atmospheric Administration Publication 41-1, U.S. Department of Commerce. Washington, D.C.
- Colwell, R.N. 1967. Remote sensing as a means of determining ecological conditions. *BioScience* 17(7):444-449.
- Cowden, G.M., chm. 1978. Public Utility Commission of Texas - Substantive Rules.
- Cronquist, C., J.P. Malott, N.H. Olsen, P.E. Parser, and F.W. Zimmerman. 1977. Potential Producibility and Recovery of Natural Gas from Geopressed Aquifers of the Cenozoic Sediments of the Gulf Coast Basin - Final Report. Gulf Universities Research Consortium. Bellaire, Texas.
- Darnell, R.M., et al. 1976. Impacts of Construction Activities in Wetlands of the United States. (Tereco Corporation, College Station, Texas) U.S. Environmental Protection Agency. Corvallis, Oregon.
- Dellwig, L.F. and J.E. Bare. 1978. A radar investigation of north Louisiana salt domes. *Photographic Engineering and Remote Sensing* 44(11):1411-1419.
- Denver Research Institute. 1979. Socioeconomic Impacts of Western Energy Resource Development: Vol. IV: Computer Model Documentation Council on Environmental Quality. Washington, D.C.
- Drilling-DCW. 1978. Digging for new sources of energy. September 1978.
- Division of State Lands, California. 1977. Geothermal Resources Program: A Dynamic Approach to Alternative Energy Development.
- Dolan, W.M. 1976. Fuels for electricity - the long-term trends and geothermal. 1976 meeting, Geothermal Resource Council.
- Dorfman, M.H. and R.W. Deller. 1976. Proceedings Second Geopressed Geothermal Energy Conference, Vol. I: Summary and Future Projections. Center for Energy Studies, The University of Texas at Austin.
- Dorfman, M.H., and R.O. Kehle. 1974. Potential Geothermal Resources of Texas. Bureau of Economic Geology, The University of Texas at Austin.
- Dosher, T.M., R.H. Osborne, S.W. Rhee, T. Wilson, and D. Cox. 1979. Methane from geopressed aquifers studied. *The Oil and Gas Journal*. April 9, 1979.
- Dow Chemical Company. 1976. Appendix B: A study of phase "O" plan. Proceedings Second Geopressed Geothermal Energy Conference, Vol. 1 Surface Technology and Resource Utilization. Center for Energy Studies, The University of Texas at Austin.
- Dowds, J.P. 1969. Statistical geometry of petroleum reservoirs in exploration and exploitation. *Journal of Petroleum Technology*, July 1969, pp. 841-852.

- Edwards, T. 1974. The Impact of State and Federal Law on Development of Geothermal Resources in Texas. Draft Report. The State of Texas Governor's Energy Advisory Council. Austin.
- EG&G Idaho, Inc. 1978. Rules of Thumb of Geothermal Direct Applications. Idaho Falls.
- Eisenstat, S.M. n.d. Geothermal Tax Considerations and Shelters. New York.
- Environmental Study Conference Bulletin. 1978. Energy, Oct. 9, 1978, pp. C6-C9.
- Espey, Huston and Associates, Inc. 1976. A Study of the Placement of Dredged Materials from Texas Ports and Waterways. Executive Summary, Vol. I, Vol. II. Austin.
- Evans, J. (ed.). 1977. Energy Studies. Vol. 3, Nos. 1-6.
- Fabos, J.G. and S.J. Caswell. 1977. Composite Landscape Assessment: Assessment Procedures for Special Resources, Hazards, and Development Suitability; Part II of the Metropolitan Landscape Planning Model (METLAND). Massachusetts Agricultural Experiment Station, University of Massachusetts at Amherst.
- Fairchild, J.B. and K.H. Wiebe. 1977. Subsidence of organic soils and salinity barrier design in coastal Orange County, California. In: Land Subsidence Symposium (pp. 334-346). International Association of Hydrological Sciences IAHS-AISH Publ. No. 121. Washington, D.C.
- Federal Energy Administration. 1977. Strategic Petroleum Reserve, Draft Supplement Final Environmental Impact Statement, Bryan Mound Salt Dome. Strategic Petroleum Reserve Office.
- Final Environmental Impact Statement - Bryan Mound Salt Dome. 1977. Draft Supplement.
- Finnemore, E.J. and M.L. Gillam. 1977. Compaction processes and mathematical models of land subsidence in geothermal areas. In: Land Subsidence Symposium (pp. 157-166). International Association of Hydrological Sciences IAHS-AISH Publ. No. 121. Washington, D.C.
- Finsterbusch, K. and C.P. Wolf (eds.). 1977. Methodology of Social Impact Assessment. Dowden, Hutchinsonson and Ross, Inc. Stroudsburg, Pennsylvania.
- Fisher, M. n.d. Investment opportunities for the individual in geothermal. A.D. Gilhart & Company, Inc. New York.
- Fitzsimmons, S., L.I. Stuart, and P.C. Wolf. 1975. Social Assessment Manual. Prepared for Bureau of Reclamation, United States Department of the Interior.
- Fogleman, S.F., L.A. Fisher, and A.R. Black. 1978. Total Energy Recovery System for Agribusiness: Lake County Study - Final Report. International Engineering Company, Inc. San Francisco.

Ford, A. 1976a. Summary Description of the BOOM I Model. Los Alamos Scientific Laboratory. Los Alamos, New Mexico.

_____. 1976b. User's Guide to the BOOM I Model. Los Alamos Scientific Laboratory. Los Alamos, New Mexico.

Gabrysch, R.K. 1973. Preliminary Report on Land-Surface Subsidence in the Area of Burnett, Scott, and Crystal Bays near Baytown, Texas. U.S. Geological Survey, U.S. Department of the Interior.

_____. 1977a. Approximate Areas of Recharge to the Chicot and Evangeline Aquifer Systems in the Houston-Galveston Area, Texas. U.S. Geological Survey Open-File Report 77-754. U.S. Department of the Interior.

_____. 1977b. Development of Ground Water in the Houston District, Texas, 1970-74. U.S. Geological Survey, U.S. Department of the Interior.

Gabrysch, R.K., and C.W. Bonnet. 1975a. Land-Surface Subsidence in the Area of Moses Lake Near Texas City, Texas. U.S. Geological Survey, U.S. Department of the Interior.

_____. 1975b. Land Surface Subsidence In the Houston-Galveston Region, Texas. Texas Water Development Board Report 188. Austin.

Gardner, G.H.F., L.W. Gardner, and A.R. Gregory. 1974. Formation velocity and density - the diagnostic basics for stratigraphic traps. Geophysics 39(6):770-780.

Garg, S.K. and J.W. Pritchett. 1977. Two-phase flow in geopressured geothermal wells. In: Proceedings, Third Geopressured-Geothermal Energy Conference, Vol. 1 (pp. ES-85-RD-114), J. Meriwether (ed.). University of Southwestern Louisiana. Lafayette.

Garza, S. 1977. Artificial Recharge for Subsidence Abatement at the NASA-Johnson Space Center - Phase I. U.S. Geological Survey, U.S. Department of the Interior.

Gates, G.L., W.H. Caraway, and H.J. Lechtenberg. 1977. Problems in injection of waters in Wilmington oil field, California. In: Land Subsidence Symposium (pp. 319-324). International Association of Hydrological Sciences IAHS-AISH Publ. No. 121. Washington, D.C. 669 pp.

Geertsma, J. 1973. Land Subsidence above compacting oil and gas reservoirs. Journal of Petroleum Technology, June 1973, pp. 734-744.

Geothermal Energy Act - Hearing Before the Subcommittee on Water and Power Resources of the Committee on Interior and Insular Affairs, U.S. Senate, 93rd Congress. 1974. U.S. Government Printing Office. Washington, D.C.

- Geothermal Resources Council. 1978. Commercialization of Geothermal Resources. Davis, California.
- Geraghty & Miller, Inc. 1972. Ground-Water Contamination; An Explanation of Its Causes and Effects.
- Gilliam, M.L., et al. 1976. The Analysis of Subsidence Associated with Geothermal Development, Vol. 2, Research. Systems Control, Inc. Palo Alto, California.
- Ginn, R.F. 1973. Ground-water contamination from natural gas, W.H. Bauer ranch near Carancahua Bay, Jackson County, Texas. Texas Water Development Board, unpublished file report. Austin.
- Goldsmith, M. 1978. Cooling water requirements for geothermal power plants and water availability in the Imperial Valley. In: Geothermal Energy: A Novelty Becomes Resource. Geothermal Resources Council Transactions. Vol. 2, Section 1, July 1978.
- Gordon, T.J., T.C. Wright, E. Fein, T.R. Munson, and R.C. Richmond. 1978. The Uses of Geothermal Heat for Crop Drying and Related Agricultural Applications -- Final Report. The Futures Group. Glastonbury, Connecticut.
- Graduate Management Research Center. 1975. Spurring Synthetic Fuel Production. The University of Texas at Austin.
- Grant, M.A. 1978. Two-phase linear geothermal pressure transients: a comparison with single-phase transients. New Zealand Journal of Science 21:355-364.
- Gregory, A.R. 1977. Engineering parameters used in the geopressured-geothermal fairway evaluation and test well site location, Frio Formation, Texas Gulf Coast. In: Proceedings Third Geopressured Geothermal Energy Conference, Vol. 1 (pp. G1-349-G1-424), J. Meriwether (ed.). Center for Energy Studies, University of Southwestern Louisiana. Lafayette.
- Greider, B. 1976. Status of economics and financing of geothermal energy power production. Paper delivered at 1976 meeting of Geothermal Resources Council Dinner.
- Gustavson, T.C. and C.W. Kreidler. 1976. Geothermal Resources of the Texas Gulf Coast; Environmental Concerns Arising from the Production and Disposal of Geothermal Waters. Geological Circular 76-7, Bureau of Economic Geology, The University of Texas at Austin.
- Gustavson, T.C., M.M. McGraw, M. Tandy, F. Parker, and D.G. Wohlschag. 1977. Ecological Implications of Geopressured-Geothermal Energy Development Texas-Louisiana Gulf Coast Region. Performed for: U.S. Department of the Interior. Bureau of Economic Geology, The University of Texas at Austin.
- Hahn, E.A. 1976. Institutional Barriers to Geothermal Energy Development. Federal Energy Administration.
- Hamilton, D. and R.L. Meehan. 1971. Ground rupture in the Baldwin Hills. Science 172(3981):333-334.

- Hardin, F.R. and G.C. Hardin, Jr. 1961. Contemporaneous normal faults of Gulf Coast and their relation to flexures. *American Association of Petroleum Geologists Bulletin* 45(2):238-248.
- Harrell, T.A. n.d. Legal impediments to the development of the geopressed resource. Mineral Law Institute, LSU Law Center. Baton Rouge, Louisiana.
- Harvey, W.W., F.C. Brown, and M.J. Turchan. 1976. Control of Hydrogen Sulfide Emission from Geothermal Power Plants Annual Status Report, June 1, 1975-May 31, 1976. Energy Research and Development Administration, Division of Geothermal Energy.
- Healy, J.H., W.W. Rubey, D.T. Griggs, and C.B. Raleigh. 1968. The Denver earthquakes. *Science* 161(3848):1301-1310.
- Hertsgaard, T., S. Murdock, N. Toman, M. Henry, and R. Ludke. 1978. REAP Economic-Demographic Model: Technical Description. North Dakota Regional Environmental Assessment Program. Bismarck.
- Henley, A.D. 1966. Seismic activity near the Texas Gulf coast. *Engineering Geology - Bulletin of the Association of Engineering Geologists* 3(1):33-39.
- Herrera, I., J. Alberro, R. Grane, and J.J. Hanel. 1977. Development of artificial reservoirs by inducing land subsidence. In: Land Subsidence Symposium. Proceedings of the Second International Symposium on Land Subsidence held at Anaheim, California, 13-17 December, 1976. International Association of Hydrological Sciences, IAHS-AISH Publ. No. 121. Washington, D.C.
- Hickel, W.J. (chm.). 1972. Geothermal Energy: A National Proposal for Geothermal Resources Research. University of Alaska.
- Hoover, D.B. and J.A. Dietrich. 1969. Seismic Activity During the 1968 Test Pumping at the Rocky Mountain Arsenal Disposal Well. U.S. Department of the Interior, Geological Circular 618. Washington, D.C.
- Horvath, J.C. and R.L. Chaffin. 1971. Geothermal energy, its future and economics. *Atlanta Economic Review* 21(12):16-33.
- House, P.A., P.M. Johnson, and D.F. Towse. 1975. Potential Power Generation and Gas Production from Gulf Coast Geopressed Reservoirs. Lawrence Livermore Laboratory, University of California. Livermore.
- Hubbert, M.K. and W.W. Rubey. 1959. Role of fluid pressure in mechanics of overthrust faulting. I. Mechanics of fluid-filled porous solids and its application to overthrust faulting. *Bulletin of the Geological Society of America* 70:115-166.
- Johnson, L.L., E.W. Merrow, W.S. Baer, and A.J. Alexander. 1976. Alternative Institutional Arrangements for the Developing and Commercializing Breeder Reactor Technology. Rand. Santa Monica, California.

- Jones, J. 1964. Fish and River Pollution. Butterworth. London.
- Jones, L.L. 1977. External costs of surface subsidence: upper Galveston Bay, Texas. In: Land Subsidence Symposium, Proceedings of the Second International Symposium on Land Subsidence, held at Anaheim, California, 13-17 December 1976.
- Jones, P.H. 1969. Hydrodynamics of geopressure in the Northern Gulf of Mexico Basin. Journal of Petroleum Technology, July 1969, pp. 803-910.
- Jorgensen, D.G. 1973. Analog-Model Studies on the Effects of Recharge Wells Along the Houston Ship Channel on Potentiometric Surfaces of the Chicot and Evangeline Aquifers, Houston, Texas. U.S. Geological Survey Open-File Report. U.S. Department of the Interior.
- _____. 1975. Analog-Model Studies of Ground-Water Hydrology in the Houston District, Texas. Texas Water Development Board Report 190. Austin.
- _____. 1977. Salt-Water Encroachment in Aquifers Near the Houston Ship Channel, Texas. Geological Survey Open-File Report 76-781, U.S. Department of the Interior. Washington, D.C. 46 pp.
- Jorgensen, D.G. and R.K. Gabrysch. 1974. Simulated Water-Level Changes Resulting from Proposed Changes in Ground-Water Pumping in the Houston, Texas, Area. U.S. Geological Survey, U.S. Department of the Interior.
- Justus, J.K. 1975. Geothermal energy issue brief number IB74056. The Library of Congress Congressional Research Service. Washington, D.C.
- Kadlec, J.A. and W.A. Wentz. 1974. State of the Art Summary and Evaluation of Marsh Plant Establishment Techniques: Induced and Natural. Vol. I. Report to U.S. Army Corps of Engineers 074-9.
- Kahn, W.D. and F.O. Vonbon. 1976. Detectability of land subsidence from space. In: Land Subsidence Symposium (pp. 246-256). International Association of Hydrological Sciences IAHS-AISH Publ. No. 121. Washington, D.C.
- Kash, D.E. and I.L. White. 1973. Energy Under the Oceans. University of Oklahoma Press. Norman.
- Kharaka, K., E. Callender, and R.H. Wallace, Jr. 1977. Geochemistry of geopressured-geothermal waters from the Frio clay in the Gulf Coast region of Texas. Geology 5:241-244.
- Kiersch, G.A. (ed.). 1968. Engineering Geology Case Histories Number 6. The Ecological Society of America.

- Kim, Y.Y. and R.G. Thompson. 1977. An Economic Model of New Crude Oil and Natural Gas Supplies in the Lower 48 States. Governor's Energy Advisory Council. Austin, Texas.
- Knapp, R.M., O.F. Isokrari, S.K. Garg, and J.W. Pritchett. 1977. An analysis of production from geopressured-geothermal aquifers. Paper presented at 52nd Annual Fall Technical Conference and Exhibition, The Society of Petroleum Engineers of AIME, Dallas.
- Kreitler, C.W. 1976. Lineations and Faults in the Texas Coastal Zone. Bureau of Economic Geology Report of Investigations No. 85, The University of Texas at Austin.
- _____. 1977a. Fault control of subsidence, Houston-Galveston, Texas. In: *Geoscience and Man*, H.J. Walker (ed.), 18:7-19, School of Geoscience, Louisiana State University. Baton Rouge.
- _____. 1977b. Faulting and land subsidence from ground-water and hydrocarbon production. Houston-Galveston, Texas. In: *Land Subsidence Symposium* (pp. 435-446). International Association of Hydrological Sciences IAHS-AISH Publ. No. 121. Washington, D.C.
- Krieger, R.A. 1961. Ground water contamination in the Greensburg oil field, Kentucky. In: *Ground Water Contamination* (pp. 91-97). Robert A. Taft Sanitary Engineering Center, U.S. Department of Health, Education, and Welfare. Cincinnati, Ohio.
- Kruger, P. and C. Otte (eds.). 1973. *Geothermal Energy*. Stanford University Press.
- Land Subsidence - Symposium - Subsidence Terrestre. 1976. Proceedings of the 2nd International Symposium on Land Subsidence, Anaheim, California.
- Larson, T. 1977. The costs of geothermal energy development - final report. *Geothermal World Directory, 1977-78*, pp. 314-336.
- Lawrence Berkeley Laboratory. 1977. *A Study of Brine Treatment, Final Report*. University of California. Berkeley.
- Lawton, D.L., and D.F. Palmer. 1978. Enhancement of linear features by rotational exposure. *Photogrammetric Engineering and Remote Sensing* 44(9):1185-1189.
- LeBlanc, L. n.d. Platform price tag climbs. *Offshore*, pp. 86, 88.
- Leeton, H.B., P.L. Bossett, J.E. Knizner, and F.M. Smith. 1973. Finance and economics of offshore operations. *World Oil*, July 1973, pp. 81-91.
- Leistritz, F.L., T.A. Hertsgaard, D.M. Senechal, S.H. Murdock, N.E. Toman, K. Wiig, and G. Schaible. 1978. *The REAP Economic Development Model: Background, Structure, and Applications*. North Dakota Regional Environmental Assessment Program. Bismarck.

- Leitner, P. 1978. An Environmental Overview of Geothermal Development: The Geysers-Calistoga KGRA; Vol. 5 Ecosystem Quality. Lawrence Livermore Laboratory, University of California. Livermore.
- Letlow, K., S.C. Lopreato, M. Meriwether, P. Ramsey, and J.K. Williamson. 1976. The development of geothermal energy in the Gulf coast: socio-economic demographics, and political considerations. In: Proceedings - Second Geopressured-Geothermal Energy Conference - Volume 5 - Legal Institutional and Environmental. Center for Energy Studies, The University of Texas at Austin.
- Li, C.T. and D.P. Alzheimer. 1976. Removal of H₂S from Geothermal Steam. Final Report. Prepared for the Energy Research and Development Administration by Battelle Pacific Northwest Laboratories.
- Lienau, P.J. 1978. Agribusiness Geothermal Energy Utilization Potential of Klamath and Western Snake River Basins, Oregon. Oregon Department of Geology and Mineral Industries/Oregon Department of Economic Development. Portland.
- Lindsey, M.K. and P. Supton. 1975. Geothermal Energy: Legal Problems of Resource Development. Stanford Environmental Law Society. Stanford, California.
- Longley, W.L., R. Jackson, B. Snyder. In press. The Development of Methods and Standards of Operation to Protect Fish and Wildlife Resources and Supporting Habitat of Coastal Wildlife Refuges During Oil and Gas Development. Fish and Wildlife Service, U.S. Department of the Interior.
- Lopreato, S.C. and M. Blisset. 1977. An Attitudinal Survey of Citizens in a Potential Gulf Coast Geopressured-Geothermal Test-Well Locality. Center for Energy Studies, The University of Texas at Austin.
- Lopreato, S.C., M. Meriwether, and P. Ransey. 1976. The nature of the region: baseline social and demographic data. Chapter 1 In: Proceedings Second Geopressured Geothermal Energy Conference, Vol. V Legal, Institutional and Environmental (J.H. Vanston). Center for Energy Studies, The University of Texas at Austin.
- Los Alamos Scientific Laboratory. 1977. Hot Dry Rock Geothermal Energy Development Project, Annual Report, Fiscal Year 1977. Los Alamos, New Mexico.
- Magill, P., F. Holden, and C. Ackley. 1956. Air Pollution Handbook. McGraw Hill. New York.
- Mahall, B.E. and R.B. Park. 1976. The ecotone between Spartina foliosa trin. and Salicornia virginica L. in salt marshes of northern San Francisco Bay: III, Soil aeration and tidal immersion. J. Ecol. 64(3):811-819.
- Marcou, O'Leary and Associates, Inc. 1975. Economic and Social Indicators with Reference to Land Use in Subsidence-Prone Area in Northeastern Pennsylvania, Vol. 1, General Findings and Recommendations. For Appalachian Regional Commission. Washington, D.C.

Marcus, P.A. (ed.). 1976. Directory to U.S. Geological Survey Activities in Coastal Areas 1974-76. U.S. Government Printing Office. Washington, D.C.

Maryland Major Facilities Study, Volume 2: Eastern Shore Power Plant Siting Study. 1977. Prepared for the Energy and Coastal Zone Administration, Maryland Department of Natural Resources by Rogers & Golden, Inc. and Alan Mallach/Associates in association with Dames & Moore.

Maryland Major Facilities Study, Volume 3: Economic, Fiscal, and Social Assessment Handbook. 1977. Prepared for the Energy and Coastal Zone Administration, Maryland Department of Natural Resources by Rogers & Golden, Inc. and Alan Mallach/Associates in association with Dames & Moore.

McCoy, R.M. 1967. An evaluation of radar imagery as a tool for drainage basin analysis. CRES Technical Report 61-31. University of Kansas Center for Research, Inc., Engineering Science Division. Lawrence.

McGinnis, J.T., R.A. Ewing, C.A. Willingham, S.E. Rogers, D.H. Douglass, and D.L. Morrison. 1972. Environmental Aspects of Gas Pipeline Operations in the Louisiana Coastal Marshes. Battelle Columbus Laboratories. Columbus, Ohio.

McMahan, C.A. 1968. Biomass and salinity tolerance of shoal grass and manatee grass in lower Laguna Madre, Texas. J. of Wildlife Mgt. 32:501-06.

McMillan, C. and F.N. Moseley. 1967. Salinity tolerances of five marine spermatophytes of Redfish Bay, Texas. Ecol. 48:503-506.

McNeese State University. 1978. Geopressured-Geothermal Test of the Edna Delcambre No. 1 Well, Tigre Lagoon Field, Vermilion Parish, Louisiana; Geology of the Tigre Lagoon Field, Planulina Basin. Lake Charles, Louisiana.

Meriwether, J. (ed.). 1977. Proceedings: Third Geopressured Geothermal Energy Conference, Vols. I and II. Center for Energy Studies, The University of Southwestern Louisiana. Lafayette.

Mid-Continent Oil and Gas Association. 1978. A pipeline to 78 facts about Texas oil and gas. Dallas.

MIT Energy Laboratory Policy Study Group. 1976. New Energy Technologies: An Analysis and Exploration of the Issues. Cambridge, Massachusetts.

Monarchi, D.E. and R.W. Taylor. 1977. An Introduction to Socio-Economic Model Building and the Colorado Population and Employment Model. University of Colorado Business Research Division. Boulder.

Monts, J.K. and E.R. Bareiss. 1979. Community-Land Impacts Projection System (CLIPS). The University of Texas Center for Energy Studies. Austin.

Moseley, F.N. 1975. Environmental considerations and economic implications in the development of geothermal energy. In: Proceedings First Geopressured Geothermal Energy Conference (pp. 321-324), M.H. Dorfman and R.W. Deller (eds.). Center for Energy Studies, the University of Texas at Austin.

Mountain West Research, Inc. 1978. Bureau of Reclamation Economic Assessment Model (BREAM) Technical Description. U.S. Bureau of Reclamation. Denver, Colorado.

NAS-NAE (National Academy of Sciences - National Academy of Engineering). 1972. Earthquakes Related to Reservoir Filling. National Research Council. Washington, D.C.

New England River Basins Commission. 1976. Factbook - Onshore Facilities Related to Oil and Gas Development. Boston.

Oberbeck, A.W. 1977. The geopressured geothermal resources of Texas: a report on legal ownership and royalty issues. Geothermal Energy Magazine 5(8):1838.

Ocean Industry. April 1977 12(4).

Offshore. September 1973 33(10); May 1976 36 (5).

_____. 1978a. Tables of drilling costs and well types. June 20, 1978, p. 72.

_____. 1978b. Total offshore oil services. August 1978, p. 120.

Olsen, R.J., G.W. Westley, H.W. Herzog, Jr., C.R. Kerley, D.J. Bjorstad, D.P. Voyt, L.G. Bray, S.T. Grady, and T.A. Nakosteen. 1977. Multiregion: A Simulation-Forecasting Model of BEA Economic Area Population and Employment. ORNL/RUS-25. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Orbit III International Search Service. 1977. Geothermal citation lists, 2 vols.

Pearson, R.O. 1977. Use of Geothermal Heat for Sugar Refining - Final Report, October 1, 1976 - May 31, 1977. TRW Systems and Energy. Redondo Beach, California.

Peterson, L. and K.K. Seo. 1974. Geothermal Power Economics: An Annotated Bibliography, Vol. II. Hawaii Geothermal Project, University of Hawaii.

Petroleum Extension Service. 1951. A Primer of Oilwell Drilling (3rd Edition). The University of Texas at Austin.

_____. 1966. A Primer of Pipe Line Construction. 2nd ed. Industrial and Business Training Bureau, The University of Texas at Austin.

_____. 1976. Blowout Prevention. Lessons in Rotary Drilling, Unit III - Lesson 3. The University of Texas at Austin.

Pick, J.B., C. Starnes, T.H. Hwan, and E.W. Butler. 1976. Geothermal Fields, Imperial County, California. Proceedings of the American Statistical Association. University of California. Riverside.

- Podio, A.L., K.E. Gray, O.F. Isokrari, R.M. Knapp, I.H. Silberberg, and T.W. Thompson. 1976. Proceedings Second Geopressured-Geothermal Energy Conference, Vol. III: Reservoir Research and Technology. Center for Energy Studies, The University of Texas at Austin.
- Powers, R.E. 1972. Side-look at radar provides a new tool for topographic and geologic surveys. Westinghouse ENGINEER, November 1972.
- Princeton University, Center for Environmental Studies. 1978. Unpublished case study of siting of energy facilities in Hudson County, New Jersey.
- Pritchett, J.W., S.K. Garg, and T.D. Riney. 1977. Numerical simulation of the effects of reinjection upon the performance of a geopressured geothermal reservoir. In: Proceedings Third Geopressured Geothermal Energy Conference, Vol. 1 (pp. E5-73-E5-112), J. Meriwether (ed.). Center for Energy Studies, University of Southwestern Louisiana. Lafayette.
- Ramachandran, G. 1977. Economic Analyses of Geothermal Energy Development in California. Stanford Research Institute. Menlo Park, California.
- Rancilio, J.A. 1977. Injection well operation and maintenance. In: Land Subsidence Symposium (pp. 325-333). International Association of Hydrological Sciences IAHS-AISH Publ. No. 121. Washington, D.C.
- Ratzlaff, K.W. 1976. Chemical and physical characteristics of water in estuaries of Texas, October 1971 - September 1973. Texas Water Development Board report 208.
- Reeve, R., R. Weaver, and E. Natwig. 1976. The Navaho Economic-Demographic Model: A Method for Forecasting and Evaluating Alternative Navaho Economic Futures. Office of the State Planning Coordination. Salt Lake City, Utah.
- Rios-Castellon, L. and G.K. Underhill. 1976. Ground water survey of the Texas Gulf Coastal Plain. In: Proceedings Second Geopressured Geothermal Energy Conference, Vol. 4, Surface Technology and Resource Utilization (pp. 105-137), G.K. Underhill et al. (eds.). Center for Energy Studies, The University of Texas at Austin.
- Robinette, G.O. 1973. Energy and Environment. Kendall/Hunt Publishing Co. Dubuque, Iowa.
- Rogers, K.E. and A.W. Oberbeck. The Geopressured Geothermal Resources of Texas--Regulatory Controls Over Water Pollution. Center for Energy Studies, The University of Texas at Austin.
- Rose, A. 1977. The Economic Impact of Geothermal Energy Development. National Science Foundation.
- Rothrock, R., Jr. 1978. Maintenance, workover costs to top \$3 billion. Petroleum Engineer International, July 1978, pp. 19-21.

- Rydstrom, H.Q. 1970. Geologic Exploration With High Resolution Radar. Goodyear Aerospace Corporation. Litchfield Park, Arizona.
- Sacarto, D.M. n.d. State Policies for Geothermal Development. National Conference of State Legislatures. Denver, Colorado.
- Sato, K. and K. Watanabe. 1977. Prediction of land subsidence by means of time series analysis of water level fluctuation in observation well. In: Land Subsidence Symposium (pp. 577-586). International Association of Hydrological Sciences IAHS-AISH Publ. No. 121. Washington, D.C.
- Sauer, T.C., Jr., W.M. Sackett, and L.M. Jeffrey. 1978. Volatile liquid hydrocarbons in the surface coastal waters of the Gulf of Mexico. *Marine Chemistry* 7:1-16.
- Schulte, S.C. 1977. Capital Cost Models for Geothermal Power Plants and Fluid Transmission Systems. Battelle Pacific Northwest Laboratories. Richland, Washington.
- Shay, J.R. 1967. Remote sensing for agricultural purposes. *BioScience* 17(7):450-451.
- Sheets, M.M. 1947. Diastrophism during historic time in Gulf Coastal Plain. *Bulletin of the American Association of Petroleum Geologists* 31(2):201-226.
- Shell Oil Company. 1974a. Offshore Oilfield Development. Production Technology Series 1361 for American Petroleum Institute. Dallas.
- _____. 1974b. Offshore Oil Storage and Shipping. Production Technology Series 1349 for American Petroleum Institute. Dallas.
- _____. 1974c. Offshore Production Facilities. Production Technology Series 1369 for American Petroleum Institute. Dallas.
- _____. 1974d. The Platform. Production Technology Series 1362 for American Petroleum Institute. Dallas.
- Shepard, F.P. 1953. Sedimentation rates in Texas estuaries and lagoons. *Bulletin of the American Association of Petroleum Geologists* 37(8):1919-1934.
- Slotta, L.S., C.K. Sollitt, D.A. Bella, D.R. Hancock, J.E. McCauley, and R. Parr. 1973. Effects of Hopper Dredging and In Channel Spoiling in Coos Bay, Oregon. Oregon State University. Corvallis.
- Smart, R.M. and J.W. Barko. 1978. Influence of sediment salinity and nutrients on the physiological ecology of selected salt marsh plants. *Estuary and Coastal Marine Science* 7:487-495.
- Smith, R. 1978. Effect of salt upon hot-water dispersion in well-mixed estuaries. *Estuarine and Coastal Marine Science* 7:445-454.

Sparks, D.W. 1978. Social Impact Assessment Methodology: A Critique. Paper Presented at 14th American Water Resources Conference, Lake Buena Vista, Florida.

Stenehjem, E.J. 1978. Summary Description of SEAM: The Social and Economic Assessment Model. Argonne National Laboratory. Argonne, Illinois.

Stone, C.D. 1975. Geothermal Energy and the Law, I: The Federal Lands Management Program. University of Southern California Law Center. Los Angeles.

Stuart, A. 1978. That "very interesting dance" in the Baltimore Canyon. Fortune, September 11, 1978, pp. 66-72.

Subcommittee on Geothermal Resources of the Joint Legislative Committee on Public Domain. 1973. Geothermal Resources in California: The Problems and the Potential. Sacramento.

_____. 1974. Geothermal Resources in California: Much Heat and Some Light. Sacramento.

Sullivan, B. and P. Kobrin. 1978. The joint bidding ban: pro- and anti-competitive theories of joint bidding in OCS lease sales. American Petroleum Institute. Washington, D.C.

Talbot, J.B. 1971. Bibliography on Geothermal Research. Office of Design and Construction, U.S. Department of the Interior. Denver.

Techniques for Environmental Decision-Making Using Quantified Social and Aesthetic Values. 1974. Battelle Pacific Northwest Laboratories. Richland, Washington.

Texas Antiquities Committee. The Antiquities Code of Texas. Austin.

Texas General Land Office. 1975. Resources of the Texas Coastal Region. Map Plates 9A and 9B. Austin.

_____. 1978a. Activity Analysis: Activity Assessment Routine, Ecological Systems Component. Technical Paper No. 11. Prepared for the Texas Coastal Management Program by RPC, Inc. Austin.

_____. 1978b. Activity Assessment Routine, Ecological Systems Component (Draft Report) Technical Manual and Appendices. Prepared for the Texas Coastal Management Program by RPC, Inc. Austin.

_____. 1978c. Activity Assessment Routine, Social and Economic Component, User's Manual. Prepared for the Texas Coastal Management Program, by RPC, Inc. Austin.

_____. 1978d. Assessment of Fiscal Impacts. Technical Paper No. 7. Prepared for the Texas Coastal Management Program by RPC, Inc. Austin.

- _____. 1978e. Input-Output Models of the Texas Coastal Region. Technical Paper No. 6. Prepared for the Texas Coastal Management Program by RPC, Inc. Austin.
- _____. 1978f. A Methodology to Assess Social/Infrastructural Impacts. Technical Paper No. 8. Prepared for the Texas Coastal Management Program by RPC, Inc. Austin.
- _____. 1978g. Texas Coastal Management Program, Revised Hearing Draft, Appendix 3. Prepared for the Texas Coastal Management Program by RPC, Inc. Austin.
- Texas Water Development Board. 1970. A Water Inventory of the Texas Coastal Zone. Coastal Resources Management Program, Interagency Natural Resources Council, Division of Planning Coordination, Office of the Governor. Austin.
- _____. 1977. Continuing Water Resources Planning and Development for Texas. Austin.
- Texas Water Quality Board. 1976. Texas Water Quality Standards.
- Thompson, L. 1977. Overhead Transmission Lines Impact on Wildlife. Montana Department of Natural Resources and Conservation, Energy Planning Division.
- Thomson, D.A., A.R. Mead, and J.R. Schreiber. 1969. Environmental Impact of Brine Effluents on Gulf of California. U.S. Department of the Interior, U.S. Government Printing Office. Washington, D.C.
- Trehan, R., A. Cohen, J. Gupta, J. Leigh, and S. True. 1978. Site Specific Analysis of Geothermal Development - Data Files of Prospective Sites, Vol. II. U.S. Department of Energy. Washington, D.C.
- Underhill, G.K., R.A. Carlson, W.A. Clendenning, J. Erdos, J. Gault, J.W. Hall, R.L. Jones, H.K. Michael, P.H. Powell, C.F. Riemann, L. Rios-Castellon, S.P. Shepherd, and J.S. Wilson. 1976. Proceedings Second Geopressed Geothermal Energy Conference, Vol. IV. Center for Energy Studies, The University of Texas at Austin.
- United Nations. 1961. Proceedings: United Nations Conference on New Sources of Energy, Vol. 3, Geothermal Energy: II.
- U.S. Army Coastal Engineering Research Center. 1973. Shore Protection Manual. Vols. I, II, III. Department of the Army Corps of Engineers. Fort Belvoir, Virginia.
- U.S. Department of Energy. 1978a. Analysis of Proposed U.S. Department of Energy Regulations Implementing the Powerplant and Industrial Fuel Use Act. DOE/EIA-0102/21. Energy Information Administration. Washington, D.C.

- _____. 1978b. Environmental Readiness Document - Hydrothermal Electric and Direct Heat, Commercialization Phase III Planning. Washington, D.C.
- _____. 1978c. Geopressured-Geothermal Drilling and Testing Plan - General Crude Oil - Dept. of Energy, Pleasant Bayou No. 1 Well, Brazoria Co., TX. Nevada Operations Office.
- _____. 1978d. Proceedings: NATO-CCMS Conference on the Economics of Direct Uses of Geothermal Energy. Washington, D.C.
- _____. 1979a. Federal Loan Guarantees for Geothermal Energy Utilization, Proposed Rulemaking: Public Hearing. Federal Register 44(4):1568-1578.
- _____. 1979b. Geothermal Energy Program - Program Research and Development Announcement: Engineering and Economic Studies for Direct Applications of Geothermal Energy. San Francisco Operations Office.
- U.S. Department of Housing and Urban Development. 1975. Directory of Disaster-Related Technology. HUD Report No. 401-FDAA. Federal Disaster Assistance Administration. Washington, D.C.
- U.S. Department of the Interior. 1973. Effects of Urbanization on Floods in the Houston, Texas Metropolitan Area. U.S. Geological Survey, Water Resources Investigation 3-73. Austin, Texas.
- _____. 1974. Land-Surface Subsidence in the Area of Burnett, Scott, and Crystal Bays Near Baytown, Texas. U.S. Geological Survey.
- _____. 1976. Geothermal Handbook (Geothermal Project, 1976). Prepared for Fish and Wildlife Service by Jones & Stockes Associates, Inc. Sacramento, California.
- _____. 1978. Reconciling Electric Power Production and Fish and Wildlife Needs, Vol. II. Fish and Wildlife Service.
- U.S. Energy Research and Development Administration. 1976. A Bibliography: Geothermal Resources, Exploration and Exploitation.
- _____. 1977a. Environmental Assessment of Geopressured Waters and their Projected Uses. J.S. Wilson, J.R. Hamilton, J.A. Manning, and P.E. Muehlberg, Dow Chemical, U.S.A. Prepared for Industrial Environmental Research Laboratory, Office of Research and Development.
- _____. 1977b. Environmental Development Plan - Hydrothermal Energy Systems-FY1977.
- _____. Hydrothermal Energy Systems FY1977.
- U.S. Environmental Protection Agency. 1976. Quality Criteria for Water. Washington, D.C.

- _____. 1977a. Environmental Assessment of Geopressed Waters and Their Projected Uses. J.S. Wilson, J.R. Hamilton, J.A. Manning, and P.E. Muehlberg, Dow Chemical, U.S.A. Prepared for Industrial Environmental Research Laboratory, Office of Research and Development.
- _____. 1977b. Western Energy Resources and the Environment: Geothermal Energy. Office of Research and Development, Office of Energy, Materials, and Energy. Washington, D.C.
- U.S. Fish and Wildlife Service. 1976. Geothermal Handbook Geothermal Project, 1976. Office of Biological Services.
- _____. 1978. Impact Prediction Manual for Geothermal Development. Performed for Western Energy and Land Use Team, Office of Biological Services by Woodward-Clyde Consultants.
- Vanston, J.H. 1976. Proceedings Second Geopressed-Geothermal Energy Conference, Vol. V Legal, Institutional and Environmental. Center for Energy Studies, The University of Texas at Austin.
- Vorum, M., G.E. Lowry, S.W. Goering, and E.A. Fritzler. 1978. Non-Electric Utilization of Geothermal Energy in the San Luis Valley, Colorado - Final Report. Covey and Associates, Inc. Lakewood, Colorado.
- Walker, H.J. (ed.). 1977. Research Techniques in Coastal Environments. Vol. XVIII of Geoscience and Man Series. School of Geoscience, Louisiana State University. Baton Rouge.
- Ward, P.L. 1972. Microearthquakes: prospecting tool and possible hazard in the development of geothermal resources. *Geothermics* 1(1):3-12.
- Warren, J.P., L.L. Jones, W.L. Griffin, and R.D. Lacewell. 1974. Cost of Land Subsidence Due To Ground-Water Withdrawal. Texas Water Resources Institute Technical Report No. 57, Texas A & M University. College Station.
- Webster, R.N. 1971. Investigation of Catarina well problem (Hughes, Dimmit County, Texas). Texas Water Development Board unpublished file report. Austin.
- Weeden, S.L. 1976. Geopressed geothermal energy - will it work? *Ocean Industry*, June 1976, pp. 119-126.
- Wells, G.L. and R.K. Holz. n.d. Color infrared photography.
- White, D.E. and D.L. Williams (eds.). 1975. Assessment of Geothermal Resources of the United States - 1975. Geological Circular 726. U.S. Department of the Interior.
- White, D.J. 1970. Investigation of ground-water contamination on northern Comanche County, Texas. Texas Water Development Board unpublished file report. Austin.

- _____. 1973. Contamination of the Charles Powell water wells in the vicinity of Morgans Creek oil field, Polk County, Texas. Texas Water Development Board unpublished file report. Austin.
- White, W.A., M. McGraw, and T.C. Gustavson. 1978. Environmental Analysis of Geopressured-Geothermal Prospect Areas, Brazoria and Kenedy Counties, Texas. Bureau of Economic Geology, the University of Texas at Austin.
- Whiting, R.L., and H.J. Ramey, Jr. 1969. Application of material and energy balances to geothermal steam production. *Journal of Petroleum Technology*, July 1969, pp. 893-900.
- Williams, F., A. Cohen, R. Pfundstein, S. Pond. 1978. Site Specific Analysis of Geothermal Development-Data Files of Prospective Sites, Vol. III. Prepared for U.S. Department of Energy, Division of Geothermal Energy.
- Wilson, J.S., J.R. Hamilton, J.A. Manning, and P.E. Muehlberg. 1977. Environmental Assessment of Geopressured Waters and their Projected Uses. Dow Chemical Co. Freeport, Texas.
- Wilson, J.S., J.E. King, and G.K. Bullard. 1977. Removal of Hydrogen Sulfide from Simulated Geothermal Brines by Reaction with Oxygen. Final Report, October 6, 1975 - February 4, 1977. Performed for Energy Research and Development Administration by the Dow Chemical Company, Texas Division.
- Wilson, J.S., B.P. Shepherd, and S. Kaufman. 1975. An Analysis of the Potential Use of Geothermal Energy for Power Generation Along the Texas Gulf Coast. Dow Chemical, U.S.A.
- Wilson, S.W. and R.A. Walter. 1976. An Optimization Technique for Geothermal Power Plants Using a Binary Fluid Cycle. Battelle Pacific Northwest Laboratories. Richland, Washington.
- Wood, H.O. and F. Neumann. 1931. Modified Mercalli Intensity Scale of 1931. *Bulletin of the Seismological Society of America* 21:277-283.
- Wood, L.A., R.K. Gabrysch, and R. Marvin. 1963. Reconnaissance Investigation of the Ground-Water Resources of the Gulf Coast Region, Texas. Texas Water Commission Bulletin 6305. Austin.
- Woodward-Clyde Consultants. 1978. Impact Prediction Manual for Geothermal Development. San Francisco.
- Woodward-Lundgren & Associates. 1974. Direction and Evaluation of Differential Surface Displacement in the Texas Gulf Coast Region. Oakland, California.
- World Oil. 1978. Geothermal activity for Rocky Mountains (What's happening in the United States). February 15, 1978, p. 17.
- Youd, T.L. 1973. Liquefaction. *Earthquake Information Bulletin* 5(6):10-17.

Zieman, J.C. and W.E. Odum. 1977. Modeling of ecological succession and production in estuarine marshes. DAC W39-73-C-D121.

Zinn, C.D. 1977a. Operations Research and Systems Analysis of Geothermal-Geopressured Resources in Texas. Interim Report. Center for Energy Studies, The University of Texas at Austin.

_____. 1977b. Operations Research and Systems Analysis of Geothermal-Geopressured Resources in Texas - Final Report. Research Report No. 10, Center for Energy Studies, The University of Texas at Austin.

GLOSSARY

10/11/1944

10/11/1944

10/11/1944

10/11/1944

10/11/1944

10/11/1944

10/11/1944

10/11/1944

10/11/1944

10/11/1944

artificial/unstable ecosystem - group of ecosystems consisting of spoil deposits, subaqueous, and made land

brackish - containing salt water

contiguous strata - layers in actual contact with each other

deeper estuarine ecosystem - group of ecosystems consisting of medium salinity bay, restricted bay, river-influenced bay, reef and reef-flank area, and channel

Frasch technique - a method of solution mining for subterranean sulfur

grassland - coastal prairie ecosystem

insular/eolian ecosystem - group of ecosystems consisting of vegetated barrier flat, washover complex, and active dune complex

internal rate of return - the rate which equates the present value of cash inflows and outflows over the life of the project

lease bonus payment - the cash sum paid by the lessee for the execution of a lease by the landowner; usually figured on a per acre basis

littoral ecosystem - group of ecosystems consisting of beach and upper shoreface

marine ecosystem - group of ecosystems consisting of nearshore gulf

payout period - estimated time needed for the cumulative annual net cash savings after taxes derived from a project to equal the net cash investment

primary lease term - the period of time during which a lease may be kept alive by a lessee even though there is no production in paying quantities by virtue of drilling operations on the leased land or the payment of rentals

royalty holiday - a period of time during which the lessee is relieved of the obligation of tendering payment of a production royalty

royalty rate - the landowner's share of production, free of expenses of production

slurry - a watery mixture of insoluble matter, such as mud or cement

spudded well - drilled well

wetland/shallow estuarine ecosystem - group of ecosystems consisting of wind-tidal flat, salt marsh, brackish marsh, inland freshwater marsh, coastal lake, grassflat, and bay transitional area

woodland (riparian) - river-associated woodland

woodland (upland) - brushland, oak mottes, and groves